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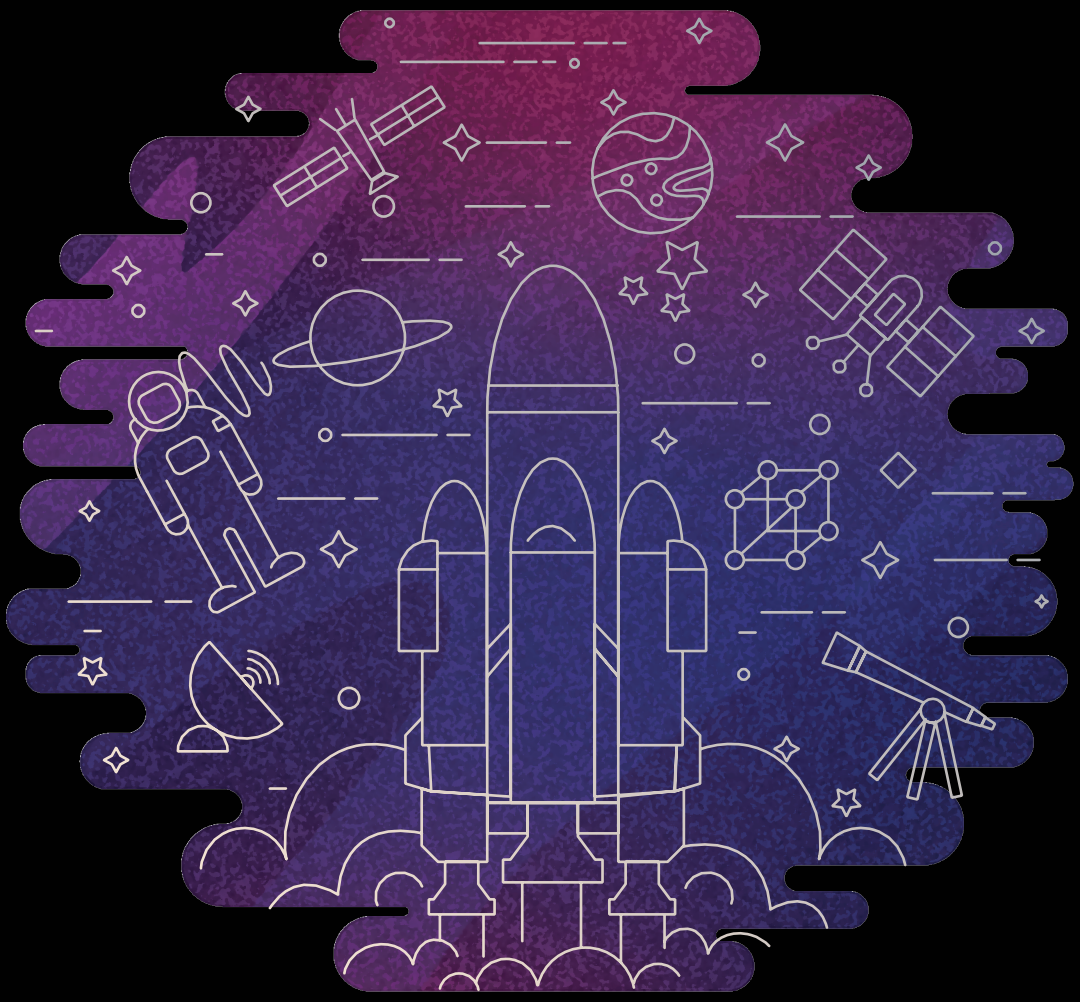

Sky is not the limit

Building Queensland's space economy

February 2019

Deloitte Access Economics

Contents

Acknowledgement

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Glossary

Acronym	Full name
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ADF	Australian Defence Force
ANZSIC	Australian and New Zealand Standard Industrial Classification
ATMS	Automated Train Management Systems
BOM	Bureau of Meteorology
C-D	Cobb-Douglas
CDE	Constant Differences of Elasticities
CES	Constant Elasticity of Substitution
CGE	Computable general equilibrium
C-ITS	Cooperative intelligent transport systems
CNSA	China National Space Administration
COSSA	CSIRO Office of Space Science and Applications
CRESH	Constant Ratios of Elasticities Substitution, Homothetic
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAE-RGEM	Deloitte Access Economics Regional General Equilibrium Model
DoD	Department of Defence
DSDMIP	Department of State Development, Mining, Infrastructure and Planning
ELDO	European Launcher Development Organisation
EO (S)	Earth Observation (from Space)
ERG	Expert Reference Group
ESA	European Space Agency
FTE	Full time equivalent
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GSP	Gross State Product
JAXA	Japan Aerospace Exploration Agency
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
OECD	Organisation of Economic Co-operation and Development
PNT	Position, Navigation and Timing
PV	Present Value
SME	Small-medium enterprise
VR	Variable Rate
WRE	Weapons Research Establishment

Executive summary

Sky is not the limit

Space has always ignited human curiosity – from the Ancient Mayan's astronomy; to Galileo; NASA landing on the moon; and now the likes of SpaceX and a new wave of private sector investment in space capability. The continuous growth in knowledge and technical capability has propelled our collective understanding of space, and what it can be used for.

Today, space is an economic opportunity, as well as an intellectual and spiritual curiosity. The young minds excited by rocket launches and people on the moon have become global leaders in science, technology, engineering and mathematics; producing high value added, knowledge intensive goods and services traded in a global supply chain.

Daily, the global space economy provides essential data and information for each and every one of us. From the internet and personal banking, to the navigation system we use in our cars or on our phones. Space is also responsible for the necessary information that enables weather monitoring, emergency planning and management; and serves as the foundation for generations of researchers, scientists and mathematicians that have innovated economies and societies to higher living standards and technological progress.

The potential for spillovers from space technology and research endeavours are broadening in scope, and becoming richer in their application. Valued at US$345 billion (in 2016), the global space economy is sizeable and growing. For much of its history, the space sector has typically been an industry led, financed and managed by government. International space agencies have dominated the agenda and driven strategy and goal setting internally. The high entry costs and risks associated with the space industry of old has necessitated considerable government involvement.

This is changing, and changing fast. The recent trend towards decentralisation of activity out of government and into the private sector has spurred growth in the commercial components of the supply chain; the global space economy today is characterised by an increasing number of private organisations and investors, working alongside space agencies to achieve the aspirational goals of the global space agenda. This has opened up opportunities for countries like Australia to participate in, and benefit from, the space economy.

Our role in the New Space era

The new national agenda is clear – Australia can, and should, play a role in the growth of the global space economy. This value is derivative of the inherent importance of space as an economic sector, but more importantly, the spillovers of space related technology into other key sectors of the economy. With proven expertise in niche areas of the global supply chain, the Australian industry has the capability to capitalise on this growth potential. The Australian Government's space industry Expert Reference Group set an ambitious and exciting goal for the Australian space community to triple the size of the Australian space economy from the 2015-16 estimate of $3.94 billion, to $10-$12 billion by 2030. This will create an industry that is roughly one-third the size of Australia's current agricultural output, and will stimulate investment along the supply chain, from research and development through to commercialisation and export.

The Queensland space economy has grand ambitions of its own – **ambitions to grow, and to be globally recognised.** But, these ambitions are grounded in the reality that Queensland is a small player in a global supply chain. The aim is not to compete with the entrenched agglomerations in the US, China and Europe; **the aim is to continue to develop niche, globally competitive, high value added goods and services that can be exported to the world.**

The small size of the industry today is actually a strength – organisations across Queensland's space economy are actively collaborating with each other, building specialised research capability to support commercial organisations and building commercial organisations out of specialised research capability. This presents a **unique opportunity for Queensland to develop a space ecosystem,** where upstream and downstream players have a co-ordinated approach to competing in the global supply chain.

The future of Queensland's space industry is strong and there are opportunities to be had. However, this is an industry where connections matter, where reputations matter and where entrenched competitive advantages arise as the result of decades of investment in specialised capability – this is not an industry that can be built overnight. Queensland is fortunate that decisions made decades ago have created the conditions for an industry ripe for growth. The question now is what decisions do we need to make today to ensure that these opportunities and ambitions are realised, for the benefit of Queensland?

Queensland's niche, but globally competitive space economy

With the global growth prospects strong, a renewed national focus, and an ambitious local industry, the space economy is an area that warrants understanding, yet there is not an existing information base in Queensland.

It is in this context that Deloitte Access Economics, with support from the Department of State Development, Manufacturing, Infrastructure and Planning, developed a data capture process to map out the current state of play in Queensland's space economy.

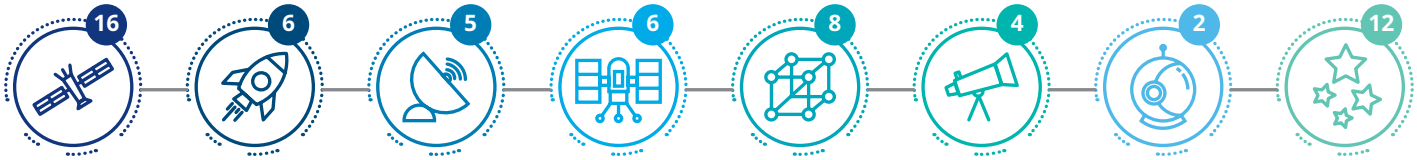
While still in its infancy, the resultant Queensland Space Economy Capability Directory provides insights into the size, scope and capability of organisations currently operating in Queensland – either as organisations located in Queensland or as organisations with a strong Queensland presence. It provides the platform for the development of a space ecosystem which can accelerate the development of Queensland's space industry.

The capability review has provided several key insights into Queensland's space industry and ecosystem:

- Where there exists **momentum across the space supply chain,** organisations whose core business is space related are drawing on transferrable skills and expertise from other areas of the Queensland industry/economy to achieve their growth aspirations.
- Organisations that do not consider space their core business are operating in **industries with transferrable skills and expertise** such as Defence (aerospace/aviation), Mining, Manufacturing and Research and Development.
- **Space activity is highly interdependent; meaning relationships are critical to success.** While organisations in Queensland's space economy are highly collaborative, growth will require increased representation of Queensland's capabilities and competitive advantages on an international platform to remain relevant in the commercially driven New Space environment.
- Queensland's **competitive advantages lie in its geographic location** which provides unique opportunities for space systems, launch activities, ground systems and space enabled services. This has fostered pockets of niche capability across the space supply chain created by a small, yet highly specialised community. Evidence of this is particularly poignant in the Research and Development sub-sector in Queensland that has grown from sustained long-term investment by Queensland universities. However, Queensland's geographic location is not currently being exploited to its full potential; a lack of the respective physical infrastructure in the launch activities and ground systems sub-sectors may hinder growth upstream.
- Queensland's **existing economic strengths, such as Mining, Manufacturing and Research and Development are a solid industry base from which growth in upstream activities can occur.** Queensland also has large potential end-user industries that can benefit from growth in space enabled services and applications.
- Accordingly, there **exists substantial areas of Queensland's existing industry that can support supply to upstream space** related organisations and drive demand for data and analytics supported by downstream space enabled services.

Figure i introduces the sub-sectors of the space economy and the number of organisations operating in each.

Figure i. Number of businesses in space economy sub-sectors



Space systems ..... Designing, building, manufacturing and operating components and systems based in space

Launch activities ..... Designing, building, manufacturing and operating equipment and services related to the launch of space systems

Ground systems ..... Designing, building, manufacturing and operating ground systems

Space enabled services ..... Designing, building, manufacturing and operating equipment, services or applications that require data or other services from space-based systems or components

Ancillary services ..... Professional services to support space-based actvities

Research & development ..... Space related research & development

Education & training ..... Space education and training

Looking forward, the combination of current competitive advantages and global growth opportunities presents a number of areas for future growth in Queensland's space economy. While the intention was not to identify specific sub-sector opportunities – this is for the industry to decide – there are many commercial opportunities for Queensland organisations with the right capabilities and networks. The broad areas for growth (as depicted in Figure ii) centre on:

- **Connecting** Queensland's organisations to the global space economy, which is set for sustained growth
- **Strengthening** existing capability to ensure that our current areas of niche expertise are world class and positioned for growth
- **Experimenting** through a continued focus on our deep – albeit niche – expertise in research and development
- **Leveraging** current strengths in the space economy, and broader strengths such as advanced manufacturing; to move into new areas of the space economy.

Moreover, the **adoption** of space enabled services by other Queensland industries was revealed as an area for – potentially large – growth, with economic dividends across the economy. This potential is explored in the future growth scenarios modelling (overleaf).

Economic profile of Queensland's space economy

Where the Queensland Space Economy Capability Directory provides a bottom up profile of the Queensland space economy, a top down profile has been developed in order to estimate the economic contribution of the space industry in Queensland today and over the next two decades. This approach 'carves out' the space industry from the broader Queensland economy.[1]

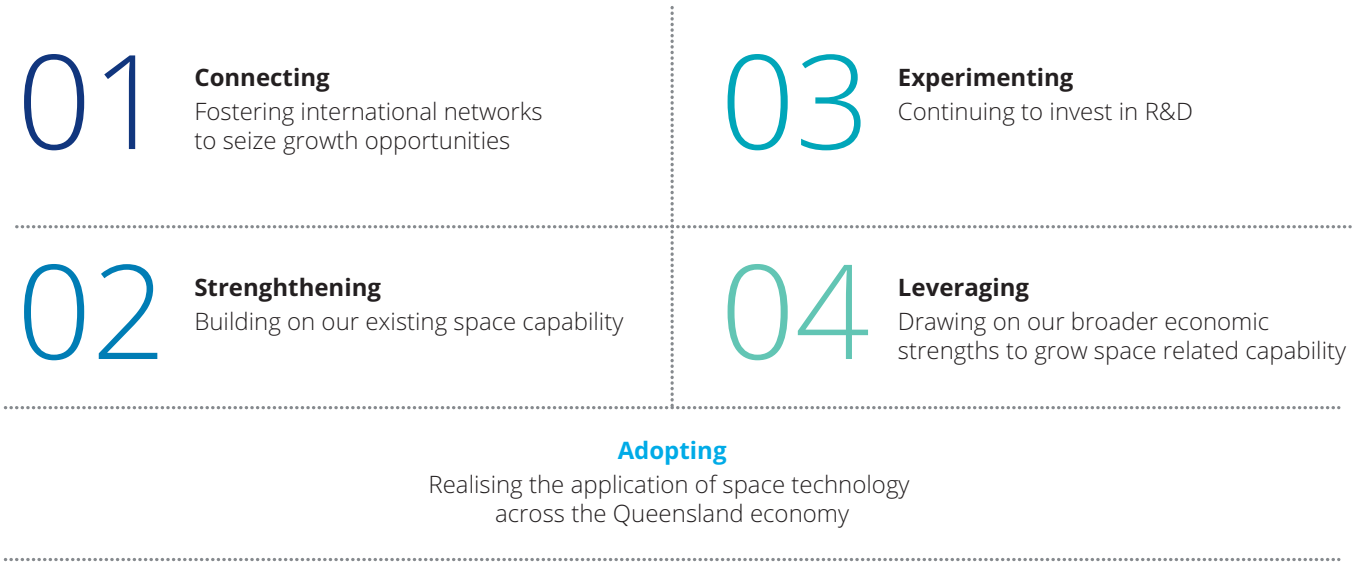
Today, the Queensland space industry directly employs around 2,000 full time equivalent jobs (FTEs) and contributes half a billion dollars in value added to Queensland's economy (2018-19). This is equivalent to about 4.4% of Queensland's agriculture industry or 2.4% of Queensland's manufacturing industry (in value added terms).

Over the next two decades, under a medium growth scenario the industry could contribute **$1.3 billion in value added to Queensland's economy and employ around 5,000 FTEs** – this is equivalent to about one quarter of the value added by today's information, media and telecommunications industry in Queensland.

Given uncertainty about future conditions in the global space industry – and global economy more generally – two additional scenarios have also been developed. The conservative growth scenario puts the Queensland space industry at around $1.1 billion in value added and 4,000 FTEs, while the high growth scenario projects value added of $1.7 billion in value added and 6,000 FTEs.

The conservative, medium and high growth scenarios have been developed to establish potential growth paths for Queensland's space industry. **The medium growth scenario represents the base case for the modelling.**

Figure ii. Areas for future growth in Queensland's space economy



2019

In the production of space related goods and services, the industry directly:

Employs approximately **2,000 FTEs**

Generates **$760 million in revenue**

Generates **$500 million in value added** (the direct economic contribution).

In the production of space related goods and services, the industry directly:

Conservative growth

Employs approximately **4,000 FTEs**

Generates **$1.7 billion in revenue**

Generates **$1.1 billion in value added**

Medium growth (base case)

Employs approximately **5,000 FTEs**

Generates **$2.0 billion in revenue**

Generates **$1.3 billion in value added**

High growth

Employs approximately **6,000 FTEs**

Generates **$2.7 billion in revenue**

Generates **$1.7 billion in value added**

2036

Potential future scenarios for Queensland's space economy

In addition to the baseline economic profile of Queensland's space industry, three scenarios have been developed to paint a picture about what's possible for space in Queensland. Analysis of these scenarios has been conducted using the previously established **medium growth scenario as the base case** (or business as usual). Therefore, **subsequent economic scenario modelling is measured relative to the medium growth scenario, or base case.**

Introducing the scenarios

Where the base economic contribution focuses on the 'core' of the space industry, **two of the three scenarios take a broader perspective on the potential economic dividends to Queensland from growth in the wider space economy – namely through the adoption of space enabled services by Queensland's powerhouse industries** (i.e. agriculture, mining, transport, construction, telecommunications and utilities). All three scenarios are measured incrementally to what would already have happened in the base case, or the medium growth scenario.

- **Scenario 1** is triggered by a step-change increase in the adoption of space enabled services by industries in Queensland that can significantly benefit from the earth observation and positioning capabilities of the space industry;
- **Scenario 2**, like scenario 1, is triggered by a step-change increase in the adoption of space enabled services, albeit under more conservative assumptions. The purpose of this scenario is to provide a sensitivity analysis for scenario 1 to provide an 'order of magnitude' assessment of the potential benefits of the adoption of space enabled services (and explore the impact of assumptions on the end results).

The third scenario centres on the establishment of space infrastructure in the launch activities and ground systems sub-sectors of Queensland's space economy; such as a rocket launch facility, or a major satellite communications park. These capabilities will support Queensland's space industry to actively participate in the global supply chain. Launch and ground system capabilities were identified by the industry as potential enablers for future growth – noting the establishment of a launch facility in Australia would require coordination by the Australian Space Agency.

- **Scenario 3** is triggered by the development of space infrastructure.

By their very nature, scenarios are generalised and do not precisely capture all aspects of the hypothesised future economic state. None of the scenarios presented in this analysis are inevitable, but at the same time they are not unrealistic and provide us with a meaningful place to start discussions about supporting growth in Queensland's space economy.

For the first two scenarios to come to fruition, major changes are required in the understanding of the value of space enabled services in industries outside of the 'core' space industry, and for the third scenario to come to fruition, development of space infrastructure would be required.

Scenario results

The scenarios are modelled using Deloitte Access Economics' Computational General Equilibrium (CGE) model. Each of the three scenarios is constructed around 'shocks' – with scenarios 1 and 2 reflecting productivity shocks, while scenario 3 reflects a capital shock in Queensland's space industry. The productivity benefits to downstream industries (e.g. agriculture, mining) are assumed to be additional to those that would have implicitly occurred in the base case.

The two adoption scenarios are reported jointly to demonstrate the range of potential economic benefits derived from increasing the adoption of space enabled services by key industries in Queensland.

The modelling indicates that the Queensland economy could increase (above the base case) by between $3.5 billion and $6 billion (in present value terms) over the period 2019 to 2036. By 2036, Queensland's gross state product (GSP) could grow in the order of between $650 million to $1.15 billion above the base case.

The **potential employment generated by the activity is estimated to range from 1,800 to 2,700 full time equivalent (FTE)** employment (in average annual terms) over the period 2019 to 2036. By 2036, FTE employment could increase in cumulative terms by between 3,300 and 4,900 FTEs above the base case.

These results highlight that even under moderate productivity assumptions, the adoption of space enabled services by other industries will deliver economic dividends for Queensland.

Table ii Summary of economy-wide impacts for Scenarios 1 and 2 (incremental to the base case)

	Scenario 1: High productivity	Scenario 2: Moderate productivity
Gross state product	$6 billion	$3.5 billion
FTE employment	4,900 FTEs	3,300 FTEs

Source: Deloitte Access Economics

Table iii Summary of economy-wide impacts for Scenario 3 (incremental to the base case)

	Total project (2019-36)	Construction phase (2019-23)	Operations phase (2024-36)
Gross state product	$82 million (in NPV terms over the total project)	$9 million (annually on average over the construction phase)	$7 million (annually on average over the operations phase)
FTE employment	24 FTEs (annually on average over the total project)	57 FTEs (annually on average over the construction phase)	12 FTEs (annually on average over the operations phase)

Source: Deloitte Access Economics

The modelling estimates show that the **establishment of space infrastructure in the launch activities and ground systems sub-sectors of the industry has the potential to grow Queensland's GSP by around $82 million over the period 2019 to 2036, adding 24 FTE jobs.**

However, while not directly modelled here, the broader economic value of launch or ground system capabilities, whether built in Queensland or elsewhere in Australia, is not derived from the construction and operation of space infrastructure alone. Value is derived from the ability of existing organisations to capitalise on the opportunities associated with significant space-related infrastructure investments.

When combined with Queensland's existing competitive advantages, **the broader economic value of both launch and ground system capability is the potential for Queensland to develop world class launch supply chains – i.e. the dynamic effects generated by deepening scale and broadening the scope of the sub-sectors.** This would enhance the development of an advanced manufacturing supply chain, with productivity spill over effects into the state's other major industries (e.g. agriculture, mining).

The potential benefits of developing space infrastructure in Queensland or another location in Australia, should be weighed against the costs and risks, including customer and market demand, which are beyond the scope of this report. Who leads and pays for the infrastructure is also beyond this report's scope.

Technical note: Scenarios 1 and 2 are based on productivity 'shocks' to downstream industries with the potential to make greater use of space enabled services (e.g. agriculture and mining). Scenario 3 is an isolated capital 'shock' to the space industry and upstream construction industry due to development of space infrastructure (i.e. there are no downstream impacts captured in this scenario).

Where to next?

The Queensland space economy is poised for, and actively seeking, growth – growth in activity, growth in value, growth in people. However, the pace of growth is not unique to Queensland; rather, the sheer volume of global demand for the commercial activities associated with space is going to benefit any region with a competitively positioned space industry. The question for Queensland is how fast the local space industry can expand to meet this demand.

Today, Queensland has a highly specialised, but highly competitive, space economy. The organisations, research institutions and individuals that comprise the 'core' space industries have world leading expertise and are already experiencing rapid growth.

However, the small scale of the Queensland industry means that there is not currently sufficient critical mass in many upstream and downstream industries in the local supply chain to ensure that the space economy in Queensland works as a co-ordinated local market. For the Queensland space economy to rapidly scale up to meet global demand, greater depth and key anchor points are required in the supply chain. Queensland needs to support growth in existing capabilities, build out capacity in adjacent areas to current strengths, improve connections within the existing supply chain, leverage untapped local demand from other industries (e.g. agriculture) and continue to invest in the early stages of research and development. These could be enhanced by space infrastructure which could reduce business and anchor the supply chain by generating demand for products and services.

In saying that, the global nature of the space economy means that it does not make sense for Queensland to be actively pursuing all growth opportunities; rather, Queensland is, and will likely always be, a small, niche, player in the global space economy and this means we need to decide where we fit in the national and global supply chains.

The resultant growth will take time. This is not an industry that can be built through short term investments. The space economy is built from decades of investment in research, equipment and, most importantly, people. The competitive advantages of Queensland's space economy in 2030, 2050 and beyond, will be the result of decisions made today. Government plays an important role in shaping the future growth path of this industry.

What the analysis in this report demonstrates is that investments in the space economy do have wider benefits for Queensland. From space education in schools, to the realisation of economic value from the commercialisation of space activities, there are economic dividends to be had across the spectrum of space sub- sectors.

Deloitte Access Economics

1 Introduction

1.1 Overview

Space has always ignited human curiosity – from the Ancient Mayan's astronomy; to Galileo; NASA landing on the moon; and now the likes of SpaceX and a new wave of private sector investment in space capability. The continuous growth in knowledge and technical capability has propelled our collective understanding of space, and what it can be used for.

With the restriction of space discovery and exploration no longer limited to government, globally space is becoming a competitive and high-growth private sector. This sector is part of a global space economy which is much more than just launching rockets. The global space economy involves all resources and undertakings that provide value to human beings in the course of discovering, understanding and utilising space.

Daily, the global space economy provides essential data and information for each and every one of us. From the internet and personal banking, to the navigation system we use in our cars or on our phones. Space is also responsible for the necessary information that enables weather monitoring, emergency planning and management; and serves as the foundation for generations of researchers, scientists and mathematicians that have innovated economies and societies to higher living standards and technological progress.

The potential for spillovers from space technology and research endeavours are broadening in scope, and becoming richer in their application. For Queensland, the state's natural, competitive and comparative economic advantages have the potential to position the economy to capitalise on the growth potential in space. But the question remains – **how can Queensland compete not only nationally, but globally?**

To begin to answer this question, an understanding of Queensland's existing space industry capability is required.

1.2 This project

The Queensland Government released the Queensland Aerospace 10-Year Roadmap and Action Plan in June 2018, setting out a vision for the future of Queensland's aerospace industry. The development of space technologies and a broader space industry is a key part of this plan.

The Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) is the Queensland Government's lead agency on matters related to the space industry.

Deloitte Access Economics has been engaged by DSDMIP to perform a capability review of Queensland's current space industry, and develop an understanding of the potential for growth in this sector.

As part of this review, Deloitte Access Economics has also undertaken economic modelling to estimate the current size of the sector, as well as build an understanding of higher growth scenarios.

1.2.1 Approach

The approach to undertaking the capability review and economic modelling was developed to reflect the unique and developing nature of Queensland's space industry and its relatively small size compared to other established Queensland sectors.

To both complement and supplement literature and existing research on the Australian and global space industry, several primary research methods were employed to document the Queensland space industry.

Table 1.1 describes the primary research and analytical approach adopted.

Table 1.1 Primary analysis conducted during this project

Analysis	Description	Sample size
Industry directory and snapshot survey (survey 1)	The survey was designed to create an industry capability directory and develop a snapshot of Queensland's current space sector. The questions asked for key information about business and services, and the scope of activities currently contributing to Queensland's space ecosystem.	59 Noting that multiple responses from the same organisation were merged.
Industry capability survey (survey 2)	The survey was designed to understand in detail the Queensland space ecosystem and supply chain – as well as the capability of the ecosystem and aspirations for growth.	18
Industry consultation	Industry consultation occurred across several channels to capture a diversity of views and capabilities. This consultation was facilitated by DSDMIP.	• Queensland Government reference group • Industry focus group • Site visits to select research institutions and businesses

Source: Deloitte Access Economics

1.3 Structure of this report

OPENING

- Chapter 2 provides the definition of the space economy and presents an economic perspective of the space supply chain.
- Chapter 3 provides an overview of the global and national context, discussing trends in the space economy and the current state of play.

PART ONE | BOTTOM UP ANALYSIS

- Chapter 4 provides a detailed look at the current composition of Queensland's space economy and is based on the findings of the Queensland Space Economy Capability Directory. It includes an overview of space economy sub-sectors, turnover ranges, employee ranges, exporting activities and composition of organisations where space is the primary industry versus not.
- Chapter 5 provides an overview of the comparative advantages of Queensland's space economy, drawing on insights gained from industry consultation and the industry capability survey. The assessment of comparative advantages is based on a capability matrix.
- Chapter 6 provides a summary of the key areas for growth in Queensland's space economy – connecting, strengthening, experimenting, leveraging and adopting.

PART TWO | TOP DOWN ANALYSIS

- Chapter 7 provides the estimate of the baseline profile of Queensland's space economy over the next 20 years, including employment and industry value added.
- Chapter 8 provides three potential future scenarios to explore how Queensland's space economy could look if 1) space enabled services are adopted across Queensland's economy and 2) space infrastructure in the launch activities and ground systems sub-sectors of the industry where established in Queensland.

PART THREE | REFLECTIONS

- Chapter 9 provides the key reflections on the capability of the Queensland space economy and the future path of the industry, including the role for government.

2 Defining the space economy

2.1 Overview

From the aspirational goal of landing a man on the moon, to the exploration of our solar system with satellite technology, the search for habitable planets and asteroid mining; the space industry has developed rapidly over the last 60 years. Countries the world over have exhibited an enduring commitment to space exploration, which has pushed related fields of expertise beyond their limits. Adequately acknowledging the vast array of upstream and downstream activities related to space is necessary to understand the way the research, technology and skills of the space industry drive improvements across the economy.

After decades of centralised control of economic activity in space, the scope of activities considered 'space related', has gradually broadened as improvements in technology driven by the traditional space sector, have extended to the wider economy. However, it is recognised that in order to usefully evaluate the capability of the Queensland space economy, not all organisations should be considered as having capabilities in space.

For example, while Uber relies heavily on data provided by Global Navigation Satellite Systems, it would not be appropriate to consider the firm as having space capability.

As such, this chapter commences by defining the space economy – where are the boundaries of the space economy and what are the sub-sectors that comprise the space economy?

Importantly for this report, an economic perspective of the space economy is also presented. This framework presents the space economy in terms of its supply chain, introducing two components of the space economy as those that 'send into space' and those that 'receive from space'.

2.2 Defining the space economy

The Organisation of Economic Co-operation and Development (OECD) definition of the 'space economy' reflects the traditional activities of the space industry, and extends this concept to the broader uses of space derived technologies and applications. For the purposes of this review, reference made to the 'space economy' will refer to the following OECD definition:

"The full range of activities and the 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-related products and services, ranging from research and development, the manufacture and use of space infrastructure (ground stations, launch vehicles and satellites) to space-enabled applications (navigation equipment, satellite phones, meteorological services, etc.) and the scientific knowledge generated by such activities. It follows that the Space Economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative of space-derived products, services and knowledge on economy and society." [2]

The sub-sectors of the space economy are further defined in Figure 2.1.

Figure 2.1 Defining sub-sectors in the space economy (count of businesses)

Space systems	Designing, building, manufacturing and operating components and systems based in space
Launch activities	Designing, building, manufacturing and operating equipment and services related to the launch of space systems
Ground systems	Designing, building, manufacturing and operating ground systems
Space enabled services	Designing, building, manufacturing and operating equipment, services or applications that require data or other services from space-based systems or components
Ancillary services	Professional services to support space-based actvities
Research & development	Space related research & development
Education & training	Space education and training

Source: Deloitte Access Economics

The concept of the space economy is a reflection of the industry's transition to 'New Space'; a model of the space industry that has a new structure (increased private actors) and different goals including agility, responsiveness, acceptance of risk and (significantly) lower costs.[3]

The evolution of 'New Space' also reflects the use and application of technologies which were originally designed and used for space exploration but have since been repurposed for alternative uses. The use of the term 'space industry' will therefore refer to the core of traditional space activities such as the research, design, manufacture and construction of infrastructure and technology that is destined for space, or to monitor activities in space.

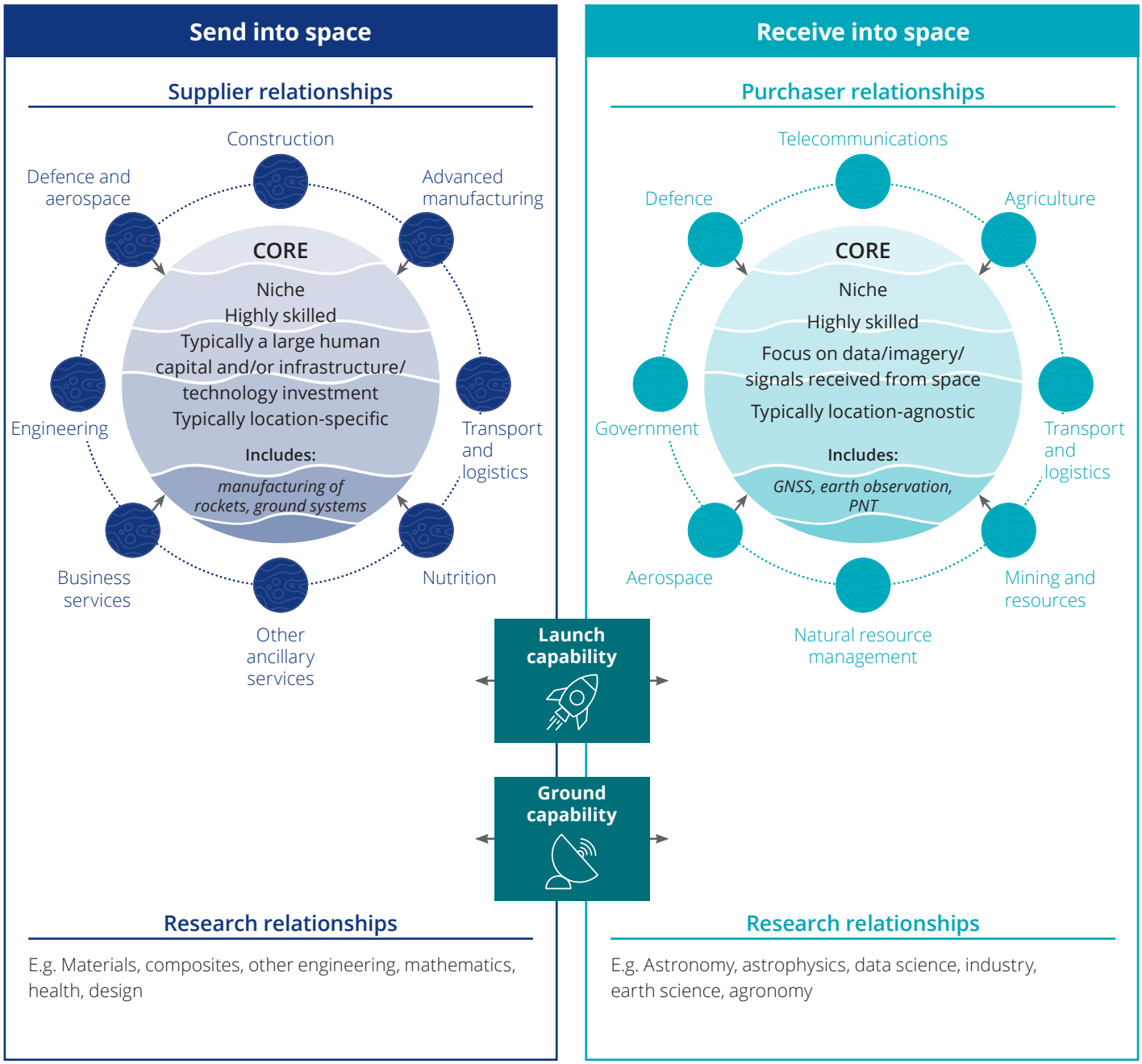
2.3 An economic perspective of the space economy

For the purposes of this analysis, an economic perspective of the space economy has been developed. Based on the supply chain interactions across the space economy, this perspective shows how the 'core' components of the space economy interact with the broader upstream and downstream supply chains. This analytical framework proves particularly useful when considering the future growth scenarios of Queensland's space economy in Chapter 8.

The figure overleaf depicts the two distinct, but interlinked, components of the space economy:

- First, there is the part of the space economy that **sends objects into space.** In the Queensland context, this particularly refers to rocket launch, but may also include satellites.
  - This core is extremely niche and requires highly skilled workers and, typically, sizeable capital investments. Due to the nature of the goods and services produced, this component is relatively location-specific, meaning that once this core is established in Queensland (through capital, know-how and technological investments), it is more likely to be fixed in location over the short to medium term.
  - The supply chain impacts for this part of the space economy in Queensland are currently focused on the upstream industries – that is, the suppliers of inputs into the core, such as advanced manufacturing.
  - The research in this part of the space economy focuses on areas such as materials and composites, mathematics, and aeronautical engineering.
- The upstream supply chain for the part of the economy that sends objects into space is the part of the space economy that receives from space, where launch capability and ground systems are the link between the two.
- Second, there is the part of the space economy that **receives from space.** In the Queensland context, this particularly refers to Global Navigation Satellite Systems (GNSS), Earth Observation (EO) and Position, Navigation and Timing (PNT).
  - This core is also highly niche, with specialist skills in data, imagery and signals analysis. The outputs of this core can be supplied from anywhere in the world with a data cable.
  - The supply chain impacts for this part of the space economy in Queensland are in the downstream industries that purchase the outputs of the core, such as agriculture and mining.
  - The research in this part of the supply chain focuses on areas such as astrophysics and astronomy.

Figure 2.2 Economic perspective of the space economy



Source: Deloitte Access Economics

3 Global and national context

3.1 Overview

This chapter commences with an overview of the global space economy, including trends in both public and private sector investment, as well as trends in the sector more broadly. The global space economy today is characterised by an increasing number of private organisations and investors, but this hasn't always been the case – the decentralisation of financing and delivering of space programs has evolved from being almost entirely public in nature, to today's substantially more commercial focus (albeit still dominated by national governments).

This evolution in government involvement has, ironically, increased the interest of many national governments in the space economy, including Australia. With the significant increase in commercial opportunities has come a wave of interest in how existing space capabilities can be supported in order to capitalise on the growth in the global space economy. In the Australian context, this has been spearheaded by the establishment of the Australian Space Agency in South Australia and the development of robust growth targets for the domestic space economy.

The speed of change in the global and national context is critical to understanding why it is time for Queensland to consider its current and future role in the space economy. Where does Queensland fit in the global space supply chain?

3.2 Global space economy

Historically, space has typically been an industry led, financed and managed by government. International space agencies have dominated the agenda and driven strategy and goal setting internally. The high entry costs and risks associated with the space industry of old necessitated government involvement. Accordingly, the space industry's market structure usually involved government purchases from a small number of prominent aerospace firms such as Boeing, Northrup Grumman or Lockheed Martin.[4]

In addition to the government's role as leader in space exploration and development, symmetries between space technology and the defence/aerospace industries led to the government being a customer of space innovations. The space industry; as Figure 3.1 demonstrates, driven by a combination of reduced public sector involvement, high-tech innovation and substantial private investment, has evolved from this historical market structure to the 'New Space' that we observe today.

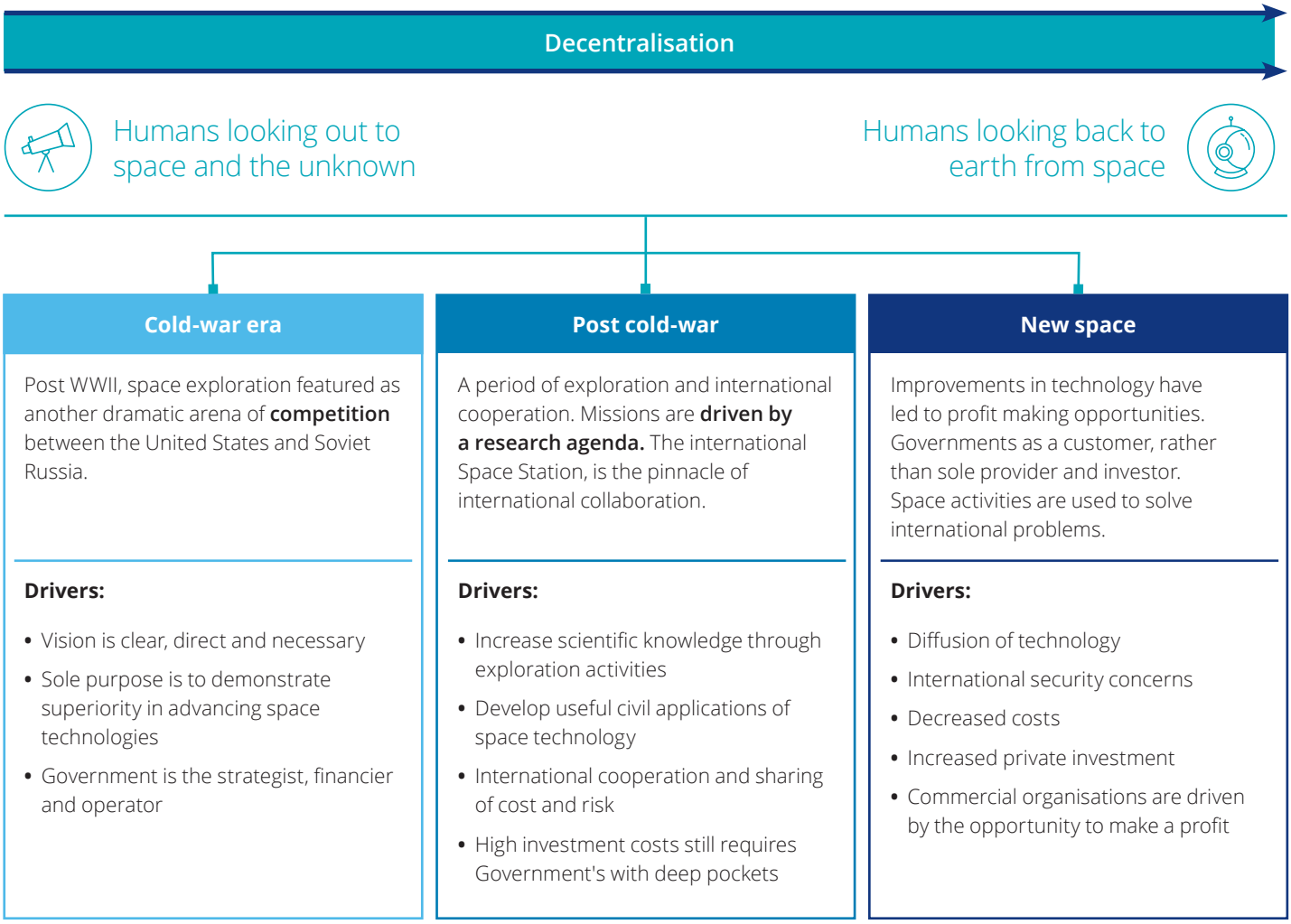
The largest disruption of the last 60 years in the global space economy has been the decentralisation of activity from government into the private sector. Sparked by the end of America's Space Shuttle program by President Obama in 2010, decentralisation meant that for many private organisations, which had long supported international space agencies, the potential for significant commercial revenues became a reality.

The global space economy today is characterised by an increasing number of private organisations and investors, working alongside space agencies to achieve aspirational goals. Rapid improvements in science and technology, coupled with increased investment, has led to a global space economy that was valued at US$345 billion in 2016.[5] Furthermore, OECD estimates put the global space economy's employment at more than 900,000 persons in 2013.[6]

"[It] may mark the final flight of the Space Shuttle, but it propels us into the next era of our never-ending adventure to push the very frontiers of exploration and discovery in space."

President Barack Obama, 2010

Figure 3.1 Evolution of government in space exploration



Source: Deloitte Access Economics

3.2.1 Increased public and private sector investment

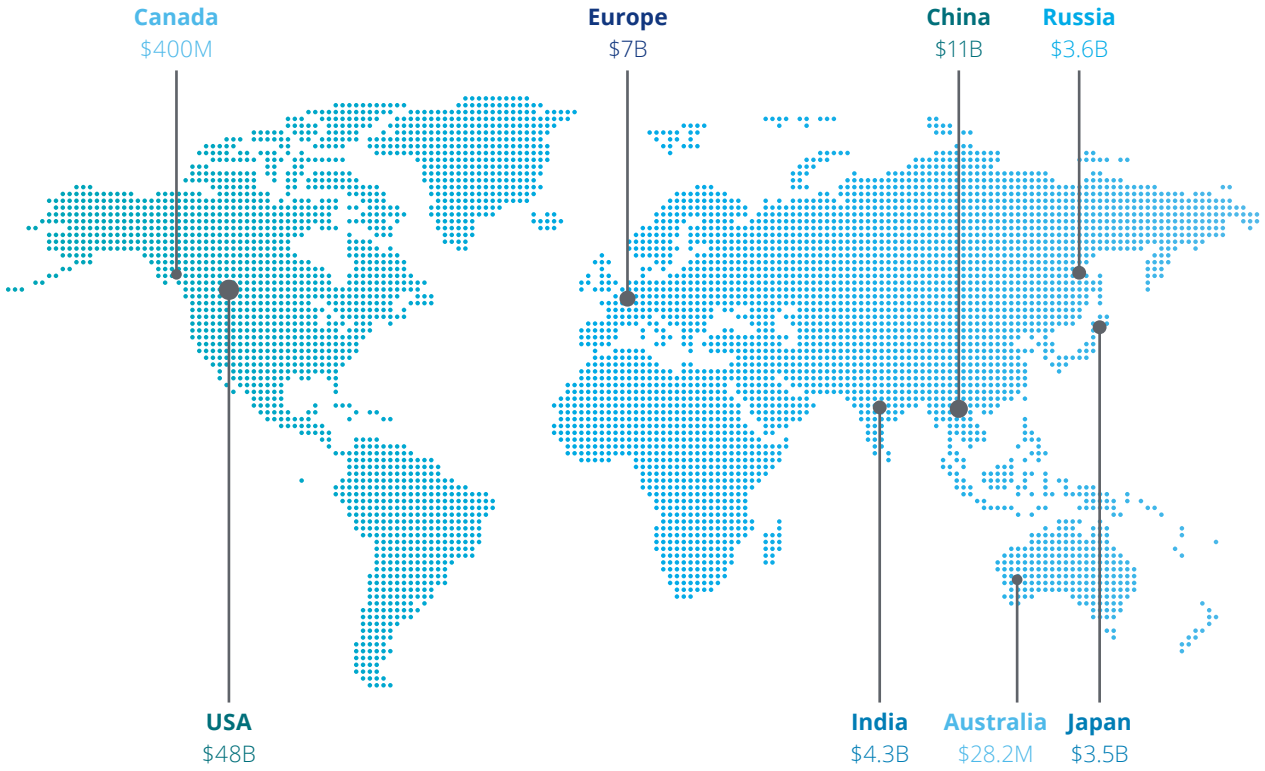
Despite the decentralisation of organisations such as the National Aeronautics and Space Administration (NASA), public actors have not disappeared – quite the opposite in fact. The space sector has distinguishing features that typically require public actors including the development and application of cutting edge technologies and longer lead times for both project development and return on investments.[7] More and more countries are investing in sovereign space economies, driven by the need for a presence in space that can be associated with security interests as well as social, economic and environmental factors.

International interest in the global space economy is substantial, as demonstrated by Figure 3.2, with nearly 50 countries maintaining space budgets. One quarter of the global space economy is made up of government budgets.

However, the dissemination of knowledge and technology from traditional areas of the space industry to the global market has introduced the opportunity for significant private sector returns. The global space economy has experienced rapid growth in private investment. Today, space is characterised by a vibrant commercial sector, as demonstrated by Figure 3.3, with growing numbers of entrepreneurs and investors. More than 60% of space-related economic activity comes from commercial goods and services.[8]

Despite the growing importance of the commercial space sector, defence and aerospace continue to drive the use of space related technology and infrastructure.

Figure 3.2 International Space Agency Budgets



France $2.4B	**Germany** $1.6B	**Italy** $1.2B	**UK** $500M	**South Korea** $318M	**UAE** $150M
Indonesia $140M	**Norway** $134M	**Malaysia** $120M	**Turkey** $100M	**Israel** $90M	**Singapore** $26M

Source: OECD, 2014

Figure 3.3 Investment in the space industry 2009 to present

Governmental space age

1969
Apollo landed on the moon

Enterprenerial space age

2009
SpaceX first successful launch of commercial payload

2010
SpaceX publishes launch prices; introduces market transparency

2012
SpaceX Dragon becomes first commercial space vehicle to berth with ISS

2014
NanoRocks launches commercial deployment via ISS

2015
SpaceX lands orbital booster, ushers in resuability

2017
SpaceX Falcon Heavy unlocks commercial deep space operations

$18B
Cumulative non-government investment in Space since 1983

412
Number of companies receiving investment

SATELLITES
250 Companies
$8.3 B

MEDIA & EDUCATION
35 Companies
$15 M

INDUSTRIES
11 Companies
$154 M

PLANETARY MARKETS
8 Companies
$244 M

LAUNCH
77 Companies
$8.6 B

BIOSPHERE
23 Companies
$515 M

INFORMATION & RESEARCH
8 Companies
$77 M

LOGISTICS
10 Companies
$147 M

Source: Space Angels, 2019

3.2.2 Growth and trends in the global space economy

Growth in the space economy is unlikely to slow down; Morgan Stanley estimates that the US$345 billion Global Space Industry will grow into a US$1.1 trillion Global Space Economy by 2040.

The use of space enabled services, reduction in costs, and the insatiable human fascination with space and the unknown, is expected to foster strong growth in the space economy. This growth will result in the increased output and value add of the sector. Specifically, innovations such as reusable rockets by SpaceX have drastically changed the space economy.

Reusable rockets have contributed to the reduction in satellite launch costs from US$200 million to US$60 million, with the potential to drop as low as US$5 million.[10] Moreover, the move away from large satellites (characterised by long life and high reliability) towards smaller, very low cost cubesat technology, is changing the structure of the satellite industry. Satellite mass production could decrease that cost from $500 million per satellite to $500,000.[11]

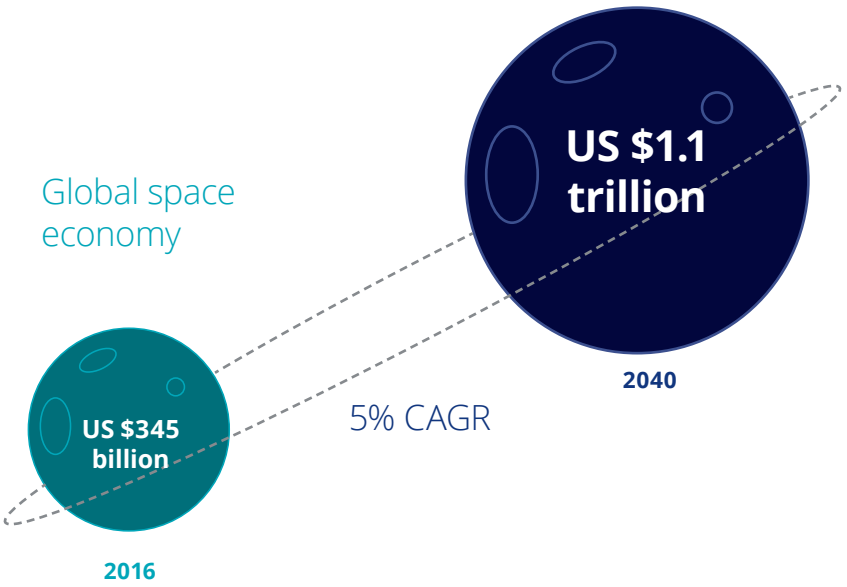
The **use of space systems and data derived from space or space enabled services generates 70% of economic activities worldwide** (based on 2015 estimates).[12] The dual use of space technologies will also drive growth, as organisations specialising in the application of EO, PNT and GNSS technologies reach industries such as agriculture, mining and transport. A further summary of these trends is provided in Figure 3.5.

Evidence of these 'New Space' organisations is emerging; in 2016, 114 investors (the majority of which are based in the United States of America [USA]) invested $2.8 billion into 43 start-up space ventures across 49 deals worldwide.[13] Analysis reveals that the size of these investments (across all types) continues to grow; the average size of the deal increased from $38 million to about $57 million on the previous year.[14]

"If one can figure out how to effectively reuse rockets just like aeroplanes, the cost of access to space will be reduced by as much as a factor of a hundred...that really is the fundamental breakthrough needed to revolutionise access to space." [9]

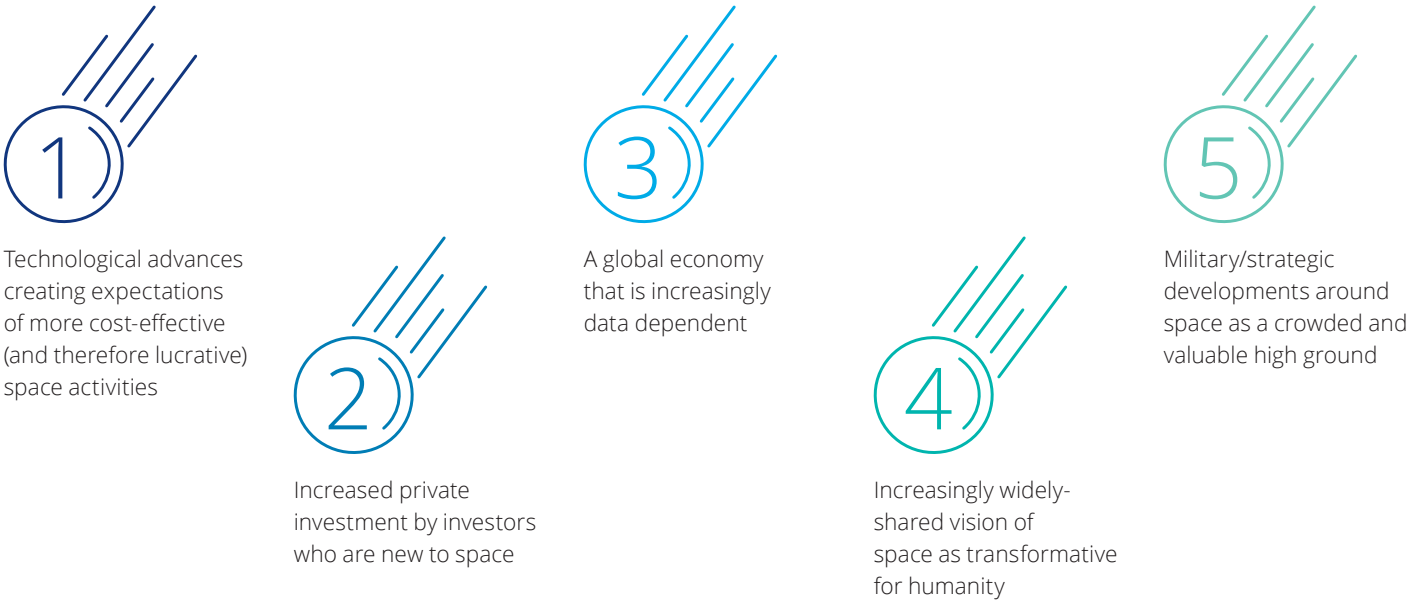
Elon Musk, 2015

Figure 3.4 Growth in the value of the global space economy



Source: Morgan Stanley

Figure 3.5 Five trends in the global space economy



Source: Bryce Space and Technology, 2017

Remote Asset Management

Remote asset management uses information, continuously collected via mobile, wired or wireless monitoring instruments, to create a two-way communication channel between assets and central monitoring applications. The 'real-time' data captured by this process allows for more effective maintenance scheduling and preventative maintenance strategy development. As a result, asset management processes are increasingly cost-effective, efficient and convenient when compared to traditional management practices such as on-site evaluations.

The practice has application across a variety of industries including transportation, food and beverage, oil and gas, metals and mining, healthcare and waste management. One particular example is within the manufacturing sector where remote monitoring procedures are used to capture critical asset parameters and track abnormality to avoid failures.

Source: Shoker, 2018; Infosys, 2018; Prescient & Strategic Intelligence, n.d.

3.3 Australian space economy

Historically, Australia has had a passionate, yet inconsistent, approach to national space activities. Australian involvement in space activities commenced with participation in the International Geophysical Year, a global scientific research program focused on understanding the Earth's relationship to its surrounding space environment.[15] The establishment of the Woomera Rocket Range in 1947 was originally used to develop long-range missiles during WWII and the cold war in Europe; this capability led to Woomera being used a testing facility for the Blue Streak rocket, which became the first stage of the Europa rocket under ELDO.[16]

Despite participating in research, development and testing related to space, Australia has not managed to sustain a scaled or vibrant space ecosystem to make it a recognised world leader in the space economy. For those who wish to pursue a career in space, aspiring enthusiasts typically seek to further their space related education overseas.[17]

However, what the Australian space industry lacks in size, it makes up for in substance. The Australian space economy today boasts several industry leaders across all sub-sectors in the space economy, with most individuals and organisations engaging in a wide variety of collaborations with international space agencies and organisations.

3.3.1 Australian Space Agency

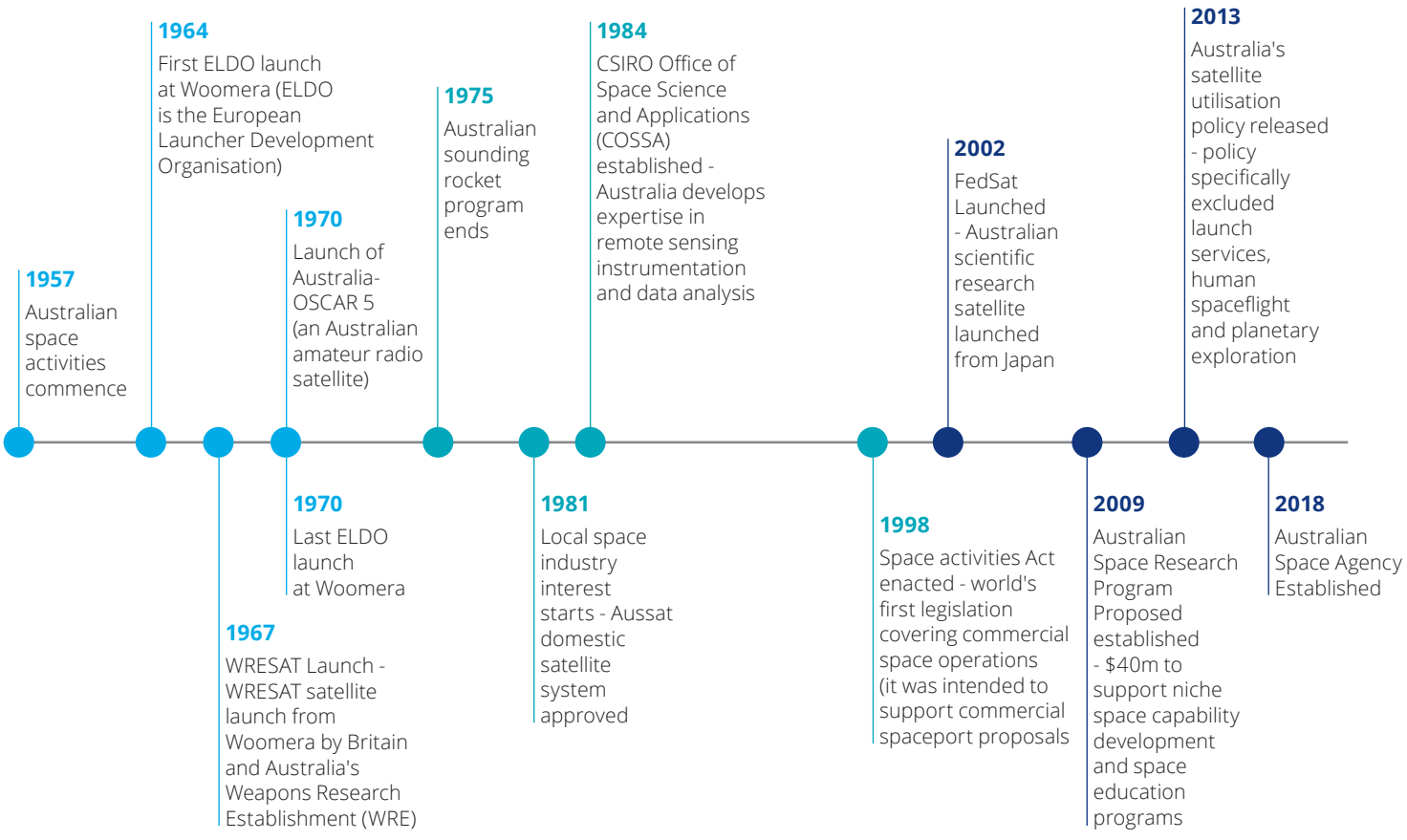
The Australian Space Agency aims to "transform and grow a globally respected Australian space industry that lifts the broader economy, inspires and improves the lives of Australians – underpinned by strong international and national engagement."[18]

The establishment of the Australian Space Agency (the Agency) in 2018 by the Australian Government, as a dedicated, ongoing and whole-of-government statutory agency,[19] signalled the intent of the Australian Government to grow the Australian space economy and set the tone for the Australian space sector moving forward.

Establishing the Agency has responded to the need – as identified by stakeholders as part of the Expert Reference Group's Inquiry – for a single point of contact for domestic and international partnerships, greater national coordination and strategic direction, government support to participate in global supply chains, and a whole-of-government approach to the space sector.[20]

Based in South Australia, the Agency has been given the responsibility for civil strategic policy direction setting, international representation, coordination of national civilian activities, and strategies to facilitate the growth of the Australian space industry sector as set out under the Agency Charter. The 2018-19 Budget allocated the Agency a budget of $41 million ($26 million over four years - $5.7 million in 2018/19, $9.8 million in 2019/20, $11.8 million in 2020/21 and $13.7 million in 2021/22), of which $15 million is to support international space engagement.[21]

Figure 3.6 Australia's space timeline



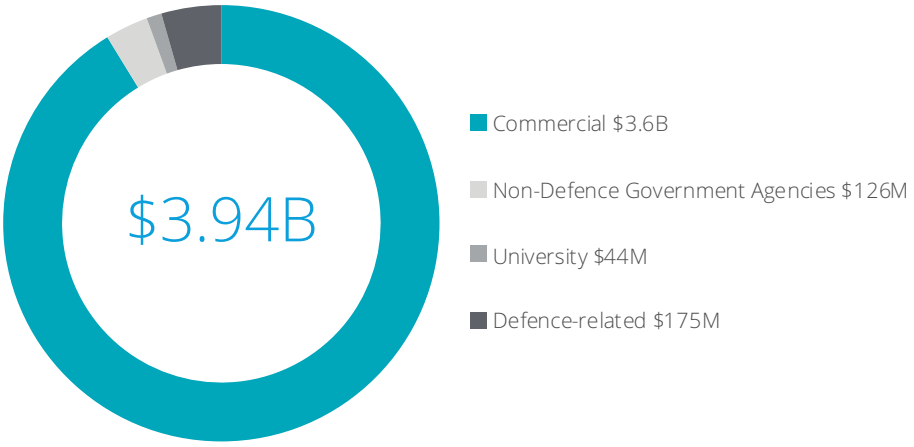
Source: Bryce Space and Technology, 2017

3.3.2 Value, growth and capability

The Australian Government's review of Australia's space industry capability to enable Australia to capitalise on the increasing opportunities within the global space industry sector (the Review) **estimated the market size of the Australian space economy in the 2015-16 financial year to be $3.94 billion**, as seen in Figure 3.7.[22]

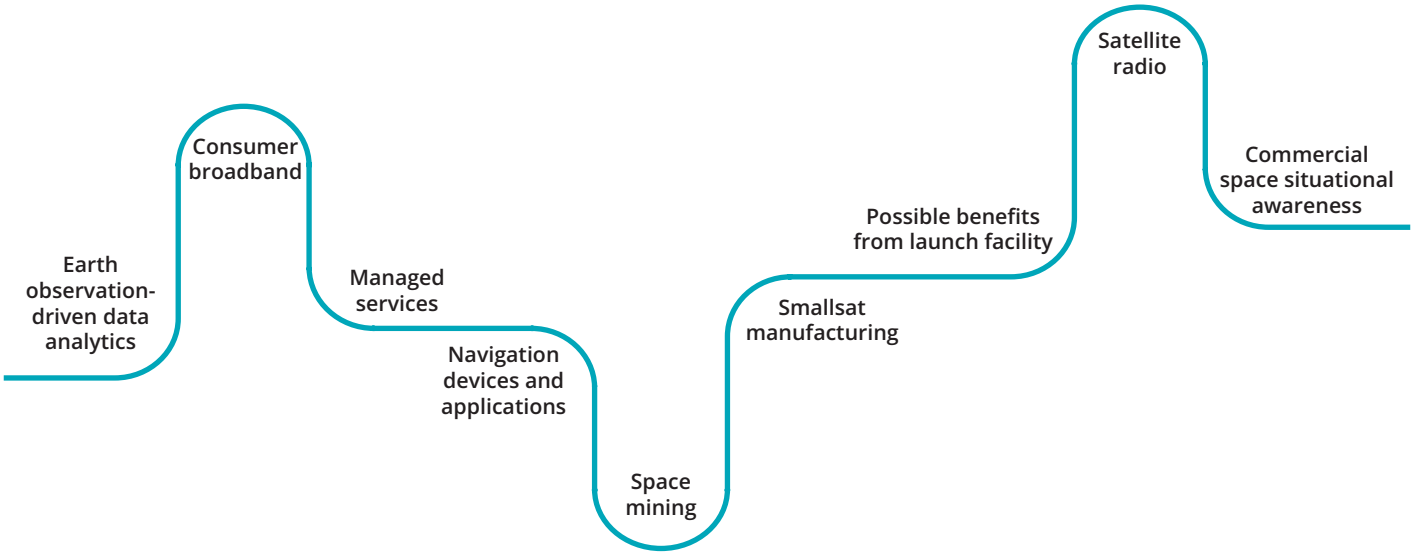
The Expert Reference Group set an ambitious and exciting goal for the Australian space community to triple the size of the Australian space economy from the 2015-16 estimate of $3.94 billion, to $10-$12 billion by 2030; representing a compound annual growth of approximately 8%.[23] This will create an industry that is roughly one-third the size of Australia's current agricultural output of AU$36.7 billion for the 2015–2016 financial year.[24] Further studies into the future of the Australian space economy have revealed several developing markets for which Australian industries have existing capability. As seen in Figure 3.8, Bryce Space and Technology highlighted where Australian businesses would be able to leverage existing strengths to compete in the global space economy.

Figure 3.7 Market size of the Australian space economy, 2015-16



Source: Australian Government Department of Industry, Innovation and Science, 2018

Figure 3.8 Markets for Australia's space economy to consider



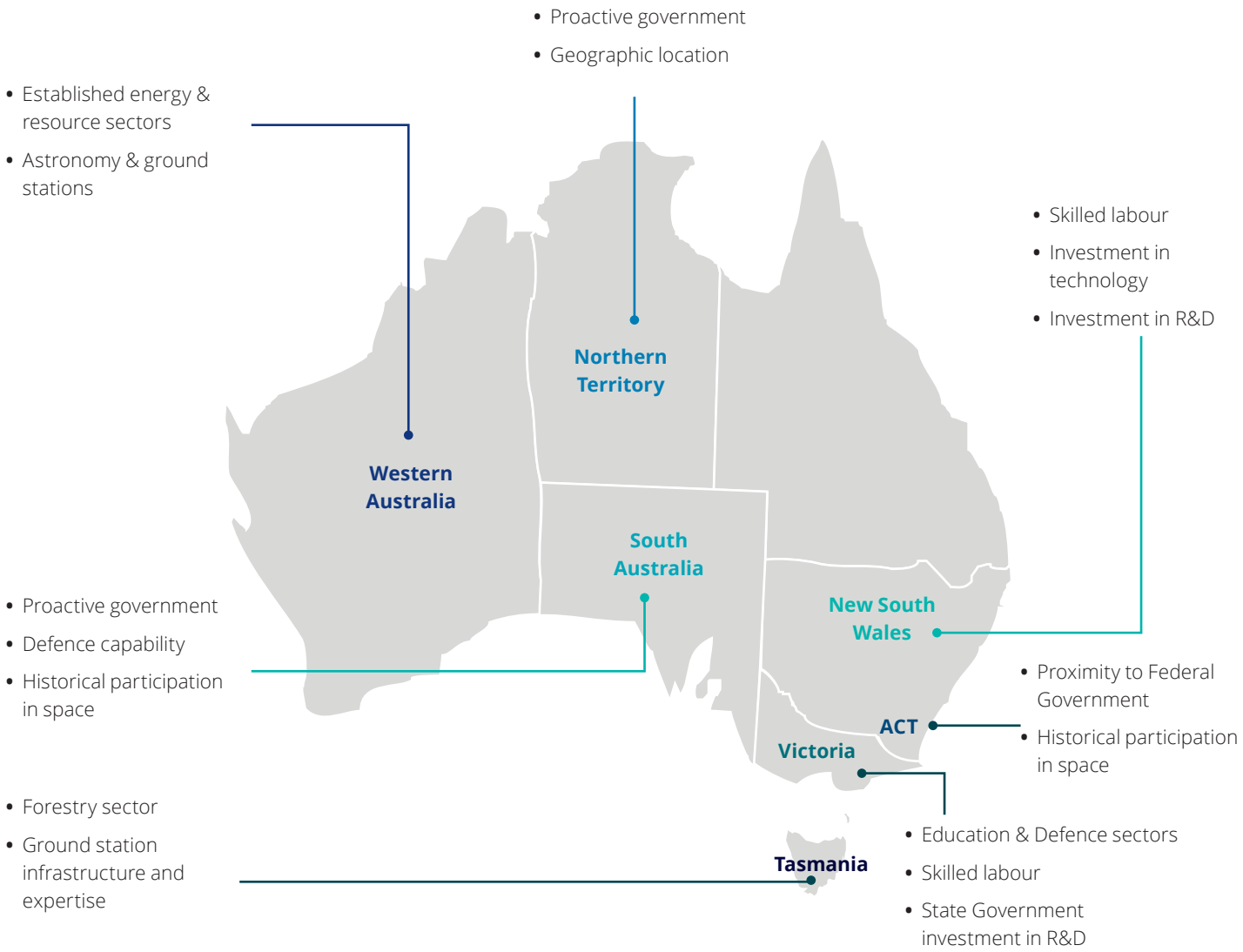
Source: Bryce Space and Technology, 2017

Previous reviews of Australian space capability have determined that Australia has capabilities along most of the space industry supply chain. However, the **strongest areas identified were where Australia has experience in integrating space sourced data into communications, Earth Observations from Space (EOS) and GNSS.**[25] This is likely due to a combination of Australia's geographic advantage, which has led to a natural cluster of capabilities in areas such as satellite communications, as well as the two way flow between technical and commercial capabilities between space related applications and other industries.[26]

Along other areas of the supply chain such as space systems, ground systems and launch activities, previous evaluations have revealed Australia as having limited or emerging capability – with only a few organisations operating. However, Australia's location and access to satellites, strong education system, technical expertise, and international partnerships and agreements means there exists potential for increased participation in the international space industry supply chain.[27] An overview of the competitive advantages across the Australian space economy are summarised in Figure 3.9.

Figure 3.9 Overview of space capability – rest of Australia

Space capability across other Australian jurisdictions



Source: Deloitte Access Economics

PART ONE | BOTTOM UP ANALYSIS

The following chapters present a bottom up view of Queensland’s space economy

4 Queensland's space economy

4.1 Overview

What gets measured gets managed, or so the saying goes. In order to develop a plan for the future of Queensland's space economy, it is important to first understand its current size and scope. However, the niche capabilities of players in Queensland's space economy, coupled with the blurred boundaries between other sectors such as aerospace, defence and advanced manufacturing, have meant that, to date, measurement of Queensland's space economy has been limited.

As explained in Chapter 1, Deloitte Access Economics fielded an industry directory and snapshot survey to create an industry capability directory and develop a snapshot of Queensland's current space sector. The questions asked for key information about businesses and services, and the scope of activities currently contributing to Queensland's space ecosystem. **The resultant Queensland Space Economy Capability Directory is the basis of all results presented in this chapter.**

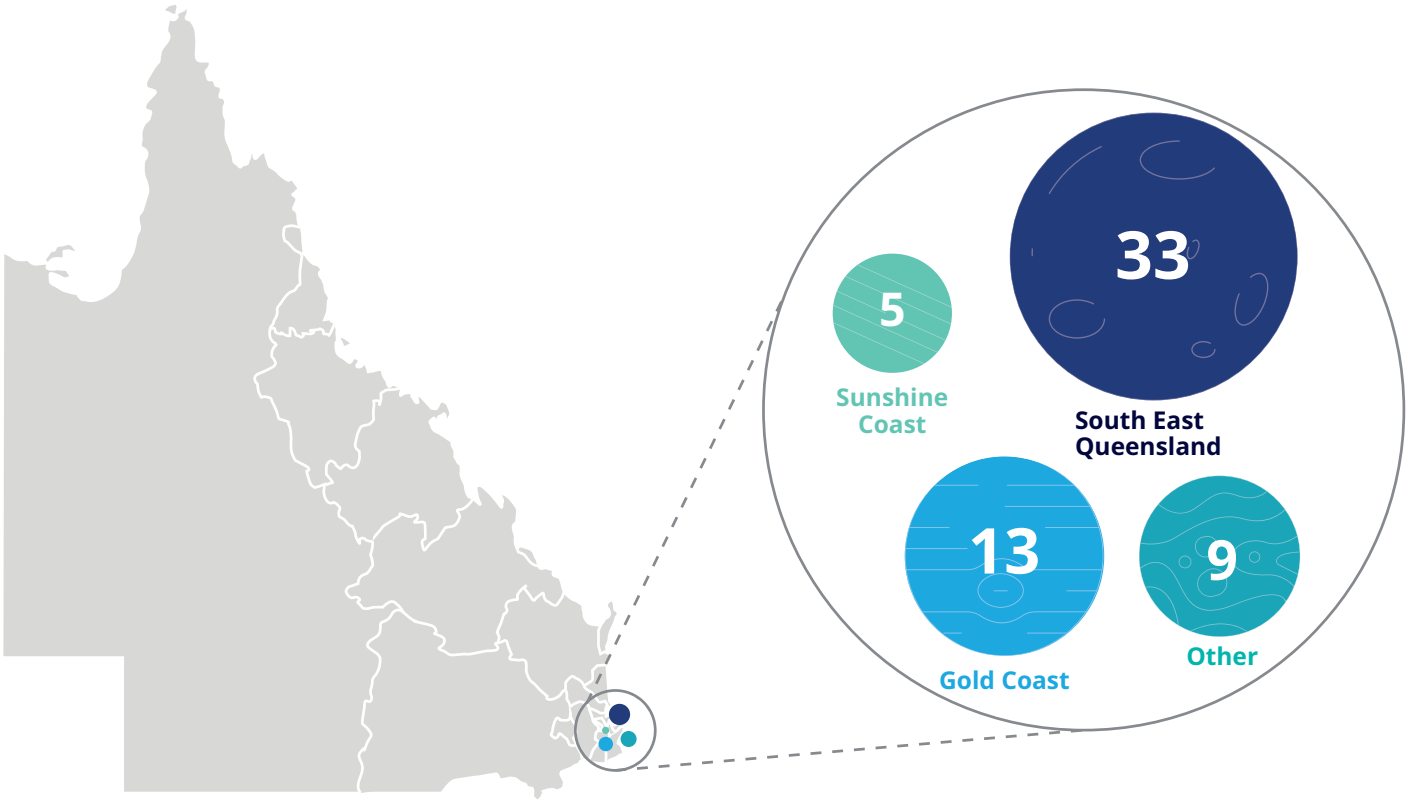
4.2 Overview of the space economy directory

The Queensland Space Economy Capability Directory is the first time information on Queensland's space economy has been captured and, as it is in its infancy, the results should be interpreted with caution. The results are limited by completion of the capability survey and the summary presented here provides a point-in-time snapshot of Queensland's space economy.

The capability directory depicts the cross-section of organisation type and primary area of capability; the organisations represented self-identified their primary area of capability in the space economy.

A data validation exercise was undertaken to ensure that organisations who responded to the survey were appropriate for analysis; from which 51 unique organisations have been included. Of the 51, 41 are headquartered in Queensland, predominantly in the wider Brisbane area. Reflecting the early stages of development in Queensland's space economy, 32 of the 41 organisations do not consider space to be their primary industry of operation. As demonstrated by Figure 4.1, the majority of organisations in Queensland's space economy are based in South East Queensland.

Figure 4.1 Location of Queensland's space economy



Source: Deloitte Access Economics

A summary of the directory, by the space economy sub-sectors (rows) and the type of organisations (columns), is presented below in Table 4.1. A full directory can be found in Appendix A.

Table 4.1 Summary of the Queensland space economy directory

		Private company	University/ Research Organisation	Government	Industrial Organisation
Space systems	Component and Material Supply	13			
	Satellite Owner/Operator				
	Space Qualified Testing and Facilities				
	Space Subsystem Supply	1			
	Specialisation on nano and micro satellites (<50kg)				
	System Engineering and Technical Support	2			
Launch activities	Component and Subsystem Management	1			
	Launch Services	4			
	Launch Support Services				
	Launch Vehicle Manufacturing and Assembly	1			
Ground systems	Antenna/Ground Station Component or Material Supplier	1			
	Ground Segment Prime/System Integration				
	Ground Segment Subsystem & Equipment Supplier				
	Prime/System Integration	1			
	System Engineering and Technical Support Services	2			
	Tracking, Telemetry & Command Operations	1			
Space enabled services	Earth Observation Services & Applications	3			
	Satellite Communications Service Providers				
	Satellite Navigation Service & Applications				
	Technical Support Services				
	User Equipment Manufacturer	3			
	User Equipment Suppliers				
Support services	Consultancy Services (e.g. IT, analytics, professional services)	5			
	Financial Services				
	Legal Services				
	Ancillary Services	3			
Research and development	R&D		4		
Education and Training	Education and Training		2		
Other	Other			1	1
	Transport, logistics and construction	1			
	General component, material, engineering supply	9			

Source: Deloitte Access Economics

4.3 Key findings

The Queensland space economy is **dominated by small-medium enterprises** (SMEs) and **large multinational organisations.** Queensland has a developing space ecosystem that has fostered a large number of highly specialised organisations, participating in areas of the space economy which do not require critical mass to operate. At the same time, these SMEs are supporting the operations of large multinational organisations participating in areas of the supply chain that are characterised by high capital and investment costs, and experienced personnel with specific capability to plan, operate and deliver large-scale projects.

Organisations with the highest turnover ranges in Queensland are typically large multinationals with extensive capability across the space supply chain. The size and turnover range of these organisations is frequently driven by their strengths in other sectors, such as Defence and Aerospace, which have symmetries with the requirements of the space economy.

Organisations in Queensland's space economy **operate in both the upstream and downstream components of the supply chain,** despite concentration in select sub-sector specialities. There are a large number of organisations clustered in the Space Systems and Other sub-sectors. This likely reflects the size and depth of the Queensland space economy.

At present, the maturity of the space economy means that there is insufficient demand to wholly support most organisations operating in the space economy. This is reflected in the **high proportion of organisations that operate primarily in other sectors.**

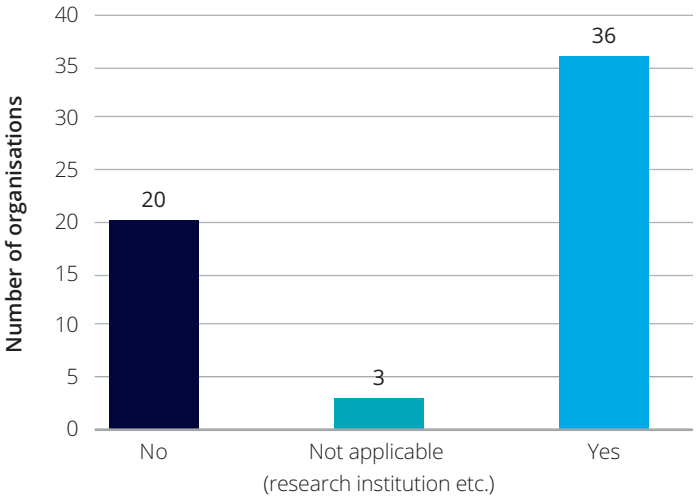
The following pages provide a more detailed breakdown of a selection of key components of the Queensland Space Economy Capability Directory:

- Exporting activities
- Turnover ranges
- Employee ranges
- Space as the primary industry versus space not as the primary industry
- Sub-sectors of the space economy.

Exporting activities

Respondents were asked to select whether they had exported goods or services overseas in the past 12 months. (n=59)

Chart 4.1 Exporting activities in Queensland's space economy



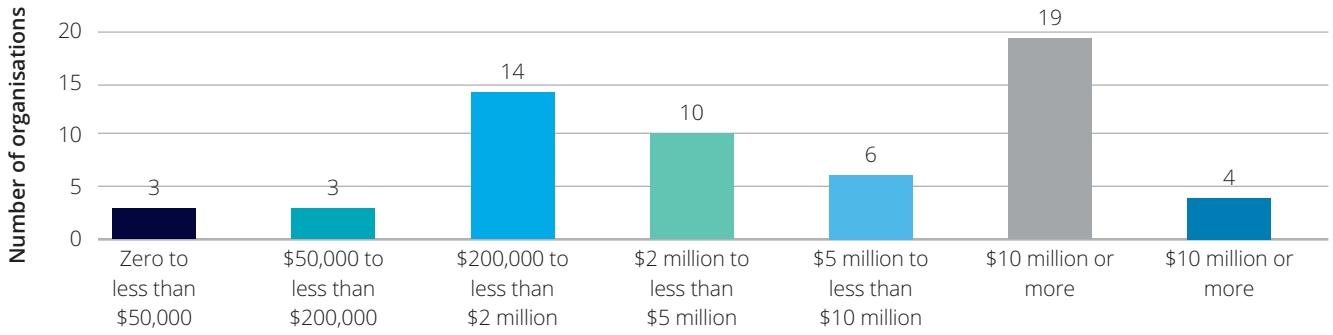
Summary of key findings

- The majority of organisations (36) exported goods in the previous 12 months
- This trend was the same across all turnover ranges, with the exception of organisations less than $200,000
- The majority of organisations that do not consider space their primary industry of operation (44) exported their products/ services (27).
- Of the organisations that do consider space their primary industry of operation (15), the majority exported their products/ services (9)
- The sub-sector with the most exporters was Space Systems (10) followed by Ground Systems (5)

Turnover ranges

Respondents were asked to select which ANZSIC turnover range was most appropriate for FY18. (n=59)

Chart 4.2 Turnover ranges in Queensland's space economy



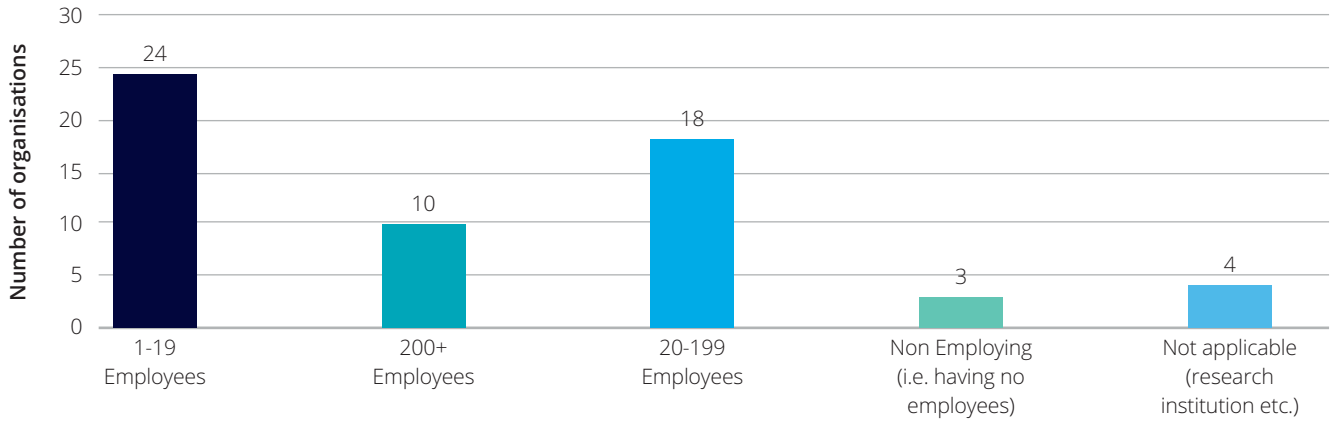
Summary of key findings

- Almost half of the organisations in Queensland had turnover range in FY18 that was greater than $2 million
- One third of organisations reported turnover in excess of $10 million; of these, organisations are typically located in the Space Systems, Ground Systems and Space Enabled Services
- The highest turnover ranges were typically reported by the Ground Systems segment (most are large multinational organisations with capability across the supply chain)
- Most of the SMEs reported turnover in the ranges $200,000 – less than $2 million (13) and $2 – 5 million (8)
- Of the 13 organisations in the range up to $2 million, most are based in Ancillary Services, whilst SMEs earning $2 - $5 million are typically located in the Space Systems sub-sector

Employee ranges

Respondents were asked to select the most appropriate employee range for FY18. (n=59)

Chart 4.3 Employee ranges in Queensland's space economy



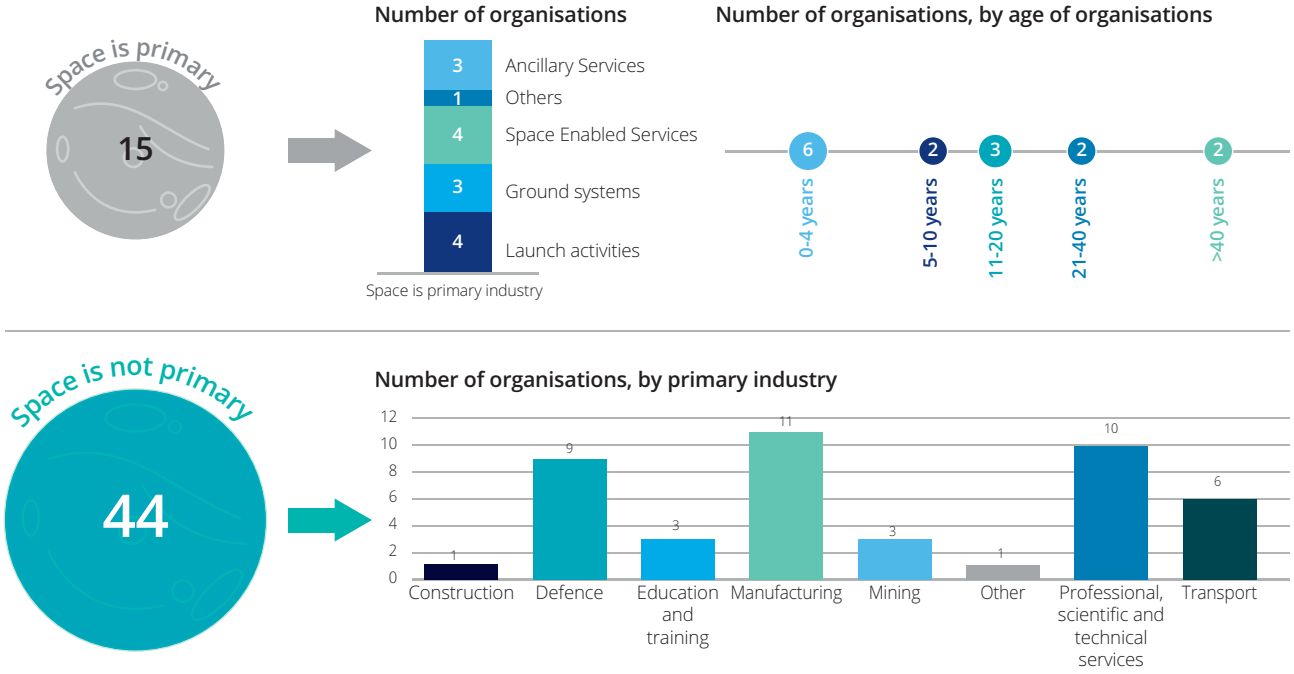
Summary of key findings

- The Queensland space economy is dominated by SMEs
  - SMEs typically sit in the Space Systems (9) sector and the Ancillary Services (5)
- Organisations employing between 20-199 (18) are primarily located in the Space Systems (6) and Ground Systems (6) sub-sectors
  - 10 organisations in Queensland selected the 200+ range
- This reflects both the universities that are engaged in space related activities as well as the large multinationals that have operations in Queensland
- The majority of organisations that consider space their primary area of operations are SMEs

Space as the primary industry?

Respondents were asked to select whether they consider the space industry as their primary industry of operation. (N=15 for primary industry and n=44 for not the primary industry)

Figure 4.2 Comparison between organisations with space as the primary industry of operation and not as the primary industry



Space is primary

- 15 organisations consider space their primary industry of operation
- Respondents were spread across Launch Activities (4), Ground Systems (3), Space Enabled Services (3), Ancillary Services (3), R&D (1) and Other (1)
- The majority (10) of organisations had turnover up to $2 million; of the organisations that earned more than $10 million (3), their primary capabilities lay in the Ground Systems and Space Enabled Services sub-sectors
- The Launch Activities sub-sector (4) was typically low employing and had turnover less than $2 million in FY18
- The majority (9) of organisations exported their products/ services in FY18; the majority were in the Ground Systems sub-sector

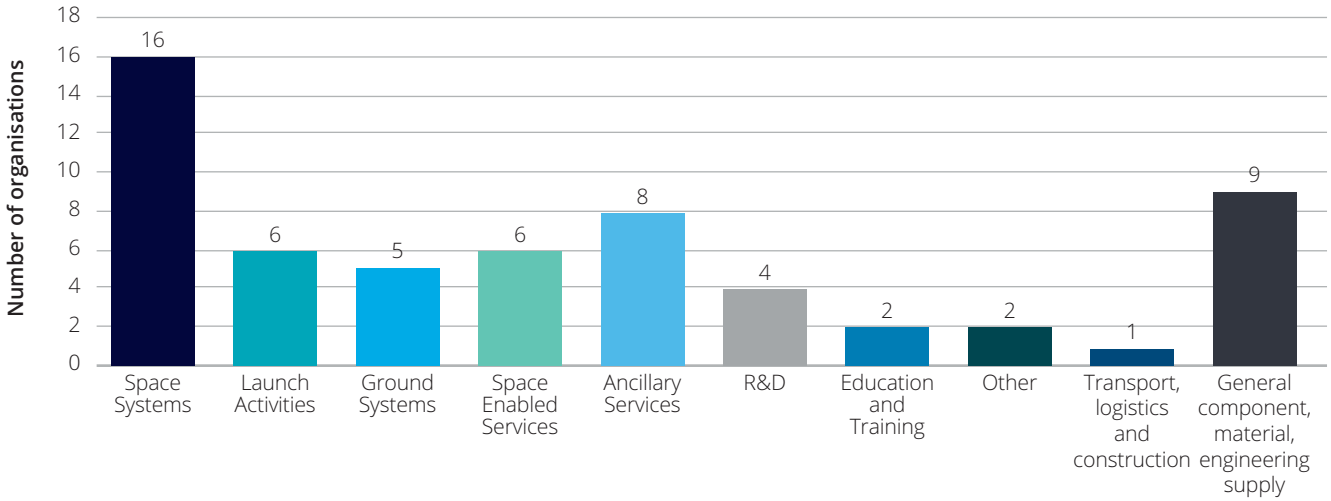
Space is not primary

- The majority of organisations (16), are engaged in the Space Systems sub-sector, followed by General, component, material, engineering supply (9) and Ancillary Services (5)
- Space Systems
  - Organisations are primary engaged in the Defence and Manufacturing and Transport sectors more broadly
- General component, material, engineering supply
  - Organisations in this sub-sector typically operate in the Manufacturing and Defence sectors
- Organisations with transferrable skills that have been engaged by the space sector include Mining, Professional, Scientific and Technical Services, Construction and Education and Training

Sub-sectors

Respondents were asked to classify their business according to their primary area of capability. These have been aggregated across sub-sectors of the space economy. (n=59)

Chart 4.4 Sub-sectors in Queensland's space economy



Summary of key findings

- Space Systems
  - The majority of organisations in the sub-sector report turnover in excess of $2 million
  - The sub-sector is dominated by small-medium enterprises (SMEs), with several (6) organisations with employees in the 20-199 range
  - The majority of organisations exported their products in FY18
  - The majority of organisations in the sub-sector have been in operation in excess of 10 years
- Launch Activities
  - The sub-sector is evenly split in the export of products/ services in FY18
  - Of the organisations in launch, 2 are SMEs whilst the rest employ upwards of 20-199 personnel
  - Organisations reported turnover in each of the ranges in FY18
  - Launch Activities is a very young sub-sector, with the majority of organisations in operation for less than 5 years
- Ground Systems
  - The majority (4) of organisations in the sub-sector reported turnover in excess of $10 million
  - The sub-sector is characterised by high-earning, high-employing organisations
  - The majority of organisations in the sub-sector have been in operation in excess of 10 years
- Space Enabled Services
  - The SMEs in the sub-sector reported turnover of up to $5 million, whilst the large organisations earned in excess of $10 million in FY18
  - The sub-sector has a broad spectrum of duration of operation length, with organisations in the less than 5 years category as well as several organisations in the excess of 10 years category
- R&D
  - 1 research organisation exported their products/services in FY18
  - As most organisations in this sub-sector are universities, they have longer duration of operations
- Other
  - Other includes the following categories: 1) transport, logistics and construction, 2) general component, material and engineering supply and 3) other. These organisations typically provide general inputs to the identified sub-sectors and as such, are engaged in the space economy (and thereby benefit from its growth) whilst not being directly involved in space related activity. Often, these organisations will facilitate the activity of space organisations.

5 Queensland's competitive advantages

5.1 Overview

The previous chapter presented an overview of the current size and scope of Queensland's space economy, highlighting the niche areas in which Queensland currently chooses to operate. Where we currently specialise, and where the opportunities for growth lie, are a function of our competitive advantages. We do not have the scale to compete in all areas of the global space economy, so where do we have the natural, physical and human advantages that ensure that when we do choose to invest, we will be competitive?

This chapter introduces the capability matrix used to identify these areas of competitive advantage. The matrix assesses natural/geographical, physical and human capital characteristics of each of the space economy sub-sectors, as well as the presence of deep markets. The evidence base underlying the assessment has been derived from industry consultations and the industry capability survey.

5.2 Capability matrix

An extensive assessment of the Queensland space economy and its capabilities across the supply chain has not previously been undertaken. As such, the development of a capability matrix and corresponding criteria was required to assess the Queensland space economy as it stands today.

Organisations across the space supply chain in Queensland, notwithstanding a few exceptions, are typically small in number and size. However, they exhibit industry-leading expertise in the often niche areas in which they operate.

Across all sub-sectors in the space economy, organisations are engaged in commercial and/or collaborative relationships with large international companies or space agencies. This reflects a vibrant ecosystem of well-connected organisations participating in highly specialised areas that often demand high entry and investment costs, and have long investment cycles.

The capability matrix has been developed and assessed using supporting evidence and analysis from a variety of sources including: the industry capability directory survey (survey 1) and industry capability survey (survey 2), focus groups, discussions with the Queensland Space Industry Reference Group, site visits, desktop research and sources from the Queensland Parliamentary Inquiry.

5.2.1 Development of criteria for assessment

The extent of capability across the Queensland supply chain largely reflects both the size of the Queensland sector, and the developing national space economy.

Despite some expert capability areas in the Queensland space economy, there does not exist the same history of operations that develops critical mass and which would permit a meaningful assessment of Queensland's capabilities relative to other space economies. For instance, the decades of investment in, and development of, the space sector in the United States and the capability of NASA is not comparable to the level of investment and development in Australia's national sector, or Queensland's.

To appropriately gauge capability across the supply chain, sub-sectors in the Queensland space industry have been assessed relative to the level of maturity of the Queensland and national space economy. The criteria and assessment approach also accounts for the recognised market criteria that are necessary conditions to the operation and growth of the space economy.

This approach reflects the performance of each sub-sector and takes into consideration the fact that Queensland's space economy has significant growth potential which, for the most part, has not yet been realised. The approach also reflects the inputs and outputs of the space economy, and highlights where Queensland may have a competitive advantage, or an existing capability that has symmetries with the global space economy.

The criteria for the capability matrix are assessed as strong, moderate or limited and include:

- **Natural/Geography –** Queensland's geographic location provides a unique or competitive advantage for the sub-sector.
- **Physical infrastructure –** availability of necessary physical infrastructure in Queensland for the sub-sector to operate e.g. satellites.
- **Human capital –** availability/ appropriateness of Queensland knowledge and expertise that is critical to development.
- **Demand –** state of the current demand for the sub-sectors products and/ or services in both the national and international market.
- **Supply –** readiness of supply for the products and/or services required by the sub-sector.

Table 5.1 details the assessment criteria for the capability matrix and the definition of the differing scales of maturity – between strong, moderate and limited capability.

5.3 Assessment of Queensland's space industry capability

A summary of the application of the capability matrix across each of Queensland's space industry sub-sectors is provided in Table 5.2.
The summary provides an overview of where capability exists in the Queensland space industry, and highlights areas with strong capability in the Queensland ecosystem. Overall, the Queensland space industry is characterised by scattered, but moderate capability in highly specialised areas.

Further detail concerning each element of the capability matrix, and the corresponding assessment across the sub-sectors of the industry, is provided in the following sections of this chapter as well as in Appendix B.

Table 5.1 Assessment criteria for capability matrix

	Natural/Geography	Physical	Human Capital	Demand	Supply
Strong	Queensland's natural environment/ geography provides a unique competitive advantage, which the sub-sector can leverage off.	Queensland's space economy has the physical infrastructure required for the sub-sector, is well established and/ or can operate independently.	Queensland's workforce is able to sustain the majority of the human capital requirements of the sub-sector, with only a small number of specialist skills imported.	There is a mature domestic and international market demand for products/services the sub-sector produces.	There is a mature domestic and international market supply for products/ services required by the sub-sector.
Moderate	Queensland's natural environment/ geography is advantageous but not critical to the development of the sub-sector.	Queensland's space economy has some physical infrastructure required by the sub-sector but relies on other jurisdictions to operate.	The human capital required by the sub-sector is not adequate to sustain development and/ or growth without skills being imported. The sub-sector frequently relies on other jurisdictions for expertise.	There is a mature international market demand and developing national market demand for products/services the sub-sector produces.	There is a mature international market supply and developing national market supply for products/services required by the sub-sector.
Limited	Queensland's natural environment/ geography does not provide any additional benefit to the sub-sector.	Queensland's space economy does not have the relevant physical infrastructure to develop the sub-sector.	There is no available expertise for the sub-sector. All human capital is imported.	There is demand in the international market (either mature or developing) on which the sub-sector relies entirely as there is no national market demand.	The international market (either mature or developing) is the primary supplier as there are no suppliers in the national market.

Source: Criteria developed by Deloitte Access Economics

Table 5.2 Queensland Capability Matrix

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Space Systems	N/A				
Launch Activities					
Ground Systems					
Space Enabled Services	N/A				
Ancillary Services	N/A	N/A			
R&D					
Education	N/A				

5.3.2 Space Systems

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Space Systems	N/A	Moderate	Limited	Moderate	Limited

The space systems sub-sector contributes to the supply, manufacture and operation of infrastructure and technology used in space. Organisations in the sub-sector are spread across three key capability areas – Component and Material Supply, Space Subsystem Supply, and System Engineering and Technical Support.

In Queensland, the majority of organisations in the sub-sector do not identify space as their primary activity of operations. There is some, but specific, physical infrastructure available to the sub-sector. This rating further reflects the size of the sub-sector, rather than the individual capability of organisations; while physical infrastructure exists, there is not critical mass in the industry.

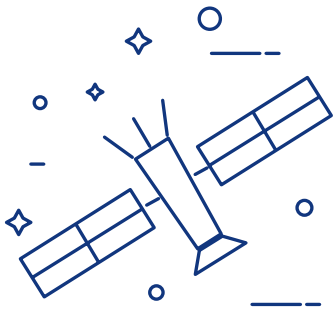
The majority of organisations have exported their products/services in the previous financial year, reflecting international demand for the products and/or services offered by the sub-sector. However, as most organisations do not consider space their primary industry of activity, these exports are unlikely to be entirely space related. This suggests that while there is capability in the sub-sector, which is likely to support the existing demand of the emerging industry in Queensland and Australia, there is scarce domestic demand for the products/ services of the sub-sector. This may limit the ability of the sub-sector to develop domestically.

It was identified that growth in the sub-sector would be well supported by existing strengths across industries such as Defence, Aerospace, Manufacturing and Mining in the Queensland economy.

Milspec Solutions

In operation for over 40 years, Milspec designs and manufactures brushless alternators and portable power systems for defence forces across the world. Milspec is an Australian organisation that provides subsystems for defence and other industry applications.

"With the new worldwide rule change of what goes into space must come back on its own power, we have the equipment to assist with this. There is also equipment that no one else manufacturers for the space program."



5.3.3 Launch Activities

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Launch Activities	Strong	Limited	Limited	Moderate	Limited

Capability in the launch sub-sector is spread across Component and Subsystem Management and Launch Services.

The Queensland launch activities sub-sector has a strong competitive advantage due to the Queensland's geography and proximity to the equator. This enables launch into both polar and equatorial orbits, as well as access to large areas of unused land and airspace.

Queensland is home to two of the most active rocket launch proponents in Australia. Both highly specialised organisations have access to interim launch facilities but not a fully operational launch site capable of supporting commercial launches. Changes in market structure of the global space economy have led to global growth in launch activity that exists to support the launch of commercial payloads into space. These payloads are driven by growth in the satellite industry; which is driven by demand for the formation of mega-constellations. In Queensland, the launch activities sub-sector does not have available to it the physical infrastructure that is required in to compete in the global launch market.

While some organisations in launch experienced differing degrees of success locating individuals with the necessary knowledge and skills, the sub-sector has to frequently rely on skills and expertise outside of Queensland to conduct their operations. The sub-sector expressed concerns about the availability of human capital with the appropriate skills required to sustain growth and development in the sub-sector.

Analysis of the launch activities sub-sector suggests there is developing demand for launch services in Australia which is currently unmet. This unmet demand is in part explained by the sub-sector presently being limited by regulation and lack of commercial launch facilities.

The size, turnover and lack of export capability of organisations in the launch sector further suggests there may be a demand/supply issue. Despite this, it is important to note organisations have been able to rely on Queensland industry for materials and manufacturing capability for many of the necessary inputs; there do however remain some inputs which the sub-sector cannot source in Queensland. For example, propulsion activities require hydrogen peroxide that organisations must import from international suppliers.

Accordingly, the limited rating given to the supply criteria in this sub-sector reflects 1) the size of the sub-sector in Queensland and 2) key limitations which make it necessary for organisations to purchase inputs outside of Queensland and which prohibit the sub-sector from growing domestically.

Gilmour Space Technologies

Founded in 2012, the Queensland based hybrid propulsion company plans to launch its first commercial hybrid rocket to space in 2020. The company plans to launch Eris-100 in 2020, a three-stage commercial vehicle capable of launch 100 kilograms to Low-Earth Orbit; followed by Eris-400 in 2021, a clustered-engine vehicle for payloads of up to 400 kilograms.

"The small satellite revolution is gaining momentum globally, with thousands of small satellites slated to launch into low-Earth orbits (LEO) over the next five years"

"Our end goal is to provide low-cost access to space, and to enable human spaceflight and exploration." **– Adam Gilmour,** CEO & Founder, Gilmour Space Technologies

Black Sky Aerospace

The Queensland company behind the sub-orbital launch, Black Sky Aerospace (BSA) is one of Australia's leading space launch proponents. BSA was responsible for Australia's first commercial rocket launch west of Goondiwindi in outback Queensland in 2018. Three commercial payloads were tested on the sub-orbital flight:

1. Space rated sensors for the Australian Centre for Space Engineering Research (ACSER).
2. A carbon ceramic panel for hypersonic flight, with embedded sensors, onboard for the University of Queensland's Composites and launch start-up Hypersonix.
3. A wrist device for skydivers which provides data on altitude, speed and GPS tracking, manufactured by Dekunu Technologies. The launch also paved the way for more BSA rocket flights in Queensland, including this re-usable rocket which landed 1.8 kilometres away from the launch site

5.3.4 Ground Systems

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Space Systems	Strong	Limited	Limited	Moderate	Limited

Organisations have identified capability in Antenna/Ground Station Component or Material Supplier, Prime/System Integration and Ground Segment/System Integration.

Similar to the launch sub-sector, ground systems benefit from a competitive advantage in geographic location. Ground systems have geographic requirements in order to achieve operational (e.g. areas of low interference) and strategic (e.g. limited ground station capability in southern hemisphere) objectives. Queensland is well positioned to leverage these objectives and support satellite launch services with large open spaces, significant uninhabited land mass close to the equator and flight paths over the ocean.

The sub-sector has limited capability with respect to the physical infrastructure required to facilitate activities. While capability exists in operating and facilitating the use of ground systems infrastructure and technology, a limitation of the sub-sector is the lack of large infrastructure, ownership of which would drive expansion and growth. An absence of ground station infrastructure limits not only the growth of the sub-sector itself, but also that of other sub-sectors including Space Enabled Services that could benefit from infrastructure flow on effects.

Ground systems organisations are primarily suppliers, technical support, or operational assistance, limiting the growth potential in downstream applications associated with the sub-sector. Australia's long historical involvement in this sector means there is significant human capital capability across the nation. However, Queensland-based organisations identified the lack of individuals participating in the sub-sector to support further long term growth. In Queensland, several of the ground segment organisations are large multinationals, which enables them to draw from their international networks to fill skills gaps.

All organisations in the ground systems segment export their products/services, which likely reflects a combination of factors at play in the sub-sector. Several of the organisations are large multinationals with significant capability across not only the space supply chain, but other industries such as Defence and Aerospace (which have similar product/ service requirements). Significant demand for these products and services exists in international markets. Consequently, growth in the sub-sector at present is not driven by developing national demand but rather the demand of international markets.

EM Solutions

Based in Yeronga, EM Solutions is a broadband satellite communications equipment manufacturer, with extensive R&D and engineering capabilities related to microwave and RF subsystems, electromagnetics, antenna design, mechanical pedestals, and stabilised platforms.

EM Solutions design and manufacture differentiated microwave and RF products and systems for satellite and broadband communications. Exporting globally, EM Solutions supply next generation high speed communications products that assist in the delivery of real-time voice, data and multimedia anywhere in the world.

5.3.5 Space Enabled Services

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Space Enabled Services	N/A	Moderate	Moderate	Moderate	Moderate

The sub-sector has access to the necessary operating infrastructure including satellites, ground stations and telescopes. However, capability growth in Queensland is limited by the lack of ownership of key physical infrastructure assets that support the sub-sector.

Constraints to growth in the sub-sector are also driven by the highly specialised nature of the fields in which organisations operate. These require human capital with specific qualifications and experience. All organisations in the sub-sector identified the difficulty in hiring a workforce with skills in the requisite fields.

Growth potential exists in the sub-sector and is driven by EO, PNT and GNSS technology, and their application across non-traditional areas in the economy. This growth will support the development of the sector.

Developing demand in Australia for products/services of the sub-sector is a constraint to growth. Organisations expressed difficulty gaining access to international markets due, in some cases, to trade relations. Despite this, the majority of organisations export their products/services. While predominantly location agnostic, exposure to industries with potential to use the sub-sector's products/services is a key advantage for organisations based in Queensland. This advantage is somewhat limited however by a lack of ground system infrastructure that would provide significant flow on effects to organisations in the sub-sector.

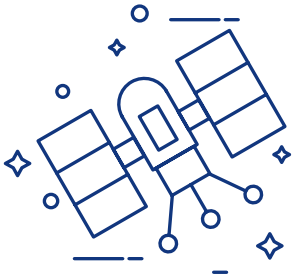
The sub-sector has moderate supply capability which reflects organisations' import requirements and strong capability at the national, but not state, level. Inputs for the sector which are not able to be sourced from Queensland include satellite imagery, software and advanced cloud computing. This does not however restrict the operational ability of organisations in the sector. Space enabled services rely heavily on inputs sourced from the Information, Media and Telecommunications sector for which the broader Australian economy has significant capability. However, the majority of expertise in the sector is not based in Queensland.

Ozius

In a country as dry as Australia, the ability to find water under the earth's surface using data from space is a game changer. And that is precisely what Queensland Earth Observation analytics company Ozius did; finding springs in the Great Artesian Basin no-one knew existed. By combining EO data with time-series historical information and real-time ground observation, Ozius is changing the space-based data analytics game.

Ozius relies on this unique combination of existing and emergent technologies; their bespoke combination of EO data analytics, machine learning, historical data and planning, environmental science and remote sensing expertise have lead the company to work with blue- chip energy and resource companies.

"Ozius is a commercial, remote sensing analytics company, which utilises space-based data from satellites" Ben Starkey, business manager of Ozius.



5.3.6 Ancillary Services

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Ancillary Services	N/A	N/A	Limited	Limited	Limited

Limited capability exists in the sub-sector at present. The breadth of skills required to provide services to the sub-sector is limited by the existing size and demand for services of organisations operating primarily in the space economy.

Despite this, some unique capabilities do exist in Queensland's space economy. Organisations with skills and experience in industries such as Defence and Aerospace have been able to provide services to some organisations in the space economy in the absence of specialised products/services. Demand for products/services provided by the sub-sector is dependent on the size of Queensland's space economy. Without broader growth in the space economy domestically, there will be limited capability in the sub-sector.

International Aerospace Law & Policy Group

Bringing together expertise in international aviation, space, drone and defence law is how IALPG works - we have diverse expertise to bring about constructive and commercial solutions to time-sensitive legal problems even where they are politically-sensitive or part of regionally important aviation projects.

IALPG's Space Law & Strategy expert, Duncan Blake "is keen to facilitate a stronger Australian space industry, as well as finding ways for all sectors of the global space industry to collaborate in the development of global space governance for a more stable and better connected world."

5.3.7 Research and Development

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
R&D	Moderate	Moderate	Moderate	Moderate	Limited

Organisations in this sub-sector are typically university or Government affiliations with industry leading expertise in niche areas of the space economy.

R&D in Queensland has formed some natural clusters of expertise, partially due to geographic advantages. Proximity to the equator, clear night skies and alternative time-zones have encouraged capability in areas such as observation, tracking and testing.

The sub-sector requires high-cost infrastructure to support operations; in some areas, Queensland organisations have world-leading capability in small pockets of expertise. This has encouraged the growth of clusters, attraction of investment and furthering of knowledge. The limited physical infrastructure is a reflection of the high investment costs associated with specific technologies.

Most of Queensland's major universities have capability in unique areas of space. Widespread expertise across organisations is not observed as the Queensland space economy is not sufficient to sustain large amounts of human capital. Organisations experience varying degrees of difficulty in hiring due to the extremely specialised areas of interest. The moderate rating reflects that where there exists human capital R&D capability in Queensland, individuals are industry leaders. However, a large scale workforce does not exist.

The sub-sector collaborates widely across the global space economy in the absence of local and national demand for expertise. However, this has also contributed to the depth of specialisation which has occurred in the sub-sector as individuals/organisations are typically well connected and at the forefront of innovations in their chosen fields. Limited supply of inputs required for the sub-sectors products/services is often met by the international market.

University of Southern Queensland (USQ)

USQ is an R&D institution with focus and capability across a number of space sub-sectors, exemplified by its different research centres/groups.

The Centre for Future Materials (CFM), home to USQ's Advanced Composites Manufacturing research programme team, provides "novel design, manufacture and testing for aerospace, space and defence advanced composite structures." Through partnerships with public and private, domestic and international entities, the centre is developing one-of-a-kind R&D capabilities.

USQ's Centre for Astrophysics (CA) specialises in R&D capabilities relevant to optical tracking, scientific imaging, spectroscopy, spectropolarimetry, photonics, celestial mechanics, space resources and space weather. The centre extensively collaborates with international institutions including the NASA Exoplanet Science Institute (Caltech) and the Harvard-Smithsonian Centre for Astrophysics on a range of R&D projects, some of which are facilitated by USQ's Mount Kent Observatory.

The Hypersonics Group (HG) delivers aerospace research outcomes in conjunction with national and international partners including the ESA and NASA. It has undertaken, and continues to be involved in, various R&D projects. An example is the 'Spacecraft re-entry break-up' initiative, an Australian-German exchange program with the Institute of Space Systems, at the University of Stuttgart, to develop dispersion models used to manage end-of-life deorbit of spacecraft.

5.3.8 Education and Training

Space industry sub-sector	Natural/ Geography	Physical	Human Capital	Demand	Supply
Education	N/A	Moderate	Moderate	Limited	Limited

Capability in the sub-sector is limited in its provision of space specific courses and opportunities. However, there exists industry-leading educational opportunities and capabilities in several areas with symmetries to the space economy.

Queensland educational institutions are well placed to leverage off existing capability should growth in the space economy drive activity in the education sector. Several of the education institutions have specialised research units dedicated to space activities as well as industry-leading expertise. However, they do not presently provide educational opportunities specifically designed for the space sector.

Limited demand for, and supply of, education and training specific to space related activities is a reflection of the size of the current local market. There has not previously been sufficient demand for education specific to the space sector; individuals seeking to further pursue space education and gain industry experience will often do so overseas. This is often referred to by space organisations as 'brain drain' and is sighted as a primary constraint to growth. This phenomena further exacerbates the problem as the existing industry is required to import expertise, reducing demand for space-related education over the long-term.

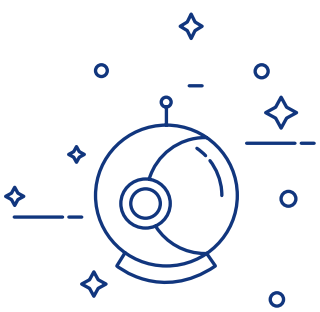
Educating the next generation

Australian Space Design Competitions provide industry-simulation events for high-school students in Australia. Competitions provide interactive, high-tempo, and dynamic environments for students to further their Science, Technology, Engineering, and Mathematics (STEM) skills. Since 2002, ASDC have partnered with a number of organisations and schools across Australia to nourish and prepare the next generation of innovative young minds.

The champion team from the ASDC Finals represents Australia at the International Space Settlement Design Competition (ISSDC), held annually the following July (due to Northern Hemisphere school years) at the Kennedy Space Centre (Florida, USA). Held at the University of Queensland, this year, the winning team comprised of representatives from two Queensland high schools; who will now go on to represent Australia.

The Aerospace Gateway to Industry Schools program was established to support the growth and development of an effective workforce for the aviation industry sector. This program provides opportunities for young people to undertake structured workplace learning, school-based apprenticeships and traineeships, full-time employment, and further study through industry-school partnerships. It has proven essential in meeting the Queensland Government's aim of transitioning young people from school to work while completing school and gaining formal qualifications.

The program currently involves a total of 18* Queensland secondary schools (government and non-government), with 300 students throughout Queensland studying Aerospace studies. There are over 30 industry partners and supporters engaged including local aerospace entities, training institutions and universities. These partners all contribute to creating pathways for students into Queensland's aerospace industry.



6 Areas for future growth in Queensland's space economy

6.1 Overview

Growth opportunities for Queensland's space economy lie at the nexus of competitive advantages, existing capabilities and global trends. However, the space economy is not something that can be grown overnight; rather, deep expertise, fostered by decades of public and private investment, is necessary to compete in the highly competitive global supply chain.

This chapter presents the key areas for growth in Queensland's space economy.

Consultations with the industry revealed four recurring themes about areas for future growth in Queensland's core space economy (Figure 6.1):

- **Connecting** into the global space economy, which is set for sustained growth
- **Strengthening** our existing capability to ensure that our current areas of niche expertise are world class and are positioned for growth
- **Experimenting** through a continued focus on our deep – albeit niche – expertise in research and development
- **Leveraging** current space economy strengths, and broader strengths such as advanced manufacturing, to move into new areas of the space economy.

Moreover, the **adoption** of space enabled services by other Queensland industries was also revealed as an area for – potentially large – growth.

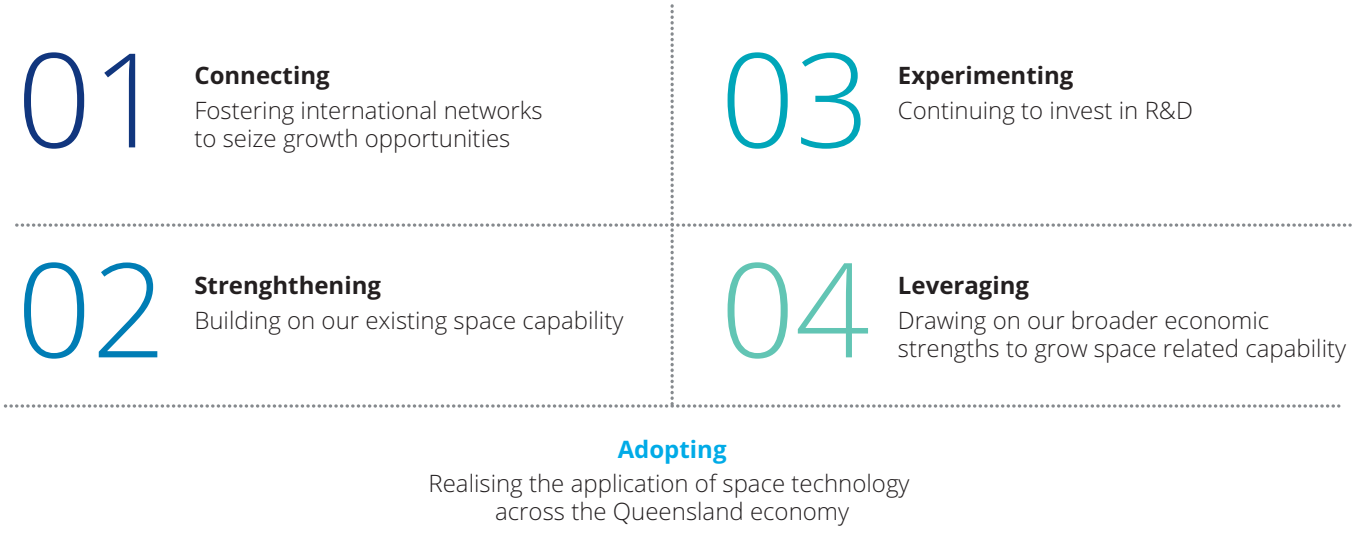
Each of these are described in more detail throughout the chapter, with evidence provided by the industry consultation process and capability survey.

6.2 Connecting

Space is the art of making the impossible possible. It requires significant coordination and allows for the sharing of challenges, risks and opportunities. It takes a village to dream, design, manufacture, test and execute all things space. Pushing the boundaries of almost every industry, space is not something agencies and organisations typically do alone. **The interdependence of space activities presents an opportunity for a developing ecosystem in Queensland.** Deep networks in international markets create opportunities for organisations to position themselves so as to capitalise on trends in global markets. Strong international demand already exists for Queensland organisations in areas for which they have niche capability and expertise however, growth requires a strong international presence and the right connections into the global supply chain.

The establishment of the Australian Space Agency signalled to the international space community Australia's intention to invest and grow its capability. As international space markets become increasingly decentralised, space agencies and organisations are forced to fill capability gaps with the expertise of commercial actors. **The pivot towards industry has created unprecedented commercial opportunities and significant investment, with the opportunity for Queensland organisations and researchers to capitalise.** Advances in space technology, led by commercial organisations with ambitious goals, have reduced costs and barriers to entry for niche players such as those in the Queensland space economy.

Figure 6.1. Areas for future growth in Queensland's space economy



Key to the success of several Queensland organisations, in the absence of a mature national market, has been their ability to foster relationships with international space agencies and organisations. Queensland's space economy is highly collaborative, with private organisations and research institutions regularly working together to solve problems. Queensland space companies have worked alongside several international space agencies including NASA, the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the China National Space Administration (CNSA). The global space economy is characterised by a willingness to share experiences and learn from others whilst remaining highly competitive. The value of deep networks and international connectedness to strengthen capability and expertise is high.

6.3 Strengthening

The Queensland space economy has capability in several niche areas across the supply chain. However, **there exists capacity for growth in both the upstream and downstream segments of the supply chain where there are exponential growth opportunities to be realised**. Evaluation of the global launch industry by Space Angels revealed that 2018 saw the realisation of commercial Small Launch vehicles, with $1.6 billion invested in the Launch industry.[28] Queensland's launch capabilities are in their infancy, insofar as there exist very few organisations operating in this area. However, where there does exist capability, organisations are well recognised and have been able to draw on local industry for support.

Looking downstream, Queensland also has an advantage in an area which has experienced significant growth in the global market – the global satellite industry (inclusive of PNT, EO and GNSS; as explained by Figure 6.2) recorded $2.4 billion in venture capital investment in 2018.[29] Importantly for Queensland, EO benefited from almost 40% of this investment. Characterised by lower capital costs and shorter investment cycles, **EO and other Space Enabled Services represent a key global growth area for which Queensland space economy has existing capabilities.**

Figure 6.2 Defining Downstream Space Activities

Earth Observation	Delivers crucial data that enables national capabilities, such as weather and warning services, disaster mitigation and monitoring our changing climate. EOS also helps protect and manage our natural and built environments for sustainable development.
Position, Navigation & Timing	Enables efficient logistics for mobile transport fleets on our roads, air, and sea. PNT services also provide time-stamping for financial transactions, and precision measurements for civil engineering, agriculture, and personal location based services.
Satellite Communication	Continues to provide a number of specialised functions, including supporting Australia's defence commitments around the world, and providing broadcast, broadband internet and telephony services. Importantly, communication satellites will help bridge Australia's digital divide, providing services to regional and remote areas that previously had poor or non-existent terrestrial based internet services.
Space Situational Awareness	Contributes to understanding of the space environment, and includes detecting, tracking and identifying objects in space, and understanding the effects of adverse space weather and space debris.

Source: Australian Government Space Coordination Committee, 2018

6.4 Experimenting

One of the greatest areas of expertise and capability for the Queensland space economy is Research and Development. Significant investment over long periods of time by several of Queensland's universities has fostered several pockets of niche capability. **Home-grown expertise and passion have driven further investment and growth in research and development in the local space economy, whilst also positioning Queensland as a viable location for international researchers to further their expertise**. Several of the organisations in other areas of the supply chain are engaged with more than one research institution to bridge knowledge gaps in their operations. Collaborative research and memorandums of understanding between organisations and universities based in Queensland are a regular feature of the space economy, and develop the expertise of both parties. Growth in Queensland's Research and Development capability contributes to the building in capability of organisations across all areas of the supply chain. Sustained investment and coordination across Queensland's diverse set of research and development capability will assist the developing space economy in Queensland to bridge gaps in capability.

6.5 Leveraging

Queensland has mature capability in several industries where alignment exists to space related activities, such as advanced manufacturing and aerospace more broadly. Encouraging organisations within industries to expand their capabilities outside the core of their existing operations and to develop space related capabilities will grow supply side competencies in the Queensland space economy. Appropriately upskilling individuals and educating organisations about the opportunities and potential symmetries in markets will encourage organisations in traditional industries to consider space as a viable opportunity to diversify their operations.

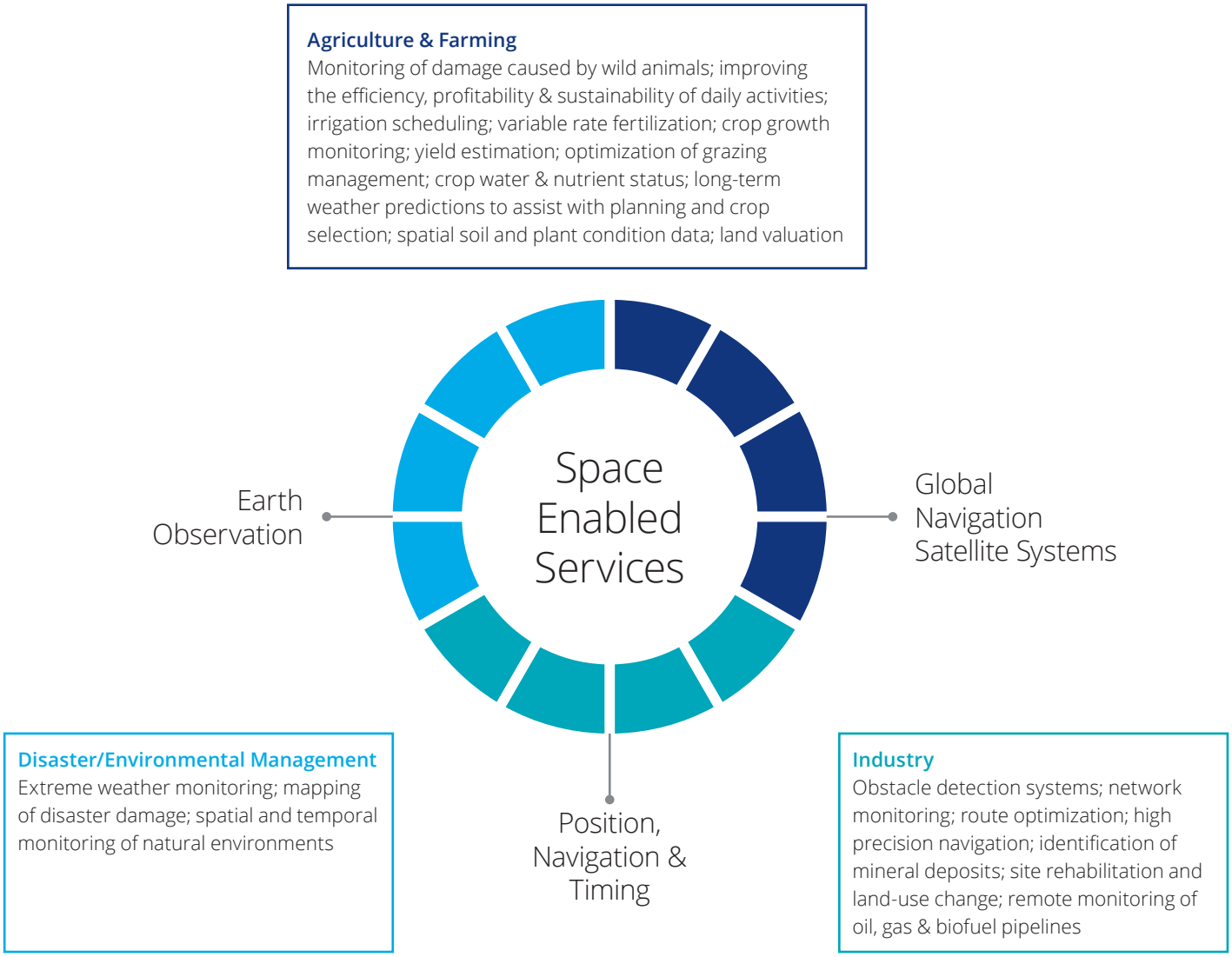
There also exists the opportunity for industries to apply their capability to developing areas of the space economy. Growth areas such as asteroid mining, space debris tracking and deep space exploration align with industries that Queensland has expert capability in and present a unique competitive advantage should organisations leverage their strengths.

6.6 Adopting

Queensland has at its fingertips a ready-made downstream market for the application of space enabled services. The challenge lies in improving end-user understanding of the full extent of possibilities that space enabled services (such as EO, PNT, GNSS and associated analytics) can provide for industry. **Engagement of new industrial end users in the development of decision-ready data and analytics could derive productivity gains across the Queensland economy.** Connecting potential demand with existing capability in supply is a catalyst to growing advanced capability in Queensland downstream organisations.

Industries such as agriculture, mining and manufacturing drive Queensland's economy. There are more than 30,000 businesses carrying out agricultural activity in Queensland.[30] Like many industries across Queensland, the high costs of production are rising and financial sustainability is a major concern to many in the agribusiness supply chain. The industry also faces a range of increasing resource and environmental constraints that need to be managed, including water scarcity, pests and disease, climate change impacts and land degradation. The use of data analytics derived from space to provide key Queensland industries with solutions to their biggest problems is a significant opportunity. **Tailored products that reflect the direct needs of industry could deliver serious economic benefits for Queensland businesses.** Necessity breeds innovation and therein lies the potential value of a mutually beneficial relationship between a growing Queensland space economy and industry.

Figure 6.3 Adopting - Application of Space Enabled Services



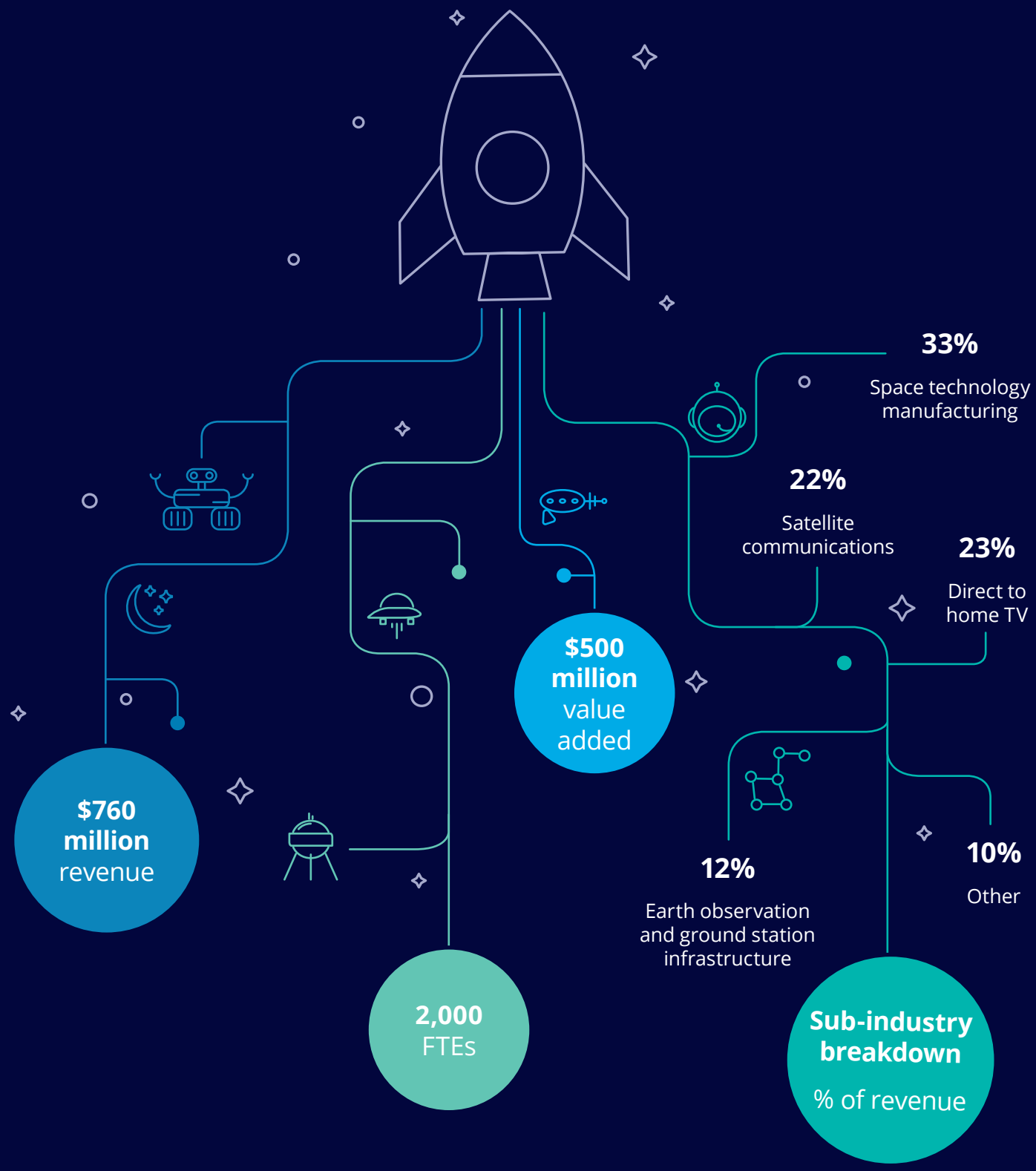
Source: Deloitte Access Economics

PART TWO | TOP DOWN ANALYSIS

The following chapters present a top down view of Queensland's space economy and are based on economic modelling (CGE) of the industry.

7 Baseline profile of Queensland's space economy

Current Queensland space economy



7.1 Overview

Where Part One of this report presented a bottom up analysis of Queensland's space economy based on information provided by organisations, Part Two provides a top down analysis based on a well-established methodology for 'carving out' the space economy from the broader Queensland economy. This approach provides an estimate of the economic contribution of the space economy today, and an estimate of the potential future economic impact of the space economy over the next two decades.

This chapter begins with a brief overview of the methodology used to construct this economic baseline – the interested reader is invited to explore the methodology in more detail in Appendix C.

From here, the current economic contribution and future potential economic impact – both in terms of employment, revenue and value added is presented (refer Figure 7.1). Revenue is the sales and services income earned by businesses through sales of products and services to customers. Value added measures the value added by businesses through the use of labour and capital. Importantly, value added is a measure of economic contribution and summed across all industries aggregates to gross domestic product (national level) or at the state level to gross state product. Value added is also a net measure as it removes the costs of goods of services used up by businesses to produce output.

Due to the nature of the CGE model used in this chapter (and the next), the space sub-sectors discussed here are not directly comparable to those used in Part One's analysis. CGE models have pre-defined databases with a specific sectoral structure, and while this analysis has tried to align with the sub-sectors of the space economy as closely as possible, there are some differences remaining.

Figure 7.1 Queensland's space industry at a glance

2019

In the production of space related goods and services, the industry directly:

- Employs approximately **2,000 FTEs**
- Generates **$760 million in revenue**
- Generates **$500 million in value added** (the direct economic contribution).

In the production of space related goods and services, the industry directly:

Conservative growth

- Employs approximately **4,000 FTEs**
- Generates **$1.7 billion in revenue**
- Generates **$1.1 billion in value added**

Medium growth (base case)

- Employs approximately **5,000 FTEs**
- Generates **$2.0 billion in revenue**
- Generates **$1.3 billion in value added**

High growth

- Employs approximately **6,000 FTEs**
- Generates **$2.7 billion in revenue**
- Generates **$1.7 billion in value added**

2036

7.2 Estimating the economic contribution in 2019

The baseline estimates of the size of Queensland's space industry has been estimated using primary data sources and integrated into the Deloitte Access Economics' CGE model using assumptions on future projected growth of the industry. This model provides a representation of Queensland's economy – households and firms and the trade linkages between them – as well as the wider Australian and global economies. The estimates of the size and scope of the space industry have been constructed by 'carving out' this industry from the existing industries within the CGE model – for example, the manufacturing, aerospace, defence sectors.

The main segments of the production of goods, services and technologies in the space industry include:

- Satellite communications;
- Direct-to-home TV;
- Earth observation and ground station infrastructure operation;
- Space technology manufacturing; and
- Other activities.

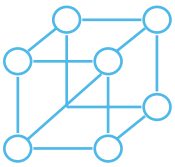
Figure 7.2 Sub-sectors of the space industry for economic modelling purposes

Satellite communications encompass mobile satellite communications, satellite internet systems, satellite data, satellite imaging and all other non-television satellite broadcasting.

Direct-to-home TV includes the satellite broadcast of pay TV and free-to-air TV

Earth observation and ground station infrastructure operation comprises base stations, ground stations, observatories, radars as well as other infrastructure required to uplink, operate and track satellite systems

Space technology manufacturing sub-sector includes the manufacture of high-technology materials, nanosatellites, nanosatellite components, satellite subsystems; and other space-related components and products.



Other space-related services include space research, space launching facilities and other ancillary space services that support activity.

7.2.1 Economic contribution of global and national space industry

To construct the Queensland baseline, it is first necessary to understand the economic contribution of the global and national space industries.

As discussed in chapter 3, the global space industry was estimated to be worth in the order of US$340-$US350 billion in 2016.[31] Using the CGE modelling space sub-sectors:

- The largest component of the space industry based on current global estimates is the **satellite communications** sub-sector. The global satellite sub-sector doubled in the 10 years to 2016.[32]
- The **direct-to-home TV** sub-sector was valued at US$100 billion.
- The **global navigation satellite systems** (GNSS) market (within earth observation), including chipsets and location services, was valued at US$85 billion.
- The **satellite ground equipment** market (within space technology manufacturing), which is mostly consumer equipment, was valued at US$60.8 billion.

The **revenue of the national space industry is estimated to be in the range of $4 billion to $5 billion** – for example, IBIS World has a revenue estimate of $5.1 billion in 2018-19 while ACIL Allen has an estimate of $4 billion in 2015.[33] Nationally, the composition of the space industry follows global trends, with the main sub-sectors currently being satellite communication and direct-to-home TV – collectively contributing around 60% of total revenue.

7.2.2 Approach to estimating the economic contribution of Queensland's space industry

The size of Queensland's space industry was estimated based on IBIS World, industry intelligence and Australian Bureau of Statistics data using a 'top down' method. This approach cuts down Queensland revenue based on the revenue generated by each segment of the national space industry in 2018-19.

The activities listed in each segment of the space industry (referred to in Figure 7.2) are aligned to the Australian New Zealand Standard Industry Classification (ANZSIC) 2006, where practical to do so. Shares to allocate national industry revenue are based on Queensland employment data by industry and place of work - 2016 Census of Population and Housing. Queensland's share of national earth observation and ground station infrastructure operations revenue is based on research conducted by IBIS World. The share of revenue from 'other activities' is an average of other industry segments given the products and services produced by this segment (e.g. space related research).

These shares are used to estimate Queensland revenue for each segment of the national space industry. Value added and employment are derived using Queensland industry revenue and national benchmarks based on IBIS World research (2018).

7.3 Queensland's space economy today

Revenue

Based on Deloitte Access Economics' calculations, the Queensland space industry's revenue is approximately $760 million in 2018-19, representing around 15% of the national space industry. A detailed analysis of industry revenue is shown in Chart 7.1 (overleaf).

Value added

Based on Deloitte Access Economics' calculations, the Queensland space industry's **value added is approximately $500 million in 2018-19.**

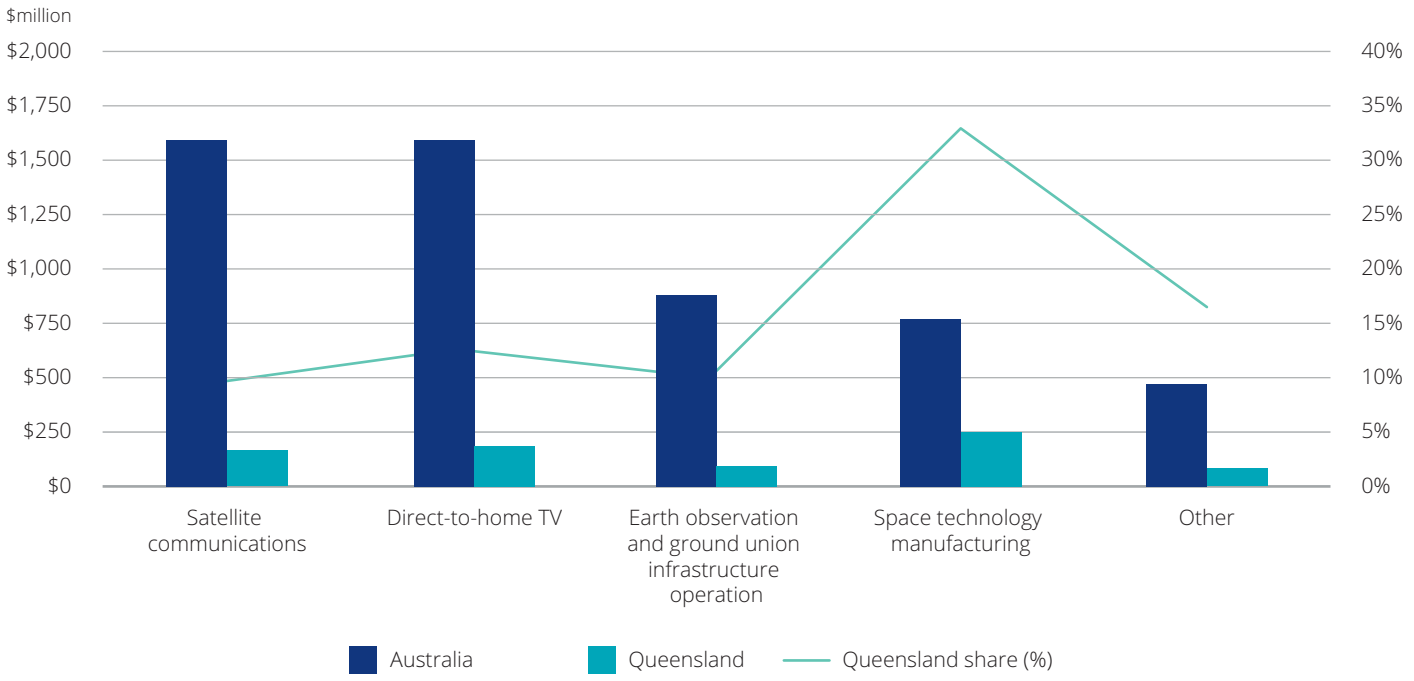
Employment

Based on Deloitte Access Economics' calculations, the Queensland space industry employed approximately 2,000 in 2018-19.

Analysis of key space sub-sectors highlights that Queensland currently has comparative strength and cluster of activity in **space technology manufacturing** which is driven by Queensland being home to a strong cluster of aerospace businesses as well as defence (including Boeing with around one third of national employment in aircraft manufacturing and repair services in Queensland based on the latest ABS census).

This is in line with the findings from Queensland Space Economy Capability Directory, which found that Queensland has strong capability in the **space systems** sub-sector, which includes activities such as high technology materials, space systems manufacturing and other related goods and services.

Chart 7.1 Space industry revenue by sub-sector



Source: Deloitte Access Economics estimates

7.4 Queensland's space economy over the next two decades

This section explores the future economic potential of the Queensland space industry. As with the estimate of the current economic contribution of the industry, estimates are provided for revenue, value added and employment.

The projections of future economic potential are based on a number of data and information sources relating to forecasts of the future of the space industry, both globally and nationally. Assumptions have then been made about the implications of these forecasts for the Queensland space industry, given its current capabilities and areas for growth.

7.4.1 Assumptions underpinning the growth forecasts

The global space industry has a strong economic outlook and economic forecasters highlight that the industry is in the growth stage of its life cycle and is currently growing faster than the economy as a whole.

Over the next five years, the global and national space industry is forecast to grow at around 7% to 8% per annum (on average).

- Morgan Stanley projects global growth to average around 8% between 2018-19 and 2023-24.[34]
- IBIS World projects revenue growth of the Australian space industry to average 7.1% over the same five year period.[35]

Looking further, Morgan Stanley forecasts **the growth of the global space sector to range from 3.5% (conservative growth), 5% (medium growth) and to 7% (high growth) over 2023-24 to 2035-36.**[36]

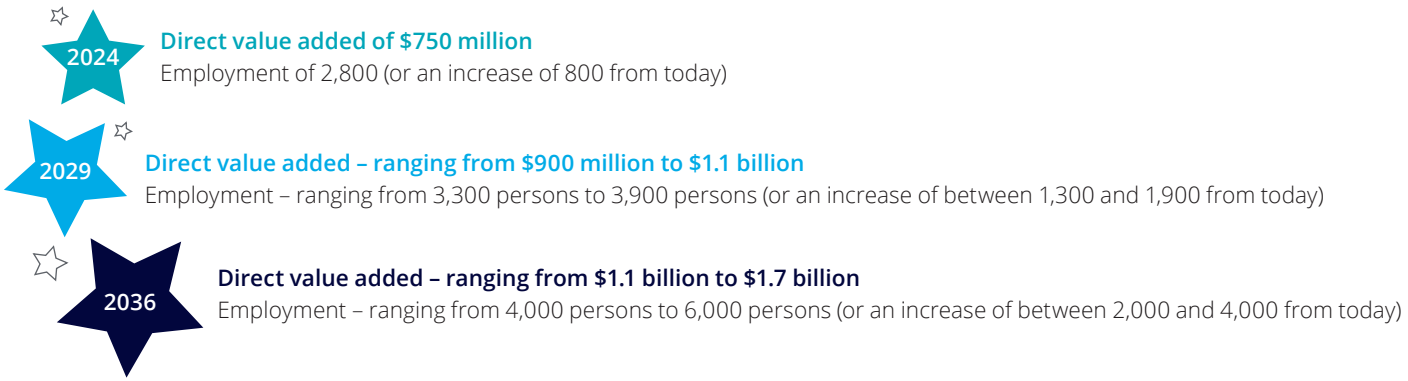
In this study of Queensland's space economy, it has been assumed that the space industry will grow at around 7% over the next five years to 2023-24. From here, the Morgan Stanley growth profile has been adopted for 2023-24 to 2035-36. While Queensland currently has a highly specialised space industry, it has the capability and potential to exploit the opportunities on offer and capture its share of the national and global industry.

The initial economic outlook is expected to be driven by the acceleration of investment and activities in the space sector both at the government and business level. Beyond this initial 5 years, growth is projected to range from 3.5% to 7% per annum on average over conservative growth, medium growth and high growth scenarios.

7.4.2 Projected growth in Queensland's space industry

Queensland's space industry is expected to surpass the one billion dollar mark by 2036.

Figure 7.3 Summary of potential growth in value added and employment in the Queensland space industry

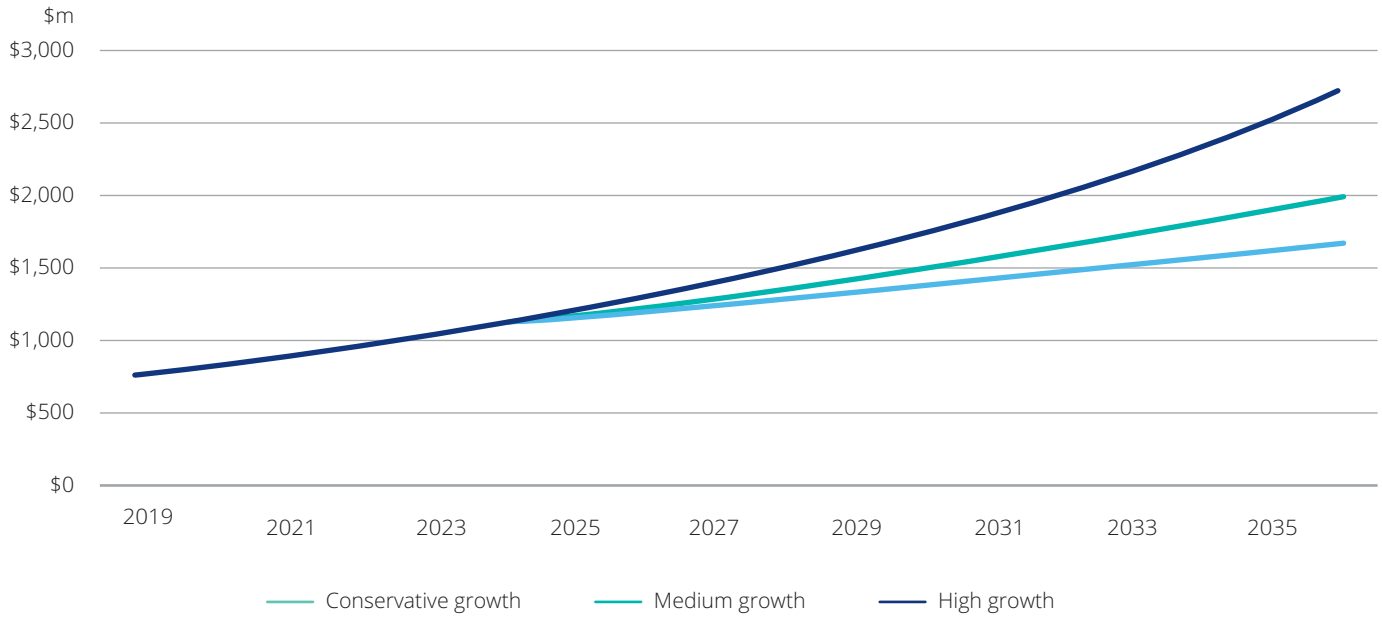


Source: Deloitte Access Economics estimates

Revenue

Economic analysis of Queensland's space industry indicates that revenue could increase to $1.7 billion by 2036 under the conservative growth case, and up to $2.7 billion over the same period under the high growth case. This represents a doubling in the size of the revenue of the space sector over the long term (the economic outlook of the study), relative to the estimated revenue of the space sector today of circa $760 million. Under the high growth scenario, the industry is projected to be more than triple the size of its estimated turnover in 2018-19 of $760 million to $2.7 billion.

Chart 7.2 Revenue projections for Queensland's space industry

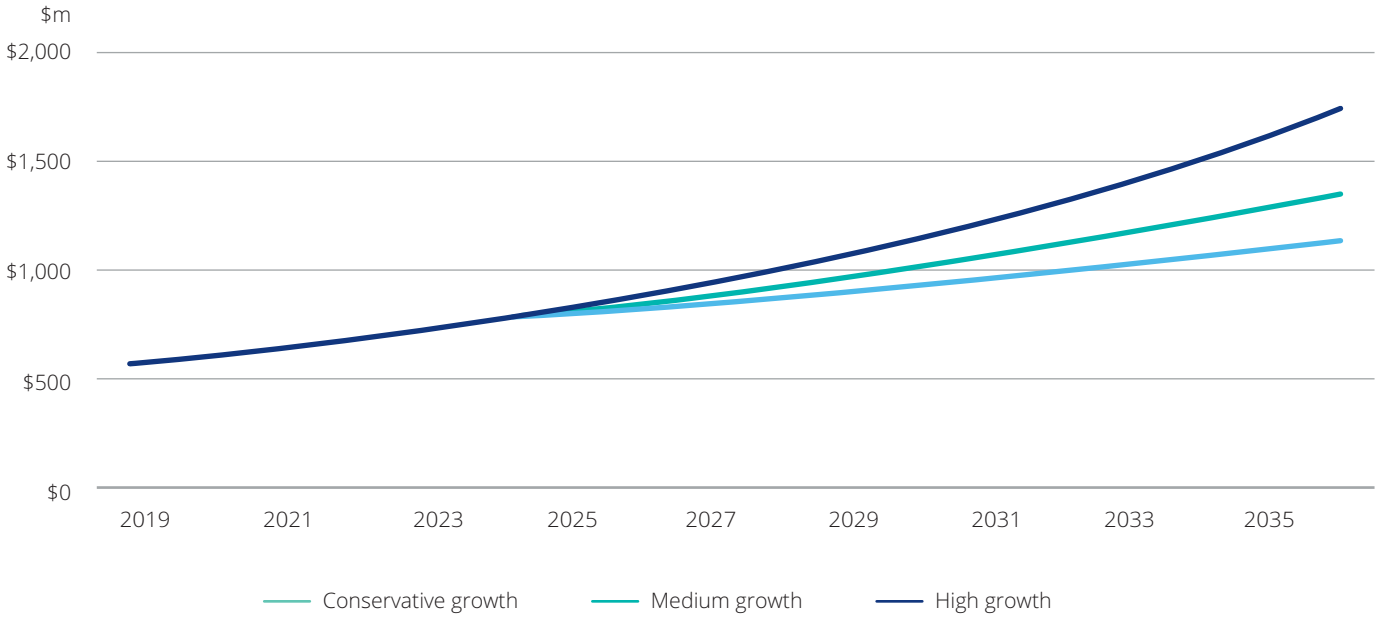


Source: Deloitte Access Economics estimates

Value added

Growth in value added for the Queensland space industry is estimated to increase to $1.1 billion by 2036 under the conservative growth case, and reach up to $1.7 billion over the same period under the high growth case.

Chart 7.3 Value added projections for Queensland's space industry

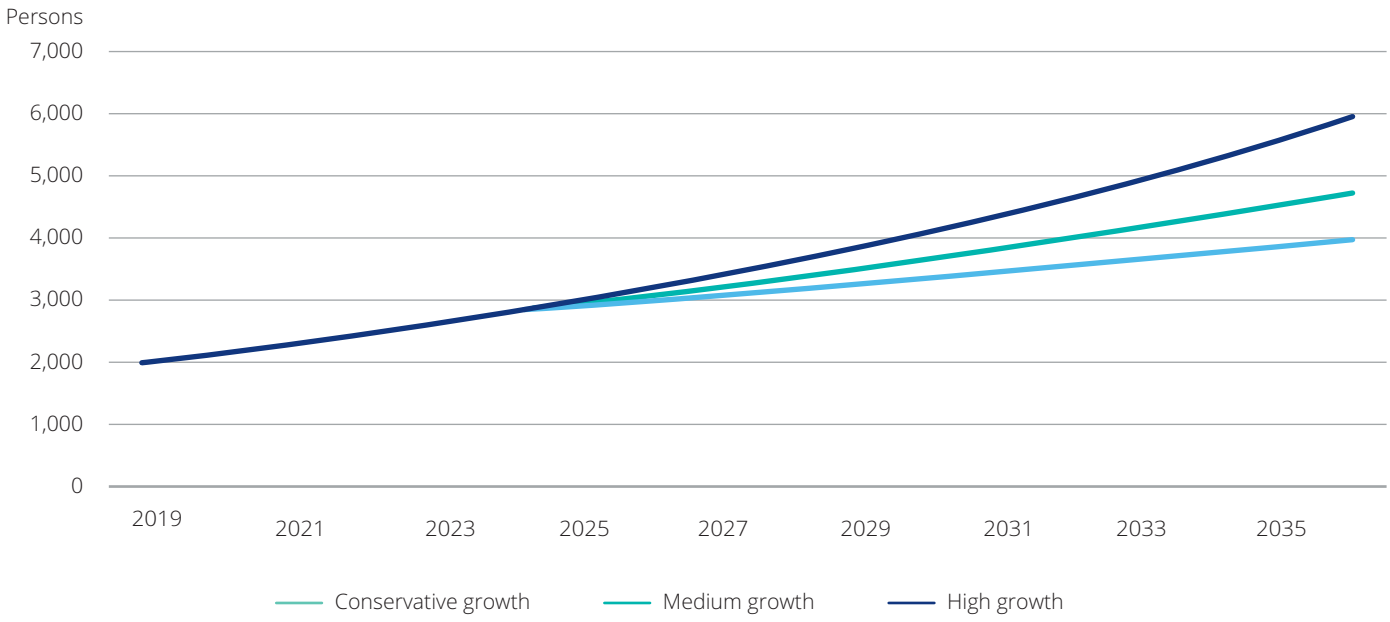


Source: Deloitte Access Economics estimates

Employment

Employment is expected to grow in line with the expansion of the industry, reaching 4,000 by 2036 under the conservative growth case, and close to 6,000 under the high growth case.

Chart 7.4 Employment projections for Queensland's space industry

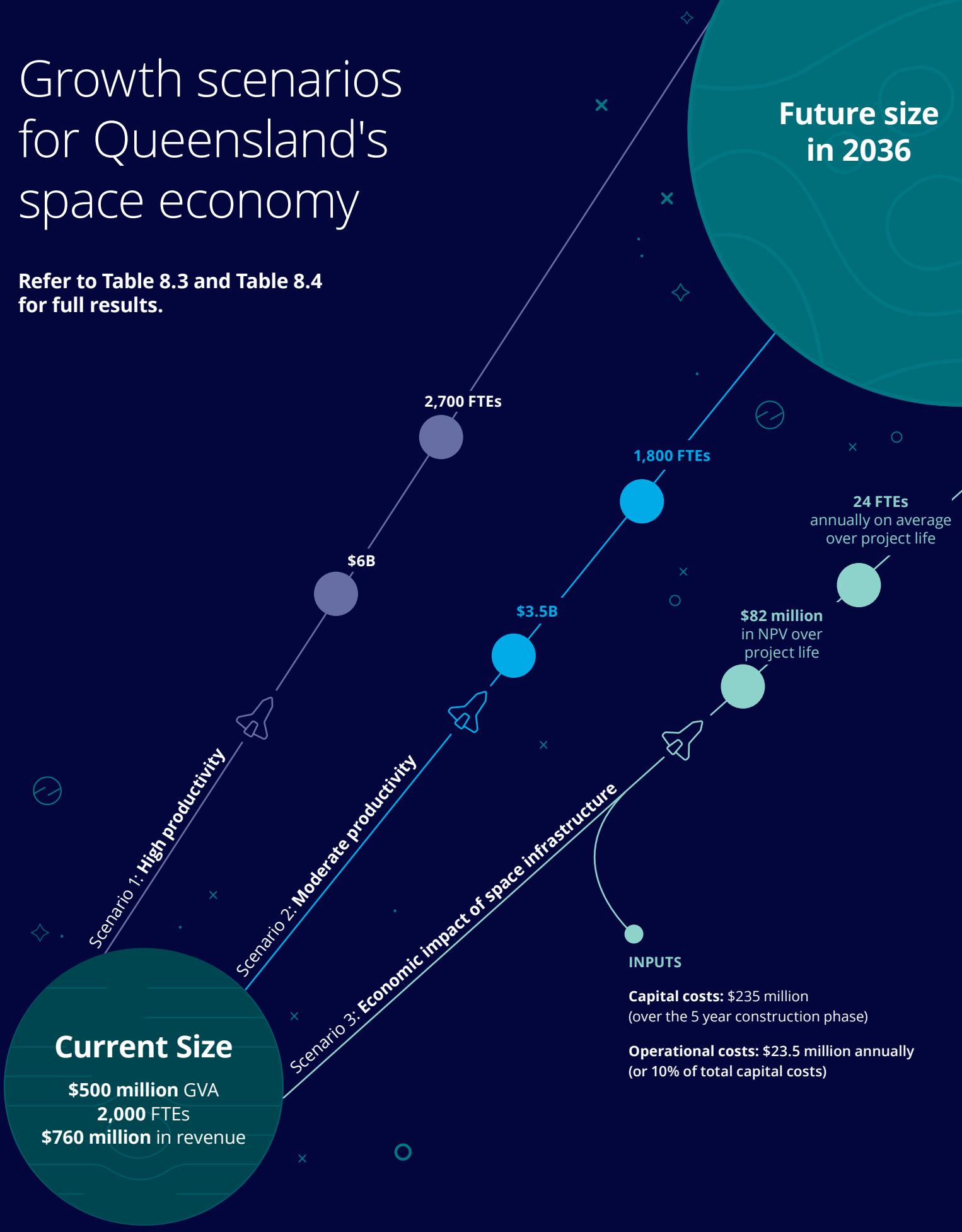


Source: Deloitte Access Economics estimates

8 Future scenarios for Queensland's space economy

Growth scenarios for Queensland's space economy

Refer to Table 8.3 and Table 8.4 for full results.



8.1 Overview

Chapter 7 provided projections for Queensland's space economy that were based on growth assumptions for the 'core' components of the space economy – while future growth is expected to be strong, this is mostly a continuation of the current growth path. This chapter, in contrast, uses hypothetical 'what if' scenarios to demonstrate how, as upstream and downstream components of the space economy develop, the industry in Queensland could deliver significant economic benefits.

In essence, these scenarios paint a picture about what's possible for Queensland's space economy.

These scenarios have been constructed based on assumptions which are realistic in nature and, as such, are not beyond the grasp of Queensland.

For the first two scenarios to come to fruition, major changes are required in the understanding of the value of space enabled services in industries outside of the 'core' space industry, and for the third scenario to come to development of space infrastructure would be required. These are described below.

8.2 The scenarios

Scenario analysis provides the mechanism for exploring 'what if' questions about the economic future of the space industry. **How does employment in the industry change when existing capability is leveraged and opportunities are capitalised on? How sensitive is the industry's growth path to changes in demand from other industries in Queensland? How does the development of space infrastructure change the industry in Queensland?**

By their very nature, scenarios are generalised and do not precisely capture all aspects of the hypothesised future economic state. They are simply possibilities. None of the scenarios presented in this chapter are inevitable, but at the same time they are not unrealistic and provide us with a meaningful place to start discussions about supporting growth in Queensland's space economy.

8.2.1 Introducing the scenarios

Scenarios are typically thought of in terms of high, medium and low. What does high growth look like in the industry versus low growth? However, for the purposes of this analysis, the scenarios are defined by their initial 'triggers' rather than their growth path.

- Scenario 1 is triggered by a step-change **increase in the adoption of space enabled services by industries in Queensland that can significantly benefit from the earth observation and positioning capabilities of the space industry** (e.g. agriculture). These purchasers of space enabled services are still within the space economy (as explained in Figure 2.2), but reside outside of the 'core' space industry that was mapped out in chapter 7.
- Scenario 2, like scenario 1, is triggered by a step-change **increase in the adoption of space enabled services, albeit under more conservative assumptions.** The purpose of this scenario is to provide a sensitivity analysis for scenario 1 to provide an 'order of magnitude' assessment of the potential benefits of the adoption of space enabled services (and explore the impact of assumptions on the end results).
- Scenario 3 is triggered by the **development of space infrastructure.**

8.2.2 Constructing the scenarios

The scenarios are modelled using Deloitte Access Economics' CGE model. Each of the three scenarios is constructed around 'shocks' – with scenarios 1 and 2 reflecting productivity shocks while scenario 3 reflects a capital shock through the development of infrastructure.

The resultant impacts on the rest of the Queensland economy are determined endogenously within the model.

The productivity benefits to downstream industries (e.g. agriculture, mining, etc.) are assumed to be additional to those that would have implicitly occurred in the base case.

The adoption of space enabled services – Scenarios 1 and 2

The expansion of the Queensland space industry has significant downstream impacts to a wide range of industries that can exploit space enabled goods, services and technologies to achieve efficiencies. Key industries include:

- Agriculture
- Mining
- Telecommunications
- Transport and logistics
- Construction
- Utilities

The specific productivity benefits for each industry are described in detail in Appendix C; these are briefly explained below and summarised in Table 8.1 (overleaf).

Productivity benefits for broadacre cropping: The use of GNSS by industry benefits both the use of inputs (such as fuel, labour and materials) and agriculture yields in broadacre cropping. Using an uptake rate of GNSS technology that increases from 40% in 2024 to 65% in 2036 (over and above business as usual) leads to a direct benefit ranging from $80 million to $110 million per annum over the period 2019 to 2036 (net of adoption costs).

Productivity benefits for mining: The application of GNSS technology in the mining industry generates benefits in the use of inputs such as labour, fuel (through automation of processes) and techniques such as precision mining (which targets higher quality product give yield improvements). The adoption profile is 25% in 2024 and increases up to 60% by 2036 (over and above business as usual). This leads to an annual benefit ranging from $300 to $425 million per annum over the period 2019 to 2036 (net of adoption costs).

Productivity benefits for telecommunications: When applied to the communications sector, GNSS technologies significantly opens up opportunities for new products over time. As well as improving the quality and efficiency of services delivered by the sector to end users. The profile of adoption increases from 60% in 2024 up to 80% by 2036 (over and above business as usual). The benefit (net of the cost of adoption costs) ranges from $50 to $70 million per annum over the period 2019 to 2036.

Productivity benefits for transport and logistics: Sustained improvements in the use and application of GNSS technologies in the transport and logistics sectors will continue benefit both industries in the future. The uptake rate is assumed to increase from 25% in 2024 up to 60% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $90 to $185 million per annum over the period 2019 to 2036.

Productivity benefits for construction: The benefits of GNSS technology to the construction sector are demonstrated in this study through the use of machine guidance and construction surveying. The profile of technological uptake increases to 25% in 2024 and again increases up to 60% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $115 to $180 million per annum over the period 2019 to 2036.

Productivity benefits for utilities: The benefits of GNSS technology in utilities has been demonstrated across a range of applications to date and in particular the precision mapping of assets. The benefits for utilities is up to 2.5% of output. The uptake of the technology is 50% in 2024 and increases up to 80% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $35 to $60 million per annum over the period 2019 to 2036.

In addition, the modelling assumes that there is additional spend on research and development by the Commonwealth Government of $25 million per annum.

This is based on Queensland capturing an increased share of the estimated $10 billion research and development expenditure over the next 20 years (or $500 million annually).[37] More specifically, it is assumed that Queensland captures around 20% of this expenditure in line with its population share (rather than just its share of the national space industry, which is estimated at around 15%). This additional 5% is assumed to be achieved through Queensland leveraging off existing capabilities in its space manufacturing and aerospace cluster. This expenditure is also assumed to be financed by the Commonwealth Government.

The uptake rates for each of the industries represent the estimated range of incremental or additional uptake for each space growth scenario (i.e. relative to the business as usual projection of the Queensland economy). In the business as usual scenario, it has been estimated that there will be an annual uptake rate of around 20% across the industries that have the potential to benefit the most from space enabled services in the Queensland economy.

Table 8.1 Summary of productivity benefits by adopting industry, Scenarios 1 and 2

Industry sector	Productivity benefit (per annum average over 2019 to 2036)		Uptake rate of technology
	Scenario 1: High productivity growth	Scenario 2: Moderate productivity growth	
Agriculture (Broadacre cropping) Controlled traffic farming, inter-row sowing and variable rate fertiliser	$110 million	$80 million	65% by 2036
Mining Autonomous haul trucks and savings associated with GNSS technologies	$425 million	$300 million	60% by 2036
Telecommunications Asset management and network planning	$70 million	$50 million	80% by 2036
Transport and logistics Fleet management and port container management	$185 million	$90 million	60% by 2036
Construction Construction surveying and machine guidance	$180 million	$115 million	60% by 2036
Utilities Asset mapping	$60 million	$35 million	80% by 2036

Source: Deloitte Access Economics calculations
Notes: Implemented in the modelling as total factor productivity shocks. The productivity benefits and uptake rates of technology are incremental to the business as usual case.

Development of space infrastructure – Scenario 3

Scenario 3 considers the potential economic impact of the development of space infrastructure in the launch activities and ground systems sub-sectors of Queensland's space economy. Such as a rocket launch facility or a major satellite communications park (noting the establishment of a launch facility in Australia would require national coordination). Launch and ground system capabilities were identified by the industry as key catalysts for future growth in Queensland's space economy. These capabilities will support Queensland's space industry to actively participate in the global supply chain.

As there is not currently a commercial launch facility in Australia, there is not a readily available benchmark for the capital and operational expenditure required to establish such a facility. The best available information source is the current proposal for the Arnhem Space Station, located in the Northern Territory – the proposal is to construct and operate multiple launch sites providing sub-orbital and orbital access for commercial, research and government organisations. The establishment of a launch facility in Australia would require coordination by the Australian Space Agency.

The space infrastructure has an estimated cost of $235 million. It is assumed that the ongoing operational expenditure will be in the order of 10% of costs of development. A summary of the direct shocks for Scenario 3 is presented in Table 8.2.

The Queensland space industry has experienced strong growth and this is expected to continue going forward. In this study, it has been assumed that the **medium growth scenario** presented in Chapter 7 represents the base case (or business as usual). The results for each of the three scenarios represent the incremental impacts above and beyond the base case.

Table 8.2 Summary of capital and operational costs, Scenario 3

Industry sector	2019–23	2024–36
Capital costs	$235 million (over the 5 year construction phase)	
Operational costs		$23.5 million annually (or 10% of total capital costs) or total of over $300 million increase in space sector output

Source: Deloitte Access Economics calculations; Manicaros, 2017

8.3 Scenarios 1 and 2 | Adoption of space enabled services

The two adoption scenarios are reported jointly to demonstrate the range of potential economic benefits derived from increasing the adoption of space enabled services by key industries in Queensland. The larger impacts are the result of the assumptions underpinning the high productivity scenario (Scenario 1), while the more moderate impacts are the result of the assumptions underpinning the moderate productivity scenario (Scenario 2).

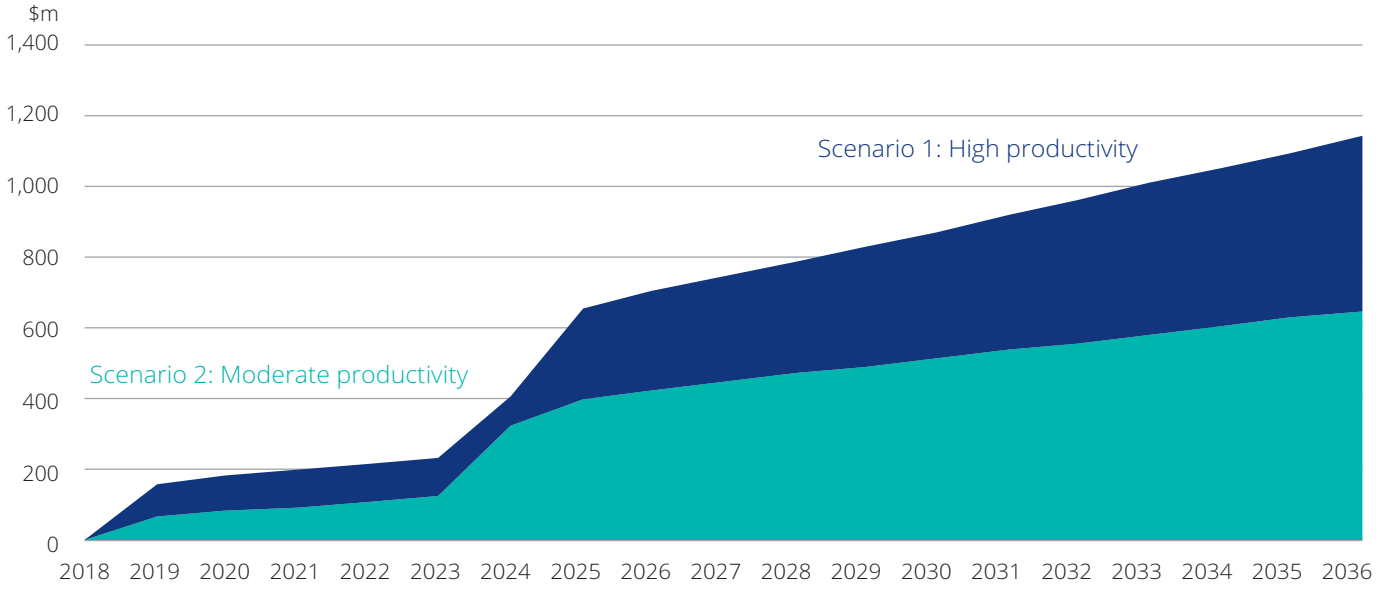
The modelling indicates that the Queensland economy could increase (above the base case) by between $3.5 billion and $6 billion in present value (PV) terms using a 7% real discount rate over the period 2019 to 2036. By 2036, gross state product (GSP) could grow in the order of between $650 million to $1.15 billion above the base case (see Chart 8.1).

These results highlight the critical role space enabled services can play in Queensland's economy. **These results also highlight that even under moderate productivity assumptions, the adoption of space enabled services by other industries will deliver economic dividends for Queensland.**

Gross State Product

The path of real gross state product (GSP) shows these benefits do take time to translate into material economic benefits (i.e. there is a lag) as industries gradually begin to adopt these technologies at a higher rate. Furthermore, in the first five years there is a direct cost to adopting industries of implementing space enabled services, and this dampens the GSP impacts. Higher GSP impacts are evidenced beyond this period through the flow-on effects stemming from direct productivity improvements.

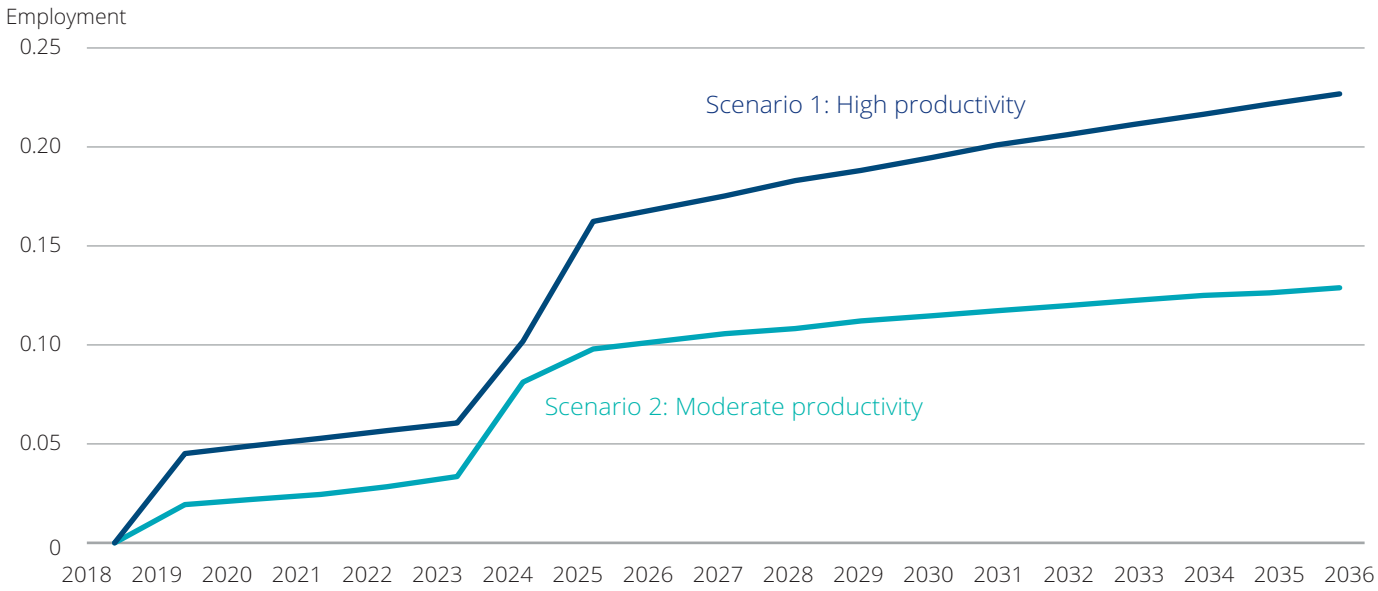
Chart 8.1 Impacts on Queensland Gross State Product, Scenarios 1 and 2



Source: Deloitte Access Economics estimates

The percentage deviations in real GSP put the impacts into context compared to the size of the Queensland's economy (Chart 8.2). The impacts (following higher adoption in 2024) **range from around 0.13% to around 0.23% of real GSP in Queensland.**

Chart 8.2 Impact on Queensland Gross State Product, % change in real GSP, Scenarios 1 and 2



Source: Deloitte Access Economics estimates

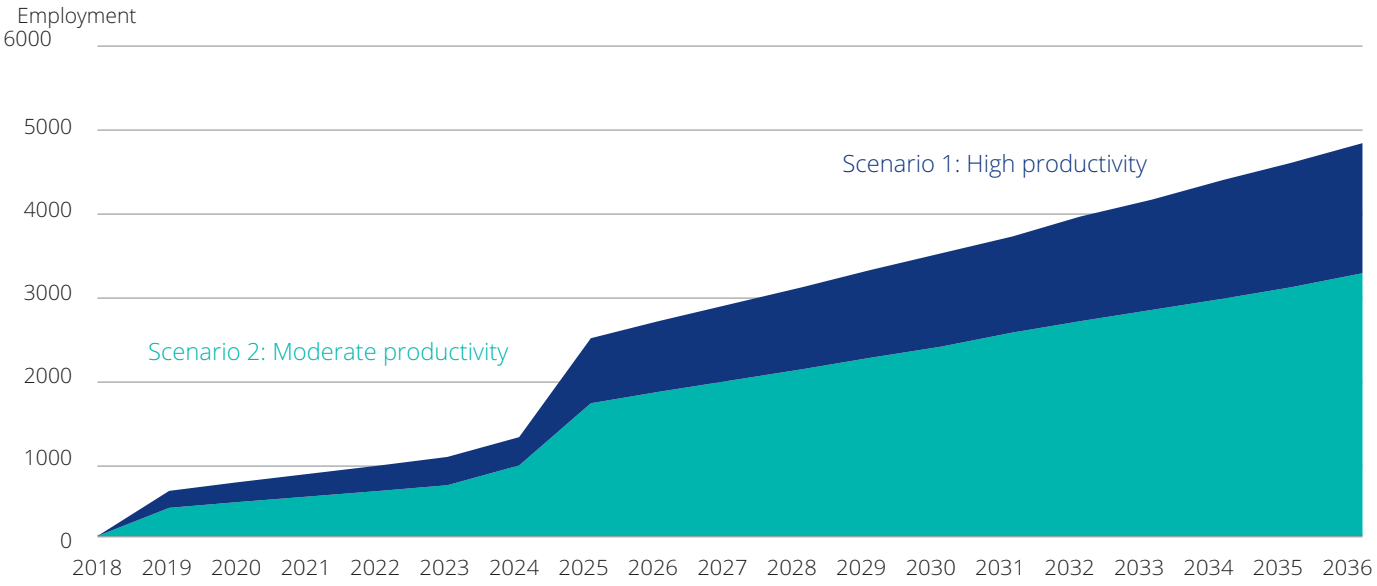
Employment

The **potential employment generated by the activity is estimated to range from 1,800 to 2,700 full time equivalent** (FTE) jobs (in average annual terms) over the period 2019 to 2036. By 2036, FTE employment could increase in cumulative terms by between 3,300 and 4,900 FTE jobs above the base case (see Chart 8.3).

The employment impacts are driven by the increased productivity (scale effect) achieved in a number of industries across the Queensland economy and a similar profile is observed for employment (as for gross state product) where the impacts start to ramp up from 2024 and beyond as the productivity benefits are realised to a greater extent.

The percentage deviation in real aggregate employment highlights that employment increases by 0.05 % in 2024, and up to 0.16% in 2036 under the high productivity scenario. The increase in employment growth is lower than the increase in real GSP growth, which is partially due to the impacts of productivity.

Chart 8.3 Impact on Queensland Full Time Equivalent (FTE) employment, Scenarios 1 and 2



Source: Deloitte Access Economics estimates

Industries

There is an increase in activity across a number of industries in the Queensland economy; particularly those that utilise space enabled services (see Chart 8.4). These industries include broadacre cropping, mining, utilities, construction, transport and logistics and communications. In addition to the industries that benefit directly, there are also positive spillover effects to other related industries including trade, communications and other services (includes finance, professional and business services). In addition, activity in the space industry is stimulated, as downstream users induce further demand for space enabled services.

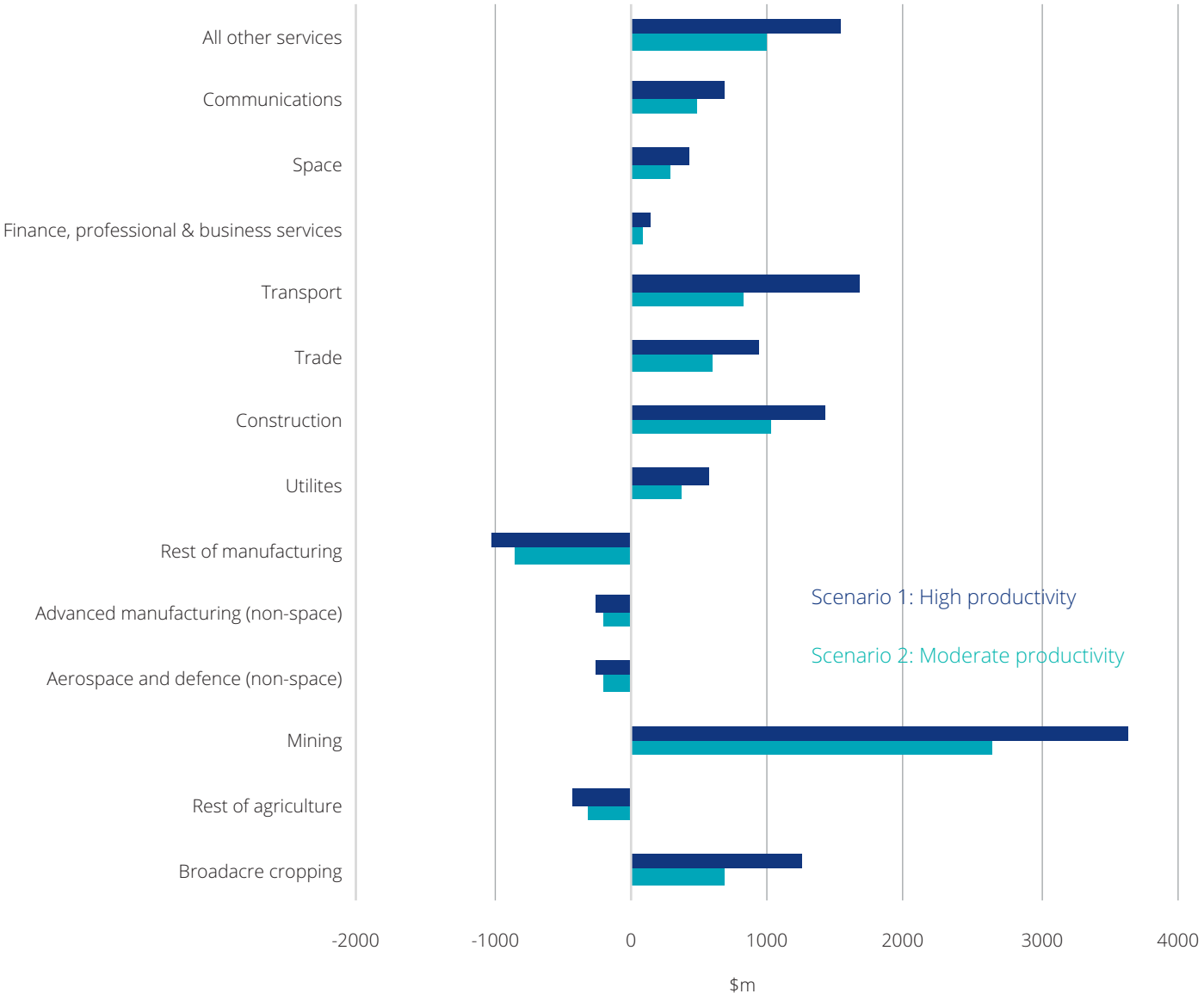
While there are some positive spillover impacts outside the adopting industries, some other Queensland industries experience crowding out – including rest of manufacturing, rest of agriculture and the non-space component of advanced manufacturing and aerospace and defence.

This result largely reflects the fact that these industries are not directly targeted in the scenario and therefore are relatively less efficient compared to the key industries exploiting space enabled services.

In addition, as the key industries become more efficient, they may require fewer inputs – such as purchases from other industries – which could potentially reduce the demand for some upstream industries. The negative deviation shown for some industries does not necessarily imply that the industry is projected to contract. Rather, it indicates that, relative to the base case, it is simply not growing as fast.

Though there are decreases in output across some industries, the additional activity due to the adoption of space enabled services has positive impact in aggregate for the Queensland economy.

Chart 8.4 NPV of impact on Queensland industry output, 2019 to 2036, Scenarios 1 and 2



Source: Deloitte Access Economics estimates

Summary

A summary of the economy-wide impacts of these two scenarios highlight the significant potential economic impacts of future growth and development of the space industry to the Queensland economy (refer Table 8.3).

Table 8.3 Summary of economy-wide impacts for Scenarios 1 and 2 (incremental to the base case)

	Scenario 1: High productivity	Scenario 2: Moderate productivity
Gross state product	$6 billion	$3.5 billion
FTE employment	2700 FTE jobs	1800 FTE jobs
Industry output		
Space	$400 million	$270 million
Broadacre cropping	$1.2 billion	$680 million
Mining	$3.6 billion	$2.6 billion
Telecommunications	$660 million	$460 million
Transport and Logistics	$1.7 billion	$810 million
Construction	$1.4 billion	$1 billion
Utilities	$550 million	$340 million

Source: Deloitte Access Economics
Notes: Gross state product and industry output are presented in NPV terms using a real discount rate of 7% over the period 2019 to 2036 and FTE employment is presented in average annual terms over the same period.

8.4 Scenario 3 | Space infrastructure

This scenario considers the "order of magnitude" economy-wide impact of the development of space infrastructure – of a similar magnitude to the proposed Arnhem Space Centre in the Northern Territory – to the Queensland economy.

The modelling estimates show that such a project has the potential to grow Queensland's GSP by around $82 million over the period 2019 to 2036 (see Table 8.4. Over the construction phase, GSP increases by around $9 million in annual average terms over the 5 years from 2019 to 2023. These impacts would also be supported over the operations phase by associated operating expenditure in the space industry – $7 million annually, on average, over the period 2024 to 2036.

The project would also potentially result in an additional 24 FTEs annually on average across the Queensland economy over the entire project (Table 8.4. Over the 5 year construction phase, the annual average number of FTEs created is 57. As the construction phase slows down, ongoing operations would support an annual average of 12 FTEs.

The space infrastructure scenario generates a relatively modest impact compared to the broader productivity benefits from the application of space related technologies to the Queensland economy.

The key industries stimulated by such a project in direct terms include the construction industry, as well as the space sector through the accumulated capital stock and operational expenditure to support ongoing operations. Direct value added in the construction and space sectors are estimated to grow by $60 million and $70 million respectively in NPV terms over the period 2019-36. There are also some small flow on impacts to other related industries, however, these are minimal given the relatively small direct shocks in this scenario.

Table 8.4 Summary of economy-wide impacts for Scenario 3 (incremental to the base case)

	Total project (2019-36)	Construction phase (2019-23)	Operations phase (2024-36)
Gross state product	$82 million (in NPV terms over the total project)	$9m (annually on average over the construction phase)	$7m (annually on average over the operations phase)
FTE employment	24 FTEs (annually on average over the total project)	57 FTEs (annually on average over the construction phase)	12 FTEs (annually on average over the operations phase)

Source: Deloitte Access Economics
Notes: Gross state product and industry output are presented in NPV terms using a real discount rate of 7% over the period 2019 to 2036 and FTE employment is presented in average annual terms over the same period.

The Queensland space infrastructure scenario (scenario 3) only captures the direct indicative expenditure and associated supply chain impacts (in the form of a capital shock). It does not capture the dynamic effects of downstream productivity gains, such as those experienced by agriculture, mining etc.(the indicative impacts of these productivity shocks are explored separately in scenarios 1 and 2).

8.5 Summary of the economic modelling

In summary, this economic modelling study:

- Estimates the current and future direct size of the space industry in Queensland, with a focus on key economic metrics such as industry value added and employment and also a breakdown across the key sub sectors that comprise the space industry in Queensland.
- Identifies the range of productivity benefits by industry from increased adoption of space enabled services over the medium to long term in Queensland.
- Highlights the range of economic impacts for medium and high expansion scenarios which are linked to different future potential adoption rates of space enabled services across the economy and measured relative to a business as usual projection for the Queensland economy.

The broader economic value of launch and ground system capabilities in Queensland

The broader economic value of launch and ground capability in Queensland or elsewhere in Australia, is not derived from the construction and operation of space-related infrastructure alone.

When combined with Queensland's existing competitive advantages, **the broader economic value of both launch and ground system capability is the potential for Queensland to develop world class launch supply chains – i.e. the dynamic effects generated by deepening scale and broadening the scope of the sub-sectors.** This would enhance the development of an advanced manufacturing supply chain, with productivity spill over effects into the state's other major industries (e.g. agriculture, mining).

The potential benefits of developing space infrastructure whether in Queensland or elsewhere in Australia, should be weighed against the costs and risks, including customer and market demand, which are beyond the scope of this report. Who leads and pays for the infrastructure is also beyond this report's scope.

The Queensland launch and ground systems infrastructure scenario (scenario 3) captures the direct indicative expenditure and associated supply chain impacts (in the form of a capital shock). However, it does not capture the downstream productivity gains, such as those experienced by agriculture, mining etc., as these productivity shocks are explored separately in scenarios 1 and 2.

PART THREE | REFLECTIONS

The following chapter presents the key reflections on the capability of the Queensland space economy and the future path of the industry.

9 Reflections

9.1 Overview

In reviewing the capability of Queensland's space economy, it is apparent that the future of Queensland's space industry is strong but also fragile. This is an industry where connections matter, where reputations matter and where entrenched competitive advantages arise as the result of decades of investment in specialised capability – this is not an industry that has been, or can be, built overnight.

Queensland is fortunate that decisions made decades ago have fostered the conditions to develop an industry ripe for growth.

Yet, there are significant competitive pressures which can lure a not insignificant part of the industry away from Queensland.

The question remains; what is needed today to ensure that the opportunities and ambitions for the space economy are realised?

Where to next?

The Queensland space economy has ambitions – ambitions to grow and ambitions to be globally recognised. These ambitions are credible, but are also grounded in the reality that Queensland is a small player in a large global supply chain. The opportunities arise, however, not in competing with the entrenched agglomerations in the likes of the US, China and Europe; but instead in continuing to develop niche, globally competitive, high value added goods and services that can be traded with the world.

In this regard, the small size of the Queensland's industry today is a strength – organisations across Queensland's space economy are actively collaborating with each other, building specialised research capability to support commercial organisations and building commercial organisations out of specialised research capability. But more can be done to enhance collaboration and develop the industry strategically.

Niche, but globally competitive

Development of the Queensland space economy has been driven by select industry leaders whose expertise and space related activities have led to the clustering of globally competitive space capabilities. These organisations have driven the growth of dispersed capability across the space supply chain: research and development, launch activities, space systems and space enabled services.

A unique opportunity is presented for Queensland to develop a more mature space ecosystem, where upstream and downstream players have a co-ordinated approach to competing in the global supply chain. Noting that while organisations in Queensland's space economy are highly collaborative, growth will require increased representation of Queensland's capabilities and competitive advantages on an international platform to remain relevant in the commercially driven global space economy.

It takes time

The significant opportunities for growth in the space economy, given Queensland's current capabilities, is well documented. It is important to note, however, that the development of any space industry takes time, patience and meaningful investments in human and physical capital. In this regard, the development of Queensland's space economy will also take time and the right strategic investments. The key to the development of the sector is the need to develop the supply chain, anchor businesses to Queensland and generate demand for the space industry supply chain.

"The exploration of space will go ahead, whether we join in it or not..."

– John F. Kennedy

Key takeaways

- Queensland's economy can benefit from growth in the space economy
- Today, Queensland has a niche but globally competitive industry, with strong research partners, and this is likely to remain the situation into the future.
- There are significant opportunities for future growth in the space economy given Queensland's current capabilities.
- Development of the space industry takes time, patience and meaningful investments in human and physical capital.
- The (increased) adoption of space enabled services by Queensland's traditional strengths can support growth in the space economy.

Strong fundamentals

Strengths present themselves at both ends of Queensland's space supply chain. Queensland's strong fundamentals of manufacturing, mining and engineering capabilities are well-positioned to support upstream industries. Yet, with competitive pressures across Australia and globally, space focussed organisations in Queensland can easily be lured away without strong economic and commercial reasons to remain in Queensland.

Further downstream, Queensland's agriculture, mining and logistics industries, to name a few, are the sectors set to benefit from growth in sub-sectors such as space enabled services.

Queensland's geographic location presents a unique competitive advantage that could be leveraged establish supporting infrastructure for the launch activity and ground systems sub-sectors.

Growing the pie, and sharing the benefits

The potential spillovers from space technology and research endeavours are broadening in scope and application across the economy. The economic modelling highlights that this has an important contribution to make to Queensland's economy. In particular, the adoption of space enabled services by Queensland industries sitting outside the core space industry has shown itself as an area for – potentially large – growth, with the economic dividends shared across Queensland's economy.

Fight for talent

The highly specialised nature of the space industry makes it difficult to attract senior and experienced talent – and difficult to retain junior talent in Queensland. Given the global scale and scope of the industry, working visas play an important role in addressing challenges around finding appropriate talent in the industry.

It is clear that the passion for space starts young but requires significant skills and experience to flourish and contribute to the space industry in Queensland. There are sound education and research platforms in Queensland, which result in the skilling up of Queenslanders – noting junior talent leave to gain overseas experience. A strong space industry in Queensland will see some of these people return and attract others from overseas seeking experience in Australia. This flow of expertise is likely to be a defining feature of the space industry in Australia.

Building space

While location agnostic industries often find it difficult to create the natural cluster of activity required to grow an industry; the space economy is characterised by high capital infrastructure investment, highly specialised expertise and long lead times. The physical infrastructure required by organisations operating within the space economy could enhance the growth of a space ecosystem.

Key gaps

- **Highly mobile workforce**, in reference to the availability of human capital associated with the highly specialised nature of the industry.
- **Absence of physical infrastructure** to enhance key sub-sectors which anchor the space economy supply chain.

Role of Government

Australia, and its states and territories, have not had the same history of long-term government investment in space as other international jurisdictions.

The history of development in the global space industry has been financed and managed by government. International space agencies have dominated the agenda and driven strategy – with the high entry costs and risks associated with the space industry dictating considerable government involvement.

This is known to be changing – and fast. The trend towards decentralisation of activity out of government and into the private sector has spurred growth in the commercial components of the supply chain. The global space economy today is characterised by an increasing number of private organisations and investors – and so too will Queensland's growing space industry.

The changing nature of space activities and the growth of non-traditional space actors requires consideration be given to the appropriate role of governments in emerging space economies.

In Queensland, this raises consideration of several points:

Regulatory responsibility

- The role of regulation and legislation remains firmly in the purview, and control, of Government. This control may not necessarily sit with a state government – such as visa requirements or import restrictions for chemical components – but understanding regulatory barriers and constraints impacting the Queensland space industry's development, will be important for Queensland.
- The regulation associated with approval processes for launch activities can be an important element in enhancing or detracting from the competitive position of Queensland in the global space market.

Facilitation rather than funding

- Space activity is highly interdependent; meaning relationships are critical to success. An identified role for government is in facilitating, and matching, such relationships – both domestically and globally.
- Growth in the capability across Queensland's supply chain will also rely on the ability of the organisations operating in the core space industry to reach out to industries with transferrable skills. How government can assist space organisations to navigate Queensland's well established industries to locate critical expertise is an opportunity.
- Ensuring the optimisation of skills development in Queensland will provide an important platform for the space industry and its development in Queensland.
- Government facilitation of higher adoption rates of space related technologies in other sectors (via an alignment of the Queensland Government's priority industry sectors) will enhance the benefits for the Queensland.

Physical infrastructure

- The clustering of physical infrastructure and know-how (people) can enhance the development of the space sector. Such clustering can lower transaction costs and enhance collaboration through joint ventures, access to research, and shared platforms.
- Physical infrastructure can, in some instances, act as the catalyst for space activity to grow at a rapid rate.

Appendices

Appendix **A**
Capability directory

This Appendix provides the full directory that is summarised in chapter 4.

	Component and Material Supply	Satellite Owner/ Operator	Space Qualified Testing and Facilities	Space Subsystem Supply	System Engineering and Technical Support	Component and Subsystem Management	Launch Services	Launch Support Services	Launch Vehicle Manufacturing and Assembly	Antenna/Ground Station Component or Material Supplier	Ground Segment Prime/ System Integration	Ground Segment Subsystem & Equipment Supplier	Prime/System Integration	System Engineering
Private Company														
Absolute Data Group Pty Ltd														
Active Electronics Plc.	✓													
AECOM														
BDGT Precision Engineering														
Beaudesert and Boonah Cranes														
Black Sky Aerospace							✓							
Boeing														
CG Composites Australia Pty Ltd	✓													
Coastal Aviation Pty Ltd	✓													
CSE						✓								
Datellite Pty Ltd														
DigitalGlobe														
DNA Anodising														
EM Solutions Pty Ltd										✓				
Fluid Seals Pty Limited	✓													
Frequentis Australasia					✓									
Gasket Solutions Pty Ltd	✓													
Geospatial Intelligence Pty Ltd														
Gilmour Space Technologies							✓							
Goonhilly Earth Station														
GPA Engineering														
Hillier Engineering Services														
Honeywell Ltd														
Hypersonix Pty Ltd							✓							
IDS Australasia					✓									
Integrated Training And Documentation														
International Aerospace Law & Policy Group (Australia's Air & Space Lawyers)														
Keysight Technologies Australia Pty Ltd														
Laser Central Pty Ltd														
Madison Sport Pty Ltd	✓													
Mastercut Technologies Pty Ltd	✓													
Metromatics Pty Ltd	✓													
Milspec Services Pty Ltd	✓													
Miniature Bearings Australia	✓													
Moody Space Centre							✓							
National Plastics & Rubber Pty Ltd														
Northrop Grumman													✓	
Northrop Grumman Australia											✓			
Nova Group														
Ozius														
Peoplesafe Consulting														

...and Technical Support Services	Tracking, Telemetry & Command Operations	Earth Observation Services & Applications	Satellite Communications Service Providers	Satellite Navigation Service & Applications	Technical Support Services	User Equipment Manufacturer	User Equipment Suppliers	Consultancy Services (e.g, IT, analytics, professional services)	Financial Services	Legal Services	Ancillary Services	R&D	Education and Training	Other	Transport, logistics and construction	General component, material, engineering supply
								✓								
								✓								
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	Component and Material Supply	Satellite Owner/ Operator	Space Qualified Testing and Facilities	Space Subsystem Supply	System Engineering and Technical Support	Component and Subsystem Management	Launch Services	Launch Support Services	Launch Vehicle Manufacturing and Assembly	Antenna/Ground Station Component or Material Supplier	Ground Segment Prime/ System Integration	Ground Segment Subsystem & Equipment Supplier	Prime/System Integration	System Engineering
PFi (Products for Industry)														
R.F.Technologies Aust Pty Ltd														
Shapecut Pty Ltd														
Solvay Interox Pty Ltd									✓					
SpaceTech International														
Studio Kite														
Swagelok Eastern Australia	✓													
Syndetic				✓										
Teakle Composites	✓													
Temperature Controls	✓													
Voestalpine High Performance Metals														
University/Research Organisation														
Bond University														
Centre for Agricultural Engineering, University of Southern Queensland														
CSIRO														
Commonwealth Scientific and Industrial Research Organisation (CSIRO)														
Earth Observation Australia and Remote Sensing Research Centre, University of Queensland														
Griffith University														
Juxi Leitner (Individual)														
Queensland University of Technology														
University of Southern Queensland - Institute for Advanced Engineering and Space Sciences														
University of Southern Queensland - Centre for Astrophysics														
University of Southern Queensland - School of Civil Engineering & Surveying														
USQ														
Government														
Office of Economic Development, Ipswich City Council														
Industrial Organisation														
SIAA														
Other														
Electrotraders														
James Dickson														

and Technical Support Services	Tracking, Telemetry & Command Operations	Earth Observation Services & Applications	Satellite Communications Service Providers	Satellite Navigation Service & Applications	Technical Support Services	User Equipment Manufacturer	User Equipment Suppliers	Consultancy Services (e.g. IT, analytics, professional services)	Financial Services	Legal Services	Ancillary Services	R&D	Education and Training	Other	Transport, logistics and construction	General component, material, engineering supply
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												✓				
												✓				
												✓				
												✓				
✓																
														Enabler to provide support to SMEs developing innovative products		
														Advocacy and development of the industry in Australia		
							✓									
															✓	

Appendix B
Capability assessment matrix – detail

Further to Chapter 4, the following details the individual capability assessments for the space economy. Queensland's capability was assessed for the following sub-sectors:

- Space Systems
- Launch Activities
- Ground Systems
- Space Enabled Services
- Ancillary Services
- Research and Development
- Education and Training

Space systems

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
N/A	Moderate	Limited	Moderate	Limited	
N/A	• Largest identified sub-sector by organisations in the short survey (16) suggests there is adequate physical infrastructure available for the sub-sector to participate in both national and international markets • Organisations were spread across three key capabilities – Component and material supply (13) – Space subsystem supply (1) – System Engineering and Technical Support (2) • Of the 13 component and material supply organisations, the majority (6) earned in the $2-5M range and the majority (8) also exported their products/services internationally	• Organisations typically employ 1-19 employees, however 6 of the organisations employed 20-199 employees, which suggests there is a strong market in Queensland for labour from which the sub-sector is able to draw upon • There are a large number of organisations who have managed to find the necessary labour to sustain their activities – growth does not appear to be limited by the availability of expertise	• 10 of the 16 organisations exported their products in the last 12 months. This reflects strong international demand for products and moderate/limited national demand	• None of the organisations in the sub-sector consider space their primary industry of operation. Therefore, organisations are unlikely to have difficulty sourcing the appropriate inputs for their operations. • However, the rating reflects the limited supply of products/ services which are directly related to space.	• The organisations that responded to the survey in the space systems sub-sector do not consider space their primary industry of operation. Organisations typically have capabilities in Defence and Aerospace and as, such have necessary inputs and expertise to enable them to provide their products/services as required. However, the size of the space economy in Queensland means they provide their products/ services to different industries and international markets. Growth in the local space industry would encourage growth in this sector.

Launch activities

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
Strong	Limited	Limited	Moderate	Limited	
• Queensland's proximity to the equator (27 degrees) • Available land close to the equator • Unused airspace close to the equator • Ability to do both polar and equatorial orbits	• No test/launch facilities in Queensland • Queensland has 2 highly specialised organisations with private launch facilities – Including the only civilian sub-orbital launch site in Australia • 5 organisations participating in the launch sub-sector – Component and Subsystem management (1) – Launch Services (2)	• Difficulty hiring due to inappropriate skills – organisation responded 'No' & 'Yes' • Organisations reflected a broad range of employees – including 1-19, 20-199 and 200+ • The sub-sector draws heavily from the Professional, Scientific and Technical Services sector in the economy for inputs	• Developing national market as evidenced by the ability to find appropriate Human Capital to operate. However, sub-sector is limited by regulatory issues and lack of launch facilities. • Size, turnover and lack of export suggests there is unmet demand at present	• Gilmour have built almost all of their suborbital rocket in Queensland • Some chemicals Black Sky had to get in • Propulsion creates issues – companies need to source hydrogen peroxide internationally • Currently also restricted by regulatory burdens • The sub-sector draws heavily from the Manufacturing sector in the economy for inputs • The sub-sector cannot source 'particular rocket motor chemicals' from Queensland (they source this from the USA/China) • The main reasons they purchase from outside of Queensland is because they have highly specialised product/ services that are not available in Queensland (and are better quality elsewhere)	• Whilst we do not have a significant number of organisations in this sub-sector, the organisations that do participate have industry leading capability • Sources include survey 1, survey 2 and Queensland Parliamentary Inquiry transcripts

Ground Systems

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
Strong	Limited	Limited	Moderate	Limited	
• Queensland's exposure to equatorial orbits, and ability to track spacecraft travelling over the Indian and Pacific Oceans • Well positioned to support satellite launch services as large open spaces with significant uninhabited landmass close to the equator and flight paths over the ocean	• Organisations have capability in: – Antenna/ Ground Station Component or Material Supplier – Prime/System Integration – Ground Segment Prime/System Integration • Whilst organisations in the sub-sector have capability in operating and using technology associated with ground systems, there exists little ownership; the sub-sector is reliant on transferrable skills/expertise from the manufacturing sector • Organisations are primarily suppliers, technical support or operational which limits growth potential in downstream applications	• As several ground segment organisations are large multinationals, they have high employee ranges – the majority selected 200+ employees • Difficulty hiring due to inappropriate skills – organisations responded 'No' • Boeing in the inquiry indicated that there were not enough individuals around that would allow for the necessary growth in the industry to occur • Australia's long history in the sector also means there is significant capability across the nation (whilst some of this might not be based in Queensland)	• All organisations export their products/services	• There is a strong international market which is driving the exports of the sub-sector • Some difficulty filling in this sub-sector as incomplete survey filling out from organisations in the sub-sector	• Several of the entities in Queensland's ground systems sub-sector are large multinational organisations that have significant presence in Queensland, Australia and internationally. They also typically have presence across several areas of the space economy, and interact with several research institutions. • Organisations are primarily contributing to inputs and technical services/support required by the sub-sector rather than growth being driven from the presence of physical infrastructure.

Space Enabled Services

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
N/A	Moderate	Moderate	Moderate	Moderate	
N/A	• The sub-sector has access to satellites, ground stations, telescopes, supercomputers, cloud storage that are required to operate	• Constraints to growth recognised the lack of a skilled workforce in the required fields. All organisations reflected that they had difficulty hiring due to inappropriate skills	• Constraints to growth reflect the lack of an Australian market for the products/services the sub-sector provides • Organisations also recognised that there are challenges accessing international markets due to 'international geopolitical trade relations' • For organisations who participate in the sub-sector, it is primarily the 'core of business operations' • The majority of organisations export their products/services • Some organisations have turnover range greater than $10M • Significant growth potential exists for applications across many industries that rely on data driven intelligence	• The sub-sector relies heavily on the Information, Media and Telecommunications sectors in the Australian economy • Organisations reflected that major purchases were made from countries such as the UK, EU and the US – which were relevant to satellite imagery and software and advanced cloud computing • Primary reason organisations purchase products/services from outside of Queensland is because the product/service they require is not available in Queensland and is highly specialised in nature	• Mature capability exists, however this is not being exploited to its full extent nor by a large number of organisations • There exists a 'ready made downstream market' for space enabled services in Queensland. There presence of mature capability in the Agriculture, Mining, Manufacturing and Professional, Scientific and Technical Services firms

Ancillary Services

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
N/A	N/A	Limited	Limited	Limited	
N/A	N/A	• Breadth of skill required across Ancillary Services is limited by the size of the space economy for which they would supply services • However, there does exist unique capabilities that are engaged in the existing activities of the space economy	• As the space economy in Queensland is still developing – there is limited, but growing demand for specialised Ancillary Services • It is anticipated that as the space economy grows, so too will the demand for the relevant supporting services, such as legal advice • There are however a few key organisations who are experienced in sectors of the economy with symmetries (such as Defence and Mining) which earn large returns for their expertise	• As the sub-sector is entirely reliant on the growth and size of the space economy, the sub-sector relies on other sectors for its primary operations (such as Mining and Professional, Scientific and Technical Services) • There do exist a few select bespoke space legal/ consulting services. However, this largely reflects the maturity of the broader space economy	• There is strong potential for growth in line with growth in the space economy • Symmetries exist with sectors such as Defence, Mining and Professional, Scientific and Technical Services which will enable skills to be transferred to satisfy demand as it may arise

Research and Development

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
Moderate	Moderate	Moderate	Moderate	Limited	
• Geographic advantages such as proximity to equator, clear night skies and alternative time-zones have encouraged R&D capabilities in areas such as observation and testing. However, these are not critical to the development of the sector and do not put the Queensland space economy at a distinct advantage.	• Significant high-cost infrastructure is required to support industry leading R&D – for which Queensland exhibits some niche capability • Limited physical infrastructure reflects the size of the space economy in Queensland and high investment costs associated with specific technologies • It is noted however that there does exist world-leading capability in small pockets of expertise which engage in international collaboration	• There exists unique capability within the Queensland R&D sub-sector which reflects the size of the Queensland space economy • Most of the major Universities in Queensland engage in differing areas of the space economy; and attract industry leading expertise – often collaborating on an international level with leading space agencies • Respondents experienced varying degrees of difficulty hiring due lack of skillset – this again largely reflects the often niche and highly specialised nature of many of the areas of interest	• The sub-sector collaborates widely across the global space economy, as there is insufficient national demand for the sector to meet. However, this has contributed to the expertise of the sub-sector. Individuals/ organisations are typically well-connected and at the forefront of innovation in their chosen fields • It is anticipated that the sub-sector will be able to support growth in the Queensland space economy; and will continue to grow in line with the rest of the industry	• Whilst there does exist industry leading expertise in the sub-sector – the majority of supply of expertise is met by the international market	• The sector is characterised by high barriers to entry and high investment costs. In the developing space economies of Australia and Queensland, this means where investment has been driven by individuals with niche capability and expertise. Small R&D ecosystems with specific capability have developed as a result. These pockets of expertise are well connected to the global space economy and are not limited by their geographic location. They often collaborate widely across the supply chain and have relationships with large multinationals and international space agencies.

Education and Training

Natural/ Geography	Physical	Human Capital	Demand	Supply	DAE Commentary
N/A	Moderate	Moderate	Limited	Limited	
N/A	• Queensland has several large, world class education facilities, with several that have specialised research units dedicated to space activities • Queensland's education providers do not specialise in space education or provide space specific programs. However, they do provide degrees with leading capability in industries with symmetry to space	• Queensland has several large, world class education professionals • However, Queensland does not have critical mass in educators for providing education specific to the space economy • The existence of individuals working at several Queensland universities with industry-leading expertise is a strength for the sub-sector	• Demand for Education & Training is required in order to provide the space economy with the appropriate skills required; however, there exists a vicious cycle in education and job opportunity. As there has not previously been enough growth in the industry to encourage sector specific education. A phenomena known as 'brain drain' occurs and does not enable the industry to find the necessary labour to grow and sustain operations	• There is limited supply of Education & Training specific to the space economy in Queensland – individuals who require the necessary education will often pursue their studies internationally	• Education and Training that is specifically directed at space activities is limited. However, Queensland has strong education and training opportunities in industries which require similar expertise and experience.

Appendix C
CGE modelling assumptions

This Appendix provides additional detail in support of the economic modelling in chapters 7 and 8. Specifically, this appendix covers:

- The approach to the economic modelling;
- Further details on the industry benefits of space enabled services; and
- The technical specification of Deloitte Access Economics' Computational General Equilibrium model.

Economic impact analysis methodology

The economic impact analysis methodology used in this study has three key components.

First: measuring the current and future size of the space sector in Queensland, including space related segments which include the space activities of the aerospace, defence and advanced manufacturing sectors. However, this is only one key part of the story of the economic potential of the space industry in Queensland.

Second: what does the future uptake of space enabled services and technologies mean for the Queensland economy as a whole? This requires exploring plausible future scenarios for the increase in diffusion, uptake and spillover impacts with a focus on those sectors in Queensland that potentially stand to gain the most based on the information on the growth and application of space enabled services known today. As a result of this future uncertainty, a range of plausible scenarios are presented.

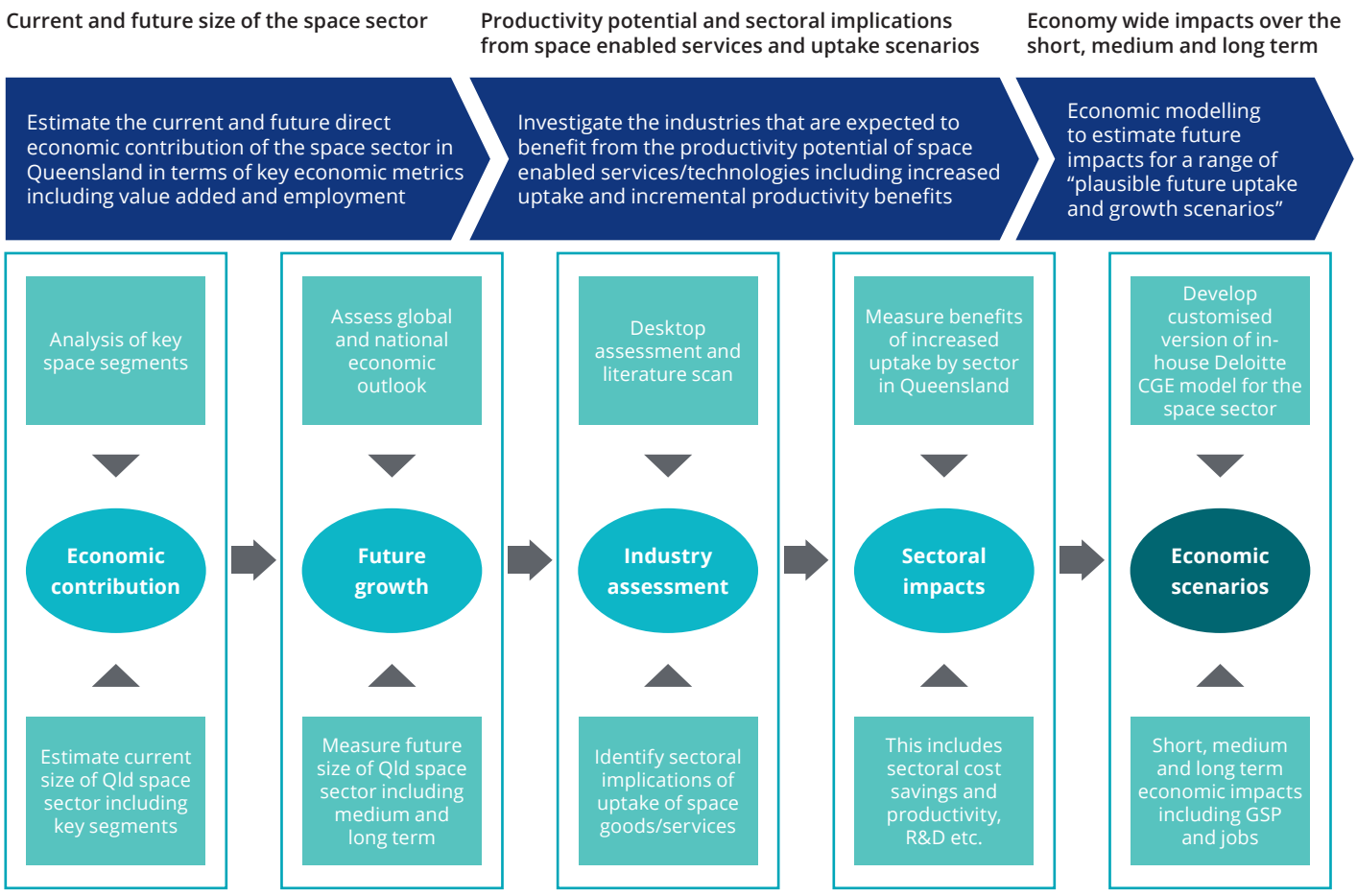
Finally, the growth trajectories of the space sector itself as well as productivity implications for broader industries is modelled within a computable general equilibrium framework to measure the short, medium and long term future economic impacts of the space sector as a whole in Queensland.

Industries that benefit from the future adoption of space enabled services

The expansion of the Queensland industry has significant downstream impacts to a wide range of industries that can exploit space enabled goods, services and technologies to achieve efficiencies. Key industries include:

- Agriculture
- Mining
- Telecommunications
- Transport and logistics
- Construction
- Utilities
- Research and development.

Figure C.1 Economic modelling methodology



Agriculture (broad acre cropping)
Techniques such as precision farming have been employed by parts of the agricultural industry in Australia. The cropping industry (including wheat, barley and rice) has historically been the largest user of GNSS technology. These techniques are also being used by the cotton, sugar and horticulture industries to a lesser extent. Select applications of precision farming techniques include controlled traffic farming, inter-row sowing and variable rate (VR) fertiliser.

Controlled traffic farming refers to the case where tractors follow set paths guided by GNSS and automated steering. By restricting movement to a set path, this method reduces the amount of land that is affected by heavy machinery. This improves the soil structure and water holding capacity of non-trafficked land, which leads to higher crop yields.[39] In addition to increased yields, there are benefits, which include labour, fuel and saving on other inputs such as herbicides and insecticides.

Inter-row sowing, involves the precise placement of seeds between the rows of the previous year's crops and this can flow through to yield increases. VR fertiliser application is centred on coordinate based fertilisation of leading to more efficient use of fertilisers.[40] The consequent benefits include a reduction in fertiliser used, freight and fuel costs, time spent refilling a machines' fertiliser spreader, chemical leaching and weed vigour.[41]

Internationally, the applications of space technologies to agriculture have been highlighted by the Canadian Space Agency. Farmers use satellite data in a range of ways including identification of soil and crop characteristics; monitoring shoot growth; better forecasting precipitation and estimating total output.[42]

The cropping sector is the leader in precision agriculture, with potential to reach 85% by 2025.[43] There are some challenges noted in relation to higher uptake in precision agriculture more generally, including high upfront costs, limited network coverage, the need for new managerial skills and the perceived complexity. The costs of adoption of GNSS technology also ranges from $30,000 with a capability of 10cm accuracy and increases to $50,000 for a higher accuracy of 2cm.[44]

Productivity benefits for broadacre cropping

The use of GNSS benefits both the use of inputs (such as fuel, labour and materials) and agriculture yields in broadacre cropping. Using an uptake rate of GNSS technology increasing from 40% in 2024 to 65% in 2036 (over and above business as usual) leads to a direct benefit ranging from $80 million to $110 million per annum over the period 2019 to 2036 (net of adoption costs).

Mining

The mining industry has a history of using GNSS technology for nearly three decades. There are a number of applications including vehicle tracking and dispatch, material tracking, drill guidance, haul road grading and maintenance, geological mapping, control of bench height, mine site surveying, accurate selective mining and autonomous haul trucks.[45] The latter two were identified by the literature as key applications having strong potential to drive productivity in the mining industry. Accurate selective mining refers to the practice of attaching GNSS to excavators to guide operators on where specifically to mine. This method allows operators to extract ores more efficiently; that is, it allows a larger amount of ore to be extracted with fewer waste, subsequently increasing yields. This was estimated to increase the level of production of the mining of zinc mine.[46] This similarly has applications to black coal mining and non-ferrous mining open-cut mining operations in Queensland.

Another area where GNSS technology is already being used in mining is autonomous haul trucks. An example of this is Rio Tinto's operations in Western Australia, and in Queensland where this approach is also being adopted[47] through the trialling of automated trucks in some mine sites. Autonomous haul trucks removes the need for human drivers by using GNSS to fully operate the truck.[48]

The main benefit of this is in the form of labour savings, but other benefits include reduced accidents, reduced haul truck travel cycle times and lower maintenance costs.[49] In 2008, just 15% of mines were using accurate selective mining technology.[50] In the same study, this was estimated to increase to between 65% and 80% by 2030. The corresponding numbers for autonomous haul trucks are 50% and 60% are line with a trend to higher levels of automation in the future.

A challenge relating to uptake includes the incompatibility of GNSS technology used at different mining sites. The development of a nation GNSS network was noted as a potential way to overcome this challenge. This would also allow suppliers of technologies to design standardised products for market.[51] Another study notes the importance of compatibility of technologies and that uptake will also be influenced by economic conditions and the need for companies to gain competitive advantages through investment.[52] These methods also currently apply only to open cut mines.

Direct benefits

The application of GNSS technology in the use of mining leads to benefits in the use of inputs to mining such as labour and other inputs including fuel through automation and techniques such as precision mining, that targets higher quality product give yield improvements. The adoption profile is 25% in 2024 and increases up to 60% by 2036 (over and above business as usual). This leads to an annual benefit ranging from $300 to $425 million per annum over the period 2019 to 2036 (net of adoption costs).

Telecommunications

GNSS technology is integral to telecommunications infrastructure and supports fixed-line telecommunications (including internet), cellular telecommunications, digital video broadcast, digital audio broadcast, terrestrial truncated radio and internet data centres.[53] Its importance stems from GNSS' ability to deliver precision timing synchronization and position information which enables the continuous transmission of information with low error rate and noise.[54] The consequent reduced infrastructure costs and capital investment outlays have a significant economic impact as demonstrated by London Economics' 2017 report which notes the improvement in gross value added to the UK economy due to GNSS use in the communications sector (and the impact of disruption to these services).[55] There is limited information concerning the adoption rate of GNSS, presumably given its broad application across the telecommunications industry as whole.

In addition to GNSS, satellite communications technology underlies a number of specialised telecommunications services including broadcasting (TV, radio), broadband and internet of things (IoT).[56] Importantly, satellite communications provides increased connectivity (and communication speeds) to remote areas previously reliant on terrestrial based internet services thereby improving equity of access to information and services.[57] This helps bridge Australia's 'digital divide' between urban and regional areas and consequently can facilitate important productivity gains.[58] Given the central role of, and significant reliance on telecommunications in other sectors in the economy; numeric estimates of the economic impact of satellite communications are not widely available.

Direct benefits

GNSS technology has significant applications to communications sectors opening up opportunities for new products over time and improving the quality and efficiency of services delivered by the sector to end users. The profile of adoption increases from 60% in 2024 up to 80% by 2036 (over and above business as usual). The benefits (net of the cost of adoption costs) ranges from $50 to $70 million per annum over the period 2019 to 2036.

Transport and logistics

Precise positioning via GNSS technology has many applications throughout the transport (including road, rail, aviation and maritime) and logistics sectors. A non-exhaustive list of examples includes:

- Logistics and fleet management – monitoring the precise position of fleet vehicles to help manage and optimise route selection, driver fatigue, fuel efficiency and timing[59]
- Road maintenance – gathering of information and data for assessment of road corridors, geometry, conditions and asset management[60]
- Cooperative intelligent transport systems (C-ITS) – connection and exchange of real-time information concerning features of the road environment e.g. road and traffic conditions so as to better connect road users to their road environment[61]
- Rail track surveying and location of infrastructure[62]
- Automated Train Management Systems (ATMS)[63]
- General maritime navigation and navigation through restricted waters[64]
- Aid to aircraft navigation[65]

The sector's early adoption of GNSS technology, particularly for monitoring, tracking and fleet management applications within the road transport and logistics sub-sectors, has been important to addressing issues of congestion, accessibility, road safety and rising fuel prices.[66] As a result, the subsectors, particularly road transport and logistics, have experienced productivity increases due to increased transport efficiency from lower fuel costs, lower congestion and improved road maintenance.[67] Hence the combined output from Australia's road transport and logistics sector has benefited as a result of the application of GNSS technology.

Improvements in precise positioning accuracy, reliability, integrity and interoperability, as well as increased technology adoption across the sector, is important to achieving further efficiencies within existing applications as well as creating new ones within the road transport and logistics subsectors.[68] Cooperative intelligent transport systems have the potential to facilitate productivity improvements through reductions in travel time, congestion and fuel consumption.[69] The use of GNSS technology has been applied at container ports and has resulted in benefits through improved container management and handling given accuracy requirement to be 2cm compared to 10cm accuracy for general transport logistics.

Direct benefits

The transport and logistics sectors have the potential to benefit in the future from the use of GNSS technology. The uptake rate is assumed to increase from 25% in 2024 and up to 60% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $90 to $185 million per annum over the period 2019 to 2036.

Construction

Precise positioning utilising GNSS technologies is a growing trend within the construction sector. This includes construction and engineering surveying and machine guidance.

Construction and engineering surveying is assisted through access to space enabled services. Prior to the adoption of GNSS technology, surveyors had to undertake the time consuming task of providing and verifying extensive control networks and using optical instruments for surveying.[70] With GNSS, this allows the critical coordinates to be identified faster and with a higher level of accuracy. This results in significant benefits, including time savings, better accuracy, reduced labour costs, safety improvements and infrastructure improvements.

Machine guidance is used amongst earthmoving machines including excavators, bulldozers and grading machines. Traditional earthmoving often requires a large degree of rework and on site surveyors. However, GNSS technologies makes it possible to reduce the amount of rework and significantly reduce the need for surveyors. The key benefits resulting from this method includes time savings, capital savings, labour savings, improved safety and improved quality of work.

These techniques have been widely adopted by the industry, particularly for surveying. Adoption rates for construction and engineering surveying and machine guidance were around 60% and 15%, respectively, a decade ago. Given the benefits of the technology these numbers are likely to increase in the future to up to numbers could increase up to 90% and 60% respectively. However this will also depend on the availability of network infrastructure across different locations to support adoption rates of this level.

Direct benefits

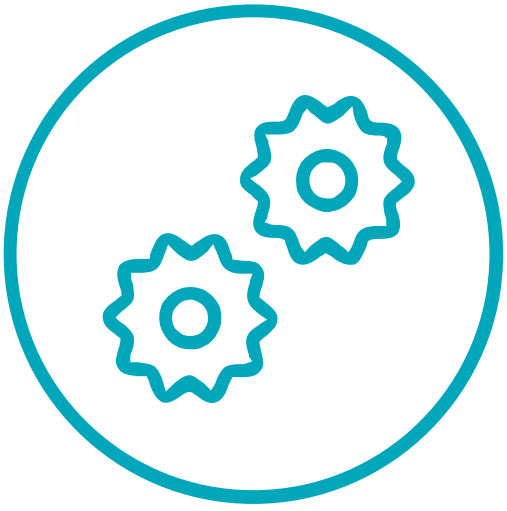
The benefits of GNSS technology to the construction sector are demonstrated in this study through the use of machine guidance and construction surveying. The profile of technological uptake increases from 25% in 2024 and up to 60% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $115 to $180 million per annum over the period 2019 to 2036.

Utilities

The utilities sector includes electricity, gas and water. GNSS is an important feature in the design, construction and management of these large infrastructure assets. In the design and construction phase, GNSS is able to accurately record the location of assets (captured in the construction sector). Another key area where GNSS can help to achieve efficiencies is in asset management, where this technology can use precise positioning to monitor and control the system, identify any faults and manage maintenance. This is able to provide operating benefits in terms of asset mapping. This is also observed by another study, citing that the use of the technology could result in cost savings (operating and maintenance) of up to 20%. The cost savings vary across the sector, with the biggest potential savings in electricity distribution and underground services.[71] Studies have shown that the adoption of GNSS technology has been far more prominent for above ground assets and could be up to 95% by 2020.[72]

Direct benefits

The benefits of GNSS technology in utilities has been demonstrated across a range of applications to date and in particular precision mapping of assets. The benefits for utilities is up to 2.5% of output. The uptake of the technology is 50% in 2024 and increases up to 80% by 2036. The benefits (net of the cost of adoption from 2020 to 2024) range from $35 to $60 million per annum over the period 2019 to 2036



Research and development in the space sector

The Commonwealth government is planning to spend $10 billion into research and development (R&D) in the space sector over the next 20 years (or $500 million per annum). If Queensland attains its current national share of R&D similar to Queensland's share of the national space industry this equates to $75 million per annum of R&D spend in Queensland. Through leveraging of competitive advantages such as advanced manufacturing and aerospace (that are interrelated with space) Queensland can increase it share to reflect its population share. This implies R&D spend of $100 million per annum and this equates to 25 million incrementally or $500 million (undiscounted) over a period of 20 years. The higher R&D attained by Queensland is modelled through increased output in the space sector.

Incremental impact measurement

In this modelling, the uptake rates for each of the sectors represent the estimated range of incremental uptake for each space growth scenario (i.e. relative to the business as usual projection of the Queensland economy). In the business as usual scenario, it has been estimated that there will be an average annual uptake rate of around 20% across the sectors that potential stand to benefit most from space enabled goods, services and technologies in the Queensland economy.

Approach to estimating the direct contribution of the space industry

Estimation of the direct economic contribution of the space industry in Queensland

A 'top down' approach has been used to estimate the size of the Queensland space industry. The starting point is the national industry that generated revenue of $5.1 billion in 2018-19 based on IBIS World (2018). This translated to value added of $3.4 billion and industry employment of 13,700 persons. The size of the industry is consistent with earlier work that valued space industry revenue nationally at $3.94 billion in 2015.[73]

A mapping was conducted to align the industry segments in IBIS World to specific industry activities as defined in the Australia New Zealand Standard Industry Classification (ANZSIC) where practical to best reflect the activities of the space sector in Queensland. Shares to allocate some Queensland revenue by segment were estimated using Queensland employment data by industry and place of work from the 2016 Census of Population and Housing, as seen in Table 9.1. Queensland's share of earth observation and ground station infrastructure operations is based on research conducted by IBIS World (2018). Queensland's share of 'other activities' is an average of all other industry segments given the products/ services produced by this segment (e.g. space related research).

Revenue for each segment is derived using Queensland's share of the segment and national revenue. Value added and employment are estimated using national benchmarks based on IBIS World research (2018).

Table 9.1 Mapping Queensland share of the national space industry by segment

IBIS World Segments of the space industry	Activity as defined in ANZSIC classification or best proxy	Queensland share of national industry
Satellite communications	Other telecommunications network operation	10.2%
Direct to home TV	Free-to-air television broadcasting Cable and other subscription broadcasting	12.4%
Earth observation and ground station infrastructure operation	Using IBIS World research on satellite communications and astronautics in Australia	10.1
Space technology manufacturing	Aircraft manufacturing and repair services	33.1%
Other activities	Space related services such as space research, space launching facilities and other ancillary services	16.5%

Constructing the baseline forecast in DAE RGEM

Baseline projection

The projected economic growth rates imposed in DAE-RGEM model for real gross state product, real investment, labour supply and population are based on underlying trend growth rates. Other macroeconomic variables (for instance, employment, exports, imports and consumption expenditure) are determined by the model. This is based on long term macro-economic forecasts developed in the Deloitte Access Economics Business Outlook and with reference to Budget forecasts developed by the Queensland Government in the 2018-19 State Budget and Mid-Year Economic and Fiscal outlook.

In the baseline the space industry is assumed to grow at 7% over the next five years to 2023-24. Beyond the short to medium term the space industry is assumed to growth at per annum out to 2036 based on a profile developed by Morgan Stanley on future growth prospects for the industry. The underlying growth in the Queensland economy is based on long term macro-economic forecasts developed by Deloitte, around 2-3% over the long term. The underlying growth in the Queensland population and labour force is consistent with these macro-economic assumptions.

Customised database for space

As part of this project it was necessary to split out the space industry out from other industries in the Queensland economy (or the relevant parts of them from other industry sectors) in our master database as they are not always explicitly represented as a separate industry sector. It was necessary to initially and uniquely identify aerospace, defence, advanced manufacturing, rest of manufacturing, communications in the data base and subsequently split out the space components of these sectors so only the non-space component remained. Correspondingly, the space sector was carved out by aggregating the relevant proportion of these industry sectors.

In order to do this, superior data was used and applied the mapping developed for the space industry to split out the relevant part of the sector from the parent industry in the database. This process used the splitcom program developed by the Centre of Policy Studies, Victoria University. This program allows the user to input data on sales/cost weights to split out an existing industry (i.e. parent industry) into two components. One part represents the new industry of interest (i.e. split from the parent industry). The other part represents the remainder of the parent industry. This is done in such in such a manner to keep the whole database balanced and to ensure valid cost and sales structures. The weights used for splitcom were developed with reference to economic datasets from the ABS (including the Australian Industry Publication and ABS National input output tables and Census data) and IBIS World industry reports.

Theory of DAE RGEM

Model theory

The Deloitte Access Economics regional general equilibrium model (DAE-RGEM) is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy with bottom up modelling of Australian regions. The model allows policy analysis in a single, robust, integrated economic framework. This model projects changes in macroeconomic aggregates such as GDP, employment, export volumes, investment and private consumption. At the sectoral level, detailed results such as output, exports, imports and employment are also produced.

The model is based upon a set of key underlying relationships between the various components of the model, each which represent a different group of agents in the economy. These relationships are solved simultaneously, and so there is no logical start or end point for describing how the model actually works. However, they can be viewed as a system of interconnected markets with appropriate specifications of demand, supply and the market clearing conditions that determine the equilibrium prices and quantity produced, consumed and traded.

DAE-RGEM is based on a substantial body of accepted microeconomic theory. Key assumptions underpinning the model are:

- The model contains a 'regional consumer' that receives all income from factor payments (labour, capital, land and natural resources), taxes and net foreign income from borrowing (lending).
- Income is allocated across household consumption, government consumption and savings so as to maximise a Cobb-Douglas (C-D) utility function.
- Household consumption for composite goods is determined by minimising expenditure via a Constant Differences of Elasticities (CDE) () expenditure function. For most regions, households can source consumption goods only from domestic and imported sources. In the Australian regions, households can also source goods from interstate. In all cases, the choice of commodities by source is determined by a Constant Ratios of Elasticities Substitution, Homothetic (CRESH) utility function.
- Government consumption for composite goods, and goods from different sources (domestic, imported and interstate), is determined by maximising utility via a C-D utility function.

- All savings generated in each region are used to purchase bonds whose price movements reflect movements in the price of creating capital.
- Producers supply goods by combining aggregate intermediate inputs and primary factors in fixed proportions (the Leontief assumption). Composite intermediate inputs are also combined in fixed proportions, whereas individual primary factors are combined using a CES production function.
- Producers are cost minimisers, and in doing so, choose between domestic, imported and interstate intermediate inputs via a CRESH production function.
- The supply of labour is positively influenced by movements in the real wage rate governed by an elasticity of supply.
- Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. A global investor ranks countries as investment destinations based on two factors: global investment and rates of return in a given region compared with global rates of return. Once the aggregate investment has been determined for Australia, aggregate investment in each Australian sub-region is determined by an Australian investor based on: Australian investment and rates of return in a given sub-region compared with the national rate of return.
- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.
- Prices are determined via market-clearing conditions that require sectoral output (supply) to equal the amount sold (demand) to final users (households and government), intermediate users (firms and investors), foreigners (international exports), and other Australian regions (interstate exports).
- For internationally-traded goods (imports and exports), the Armington assumption is applied whereby the same goods produced in different countries are treated as imperfect substitutes. But, in relative terms, imported goods from different regions are treated as closer substitutes than domestically-produced goods and imported composites. Goods traded interstate within the Australian regions are assumed to be closer substitutes again.
- The model accounts for greenhouse gas emissions from fossil fuel combustion. Taxes can be applied to emissions, which are converted to good-specific sales taxes that impact on demand. Emission quotas can be set by region and these can be traded, at a value equal to the carbon tax avoided, where a region's emissions fall below or exceed their quota.

Below is a description of each component of the model and key linkages between components.

Households

Each region in the model has a so-called representative household that receives and spends all income. The representative household allocates income across three different expenditure areas: private household consumption; government consumption; and savings.

The representative household interacts with producers in two ways. First, in allocating expenditure across household and government consumption, this sustains demand for production. Second, the representative household owns and receives all income from factor payments (labour, capital, land and natural resources) as well as net taxes. Factors of production are used by producers as inputs into production along with intermediate inputs. The level of production, as well as supply of factors, determines the amount of income generated in each region.

The representative household's relationship with investors is through the supply of investable funds – savings. The relationship between the representative household and the international sector is twofold. First, importers compete with domestic producers in consumption markets. Second, other regions in the model can lend (borrow) money from each other.

- The representative household allocates income across three different expenditure areas – private household consumption; government consumption; and savings – to maximise a Cobb-Douglas utility function.
- Private household consumption on composite goods is determined by minimising a CDE expenditure function. Private household consumption on composite goods from different sources is determined is determined by a utility function.
- Government consumption on composite goods, and composite goods from different sources, is determined by maximising a Cobb-Douglas utility function.
- All savings generated in each region is used to purchase bonds whose price movements reflect movements in the price of generating capital.

Producers

Apart from selling goods and services to households and government, producers sell products to each other (intermediate usage) and to investors. Intermediate usage is where one producer supplies inputs to another's production. For example, coal producers supply inputs to the electricity sector.

Capital is an input into production. Investors react to the conditions facing producers in a region to determine the amount of investment. Generally, increases in production are accompanied by increased investment. In addition, the production of machinery, construction of buildings and the like that forms the basis of a region's capital stock, is undertaken by producers. In other words, investment demand adds to household and government expenditure from the representative household, to determine the demand for goods and services in a region.

Producers interact with international markets in two main ways. First, they compete with producers in overseas regions for export markets, as well as in their own region. Second, they use inputs from overseas in their production.

- Sectoral output equals the amount demanded by consumers (households and government) and intermediate users (firms and investors) as well as exports.
- Intermediate inputs are assumed to be combined in fixed proportions at the composite level. As mentioned above, the exception to this is the electricity sector that is able to substitute different technologies (brown coal, black coal, oil, gas, hydropower and other renewables) using the 'technology bundle' approach developed by ABARE (1996).
- To minimise costs, producers substitute between domestic and imported intermediate inputs is governed by the Armington assumption as well as between primary factors of production (through a CES aggregator). Substitution between skilled and unskilled labour is also allowed (again via a CES function).
- The supply of labour is positively influenced by movements in the wage rate governed by an elasticity of supply is (assumed to be 0.2). This implies that changes influencing the demand for labour, positively or negatively, will impact both the level of employment and the wage rate. This is a typical labour market specification for a dynamic model such as DAE-RGEM. There are other labour market 'settings' that can be used. First, the labour market could take on long-run characteristics with aggregate employment being fixed and any changes to labour demand changes being absorbed through movements in the wage rate. Second, the labour market could take on short-run characteristics with fixed wages and flexible employment levels.

Investors

Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. The global investor ranks countries as investment destination based on two factors: current economic growth and rates of return in a given region compared with global rates of return.

- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.

International

Each of the components outlined above operate, simultaneously, in each region of the model. That is, for any simulation the model forecasts changes to trade and investment flows within, and between, regions subject to optimising behaviour by producers, consumers and investors. Of course, this implies some global conditions that must be met, such as global exports and global imports, are the same and that global debt repayment equals global debt receipts each year.

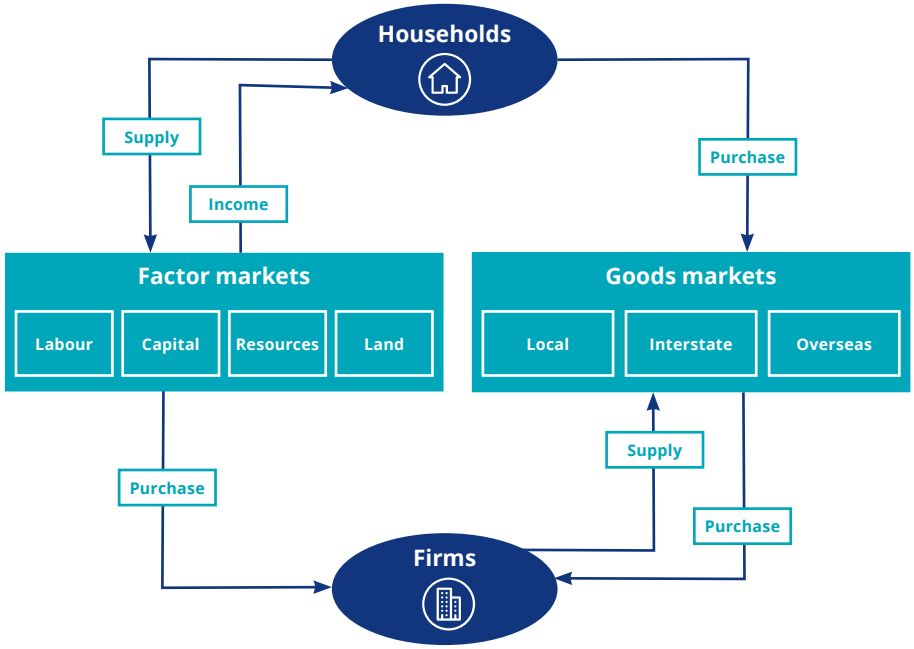
Methodology

CGE modelling is the framework that is best suited to modelling the impact of large projects or policies on the economy. In this framework, it is possible to account for resourcing constraints and opportunity costs, and to model changes in prices and the behaviour of economic agents in response to changes in the economy. This project has used the DAE-RGEM. This is a model of the Australian and world economy, and represents the interaction of households and firms with factor markets and goods markets over time. DAE-RGEM represents all economic activity in the economy, including production, consumption, employment, taxation and trade.

The circular flow of income and spending that occurs in DAE-RGEM is captured in a stylised form in Figure C.2. To meet demand for products, firms purchase inputs from other producers and hire factors of production (labour and capital). Producers pay wages and rent (factor income) which accrue to households. Households spend their income on goods and services, pay taxes and put some away for savings.

For this project, the model has been customised to represent the Queensland economy and capture the space industry, along with relevant upstream and downstream industries.

Table C.2 Stylised diagram of DAE-RGEM



Source: Deloitte Access Economics

Appendix D
Short form data capture and capability survey

The following section presents the full results of the short survey (survey 1).

It is important to note results may not add to 100% due to rounding.

Is your organisation headquartered in Queensland?

Yes	69%
No	31%

Is your organisation a...?

Government Department	2%
Industrial Association	2%
Private Company	86%
University/Research/Educational Organisation	10%

What was your turnover range in FY18?

Zero to less than $50,000	5%
$50,000 to less than $200,000	5%
$200,000 to less than $2 million	24%
$2 million to less than $5 million	17%
$5 million to less than $10 million	10%
$10 million or more	32%
Not applicable (research institution etc.)	7%

How many employees do you have in FY18?

Non Employing (i.e. having no employees)	5%
1-19 Employees	41%
20-199 Employees	31%
200+ Employees	17%
Not applicable (research institution etc.)	7%

Have you exported your goods and/or services overseas in the past 12 months?

Yes	61%
No	34%
Not applicable (research institution etc.)	5%

Have you exported your goods and/or services overseas in the past 12 months?

0-4 years	12%
5-10 years	12%
11-20 years	22%
21-40 years	32%
>40 years	22%

Do you consider the 'space industry' as your primary industry of operation?

Yes	25%
No	75%

What capability area does your organisation primarily operate in?

Space Systems	27%
Launch Activities	10%
Ground Systems	8%
Space Enabled Services	10%
Ancillary Services	14%
R&D	7%
Education and Training	3%
Other	3%
Transport, logistics and construction	2%
General component, material, engineering supply	15%

The following is a list of questions from the extended capability survey. Due to confidentiality issues, participant answers have not been included.

Is your organisation a...?

1	Industrial Association
2	Private Company
3	Private Consultancy
4	University/Research/Educational Organisation
5	Government Department
6	Other, please specify [Free text]

Please select which statement best represents your organisation's current level of engagement and/or activity in the space economy?

1	The space economy is the core of my business operations
2	The space economy is a secondary area of operation for my business
3	My organisation (or as an individual) occasionally operates in the space economy
4	My organisation (or as an individual) has recently entered the space economy
5	My organisation (or as an individual) is not currently active in the space economy

What percentage of your annual turnover range would you classify as primarily related to space economy activities in FY18?

1	None
2	<1-20%
3	21-40%
4	41-60%
5	>60%

What features of other Australian jurisdictions' (e.g. SA, WA, ACT) space sectors could Queensland learn from?

What are the key competitive advantages of Queensland's space economy and how does your organisation benefit from them?

Have you collaborated with ... in either a research or commercial capacity, in the past 5 years? Select all that apply.

1	Queensland business/es
2	Australian business/es
3	Queensland research institution/s
4	Australian research institution/s
5	An international space agency [please specify]
6	None of the above

Please identify what area of capability in the supply chain of the space economy best describes the main activity of your organisation:

1	Industrial Association
2	Private Company
3	Private Consultancy
4	University/Research/Educational Organisation
5	Government Department
6	Other, please specify [Free text]
7	Ground Segment Prime/System Integration
8	Ground Segment Subsystem & Equipment Supplier
9	Launch Services
10	Launch Support Services
11	Launch Vehicle Manufacturing and Assembly
12	Legal Services
13	Other, please specify [Fixed at bottom]
14	Prime/System Integration
15	R&D
16	Satellite Communications Service Providers
17	Satellite Navigation Service & Applications
18	Satellite Owner/Operator
19	Space Qualified Testing and Facilities
20	Space Subsystem Supply
21	Specialisation on nano and micro satellites (<50kg)
22	System Engineering and Technical Support
23	System Engineering and Technical Support Services
24	Technical Support Services
25	Tracking, Telemetry & Command Operations
26	User Equipment Manufacturer
27	User Equipment Suppliers

Have you supplied/provided goods/services to a government project in the past 5 years?

1	Yes
2	No

Have you received any of the following government support in the past 5 years?

1	Funding
2	Facilitation (e.g. networking)
3	Other (please specify)
4	No support

Considering your organisations supply chain, are there any significant purchases (that relate to your core business) that your organisation can't source within Queensland?

	Product/Service	Location (City, Country)
1	[Free text 20 words]	[Free text 5 words]
2	[Free text 20 words]	[Free text 5 words]
3	[Free text 20 words]	[Free text 5 words]
4	Not applicable	N/A

Considering your organisation's supply chain, select the top 3 industry sectors your organisation currently purchases products/services from?

1	Agriculture, Forestry and Fishing
2	Construction
3	Defence
4	Education and Training
5	Finance, Insurance and Business Services
6	Information Media and Telecommunications
7	Manufacturing
8	Mining
9	Other Services
10	Professional, Scientific and Technical Services
11	Trade
12	Transport
13	Utilities
14	Other, please specify [Fixed at bottom]
15	Don't know [Fixed at bottom]

What are the top 3 reasons you purchase products/ services for your organisation from outside of Queensland?

1	Better quality product/service outside of Queensland
2	More expertise outside of Queensland
3	Not applicable
4	Other, please specify [Fixed at bottom]
5	Price of product/service in Queensland is too high
6	Product/service is highly specialised in nature
7	Product/service not available in Queensland

Considering your organisation's supply chain, select the top 3 industry sectors your organisation currently sells products/services to?

1	Agriculture, Forestry and Fishing
2	Construction
3	Defence
4	Education and Training
5	Finance, Insurance and Business Services
6	Information Media and Telecommunications
7	Manufacturing
8	Mining
9	Other Services
10	Professional, Scientific and Technical Services
11	Trade
12	Transport
13	Utilities
14	Other, please specify [Fixed at bottom]
15	Don't know [Fixed at bottom]

What are the top 3 industry sectors that you see could potentially use the products/services of your organisation (or individual)?

1	Agriculture, Forestry and Fishing
2	Construction
3	Defence
4	Education and Training
5	Finance, Insurance and Business Services
6	Information Media and Telecommunications
7	Manufacturing
8	Mining
9	Other Services
10	Professional, Scientific and Technical Services
11	Trade
12	Transport
13	Utilities
14	Other, please specify [Fixed at bottom]
15	Don't know [Fixed at bottom]

Are you part of the supply chain of a large multinational?

1	Yes
2	No
3	Not applicable (research institution etc.)

Have you had difficulty hiring employees with the necessary skills for the space industry?

1	Yes
2	No
3	Not applicable

What area/s of the Queensland space economy do you purchase products/services from?

1	Antenna/Ground Station Component or Material Supplier
2	Component and Material Supply
3	Component and Subsystem Management
4	Consultancy Services (e.g. IT, analytics, professional services)
5	Earth Observation Services & Applications
6	Financial Services
7	Ground Segment Prime/System Integration
8	Ground Segment Subsystem & Equipment Supplier
9	Launch Services
10	Launch Support Services
11	Launch Vehicle Manufacturing and Assembly
12	Legal Services
13	None
14	Other, please specify [Fixed at bottom]
15	Prime/System Integration
16	R&D
17	Satellite Communications Service Providers
18	Satellite Navigation Service & Applications
19	Satellite Owner/Operator
20	Space Qualified Testing and Facilities
21	Space Subsystem Supply
22	Specialisation on nano and micro satellites (<50kg)
23	System Engineering and Technical Support
24	System Engineering and Technical Support Services
25	Technical Support Services
26	Tracking, Telemetry & Command Operations
27	User Equipment Manufacturer
28	User Equipment Suppliers

In the context of your organisation (or as an individual), please select the top 5 constraints to growth:

1	Long investment cycles
2	Australian market does not exist for services/goods
3	Complex access structures (to large organisations/ government)
4	Data privacy/cyber risk
5	Difficulty accessing appropriate financing
6	Expensive certification/licensing
7	High entry cost
8	High investment cost
9	Inappropriate/insufficient launch facilities
10	Insurance
11	Long lead times to acquire necessary inputs/ services for your product/service
12	Market saturation
13	No access to markets (for export)
14	No skilled workforce in the required field
15	No suppliers
16	Other, please specify [Fixed at bottom]
17	Poor collaboration across industry
18	Poor knowledge of opportunities/markets
19	Procurement programs - lengthy
20	Procurement programs – unclear
21	Technological risk
22	Unable to obtain certification/licensing/permits
23	Regulation/legislative frameworks in place do not support growth

What do you see as the greatest risk/challenge to the growth of the Queensland space economy in the short/ medium/long term?

Short (1-5 years)	[Free text 20 words]
Medium (5-10 years)	[Free text 20 words]
Long (10+ years)	[Free text 20 words]

Have you had difficulty hiring employees with the necessary skills for the space industry?

1	Yes
2	No
3	Not applicable

What are the emerging frontiers in the space economy in Queensland?

[Free text]

What has been the primary enabler of growth for your organisation?

[Free text]

What does your organisation need to scale-up activity?

[Free text]

The recently established Australian Space Agency is encouraging a 'Team Australia' approach to the development of the Australian space industry, suggesting the jurisdictions pursue their relative competitive advantages. Please indicate your view on the competitive advantages of the following space economies:

South Australia	[Free text]
Australian Capital Territory	[Free text]
New South Wales	[Free text]
Victoria	[Free text]
Northern Territory	[Free text]
Western Australia	[Free text]
Tasmania	[Free text]

References

ACIL Allen 2013, Precise positioning in the road transport sector: An estimate of the economic and social benefits of the use of augmented GNSS in the road transport sector, for the Department of Industry, Climate Change, Innovation, Research and Tertiary Education, http://www.ignss.org/LinkClick.aspx?fileticket=afaFsLr%2Brmc%3D&tabid=56, accessed 2019.

ACIL Allen 2013, Precise positioning services in the aviation sector: An estimate of the economic and social benefits of the use of augmented GNSS in the aviation sector, for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education
http://www.ignss.org/LinkClick.aspx?fileticket=1G4YG%2BEQyhE%3D&tabid=56, accessed 2019.

ACIL Allen 2013, Precise positioning services in the construction sector: An estimate of the economic and social benefits of the use of augmented GNSS services in the construction sector, for the Department of Industry, Climate Change, Innovation, Research and Tertiary Education,
http://www.ignss.org/LinkClick.aspx?fileticket=ntyClJz4fh8%3D&tabid=56, accessed 2019.

ACIL Allen 2013, Precise positioning services in the maritime sector: An estimate of the economic and social benefits of the use of augmented positioning services in the maritime sector, for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education,
http://www.ignss.org/LinkClick.aspx?fileticket=b%2F3x6KEaFS4%3D&tabid=56, accessed 2019.

ACIL Allen 2013, Precise positioning services in the rail sector: An estimate of the economic and social benefits of augmented positioning services in the rail sector, for the Department of Industry, Climate Change, Innovation, Research and Tertiary Education,
http://www.ignss.org/LinkClick.aspx?fileticket=rpl6BIao%2F54%3D&tabid=56, accessed 2019.

ACIL Allen 2013, Precise positioning services in the Utilities Sector, for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education,
http://www.ignss.org/LinkClick.aspx?fileticket=h5iRKR7fdUo%3D&tabid=56, accessed 2019.

ACIL Allen 2013, The Value of Augmented GNSS in Australia: An overview of the economic and social benefits of the use of augmented GNSS services in Australia, for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education,
http://www.ignss.org/LinkClick.aspx?fileticket=dKQ6MsXGBAw%3D&tabid=56, accessed 2019.

ACIL Allen 2015, The Value of Earth Observations from Space to Australia, for the Cooperative Research Centre for Spatial Information,
http://www.crcsi.com.au/assets/Program-2/The-Value-of-Earth-Observations-from-Space-to-Australia-ACIL-Allen-FINAL-20151207.pdf, accessed 2019.

ACIL Allen 2017, Australian Space Industry Capability: A Review, for the Department of Industry, Innovation and Science,
https://www.industry.gov.au/sites/g/files/net3906/f/June%202018/document/extra/australian_space_industry_capability_-_a_review.pdf, accessed 2019.

ACIL Allen 2017, Economic Value of Spatial Information in NSW: Estimated for 2017 and 2022,
http://www.crcsi.com.au/assets/Consultancy-Reports-and-Case-Studies/Value-of-NSW-Spatial-Information-final.pdf, accessed 2019.

ANZLIC 2017, Realising the Benefits of Precise Positioning: Road Transport,
https://link.fsdf.org.au/usecase-requirement/realising-benefits-precise-positioning-road-transport, accessed 2019.

Australian Academy of Science 2017. A vision for space science and technology in Australia: Securing and advancing Australia's interests through space research,
https://www.science.org.au/files/userfiles/support/documents/vision-space-science-technology-2017.pdf, accessed 2019.

Australian Bureau of Statistics, Count of Australian Businesses, including Entries and Exists, June 2012 to June 2016, cat. no. 8165.0 (6 June 2017).

Australian Government Department of Industry, Innovation and Science 2018, Review of Australia's Space Industry Capability: Report from the Expert Reference Group for the Review, https://www.industry.gov.au/sites/g/files/net3906/f/June%202018/document/pdf/review_of_australias_space_industry_capability_-_report_from_the_expert_reference_group.pdf, accessed 2019.

Australian Government Space Coordination Committee 2018, 2017 State of Space Report, https://www.industry.gov.au/sites/g/files/net3906/f/June%202018/document/pdf/state_of_space_report_2017.pdf, accessed 2019.

Australian Space Agency 2018, Welcome to the Australian Space Agency, https://www.industry.gov.au/sites/g/files/net3906/f/welcome-to-the-australian-space-agency.pdf, accessed 2019.

Bryce Space and Technology 2018, Start-Up Space: Update on Investment in Commercial Space Ventures, https://www.brycetech.com/downloads/Bryce_Start_Up_Space_2018.pdf, accessed 2019.

Bryce Space and Technology n.d., Global Space Industry Dynamics, https://www.industry.gov.au/sites/g/files/net3906/f/June%202018/document/extra/global_space_industry_dynamics_-_research_paper.pdf, accessed 2019.

Canadian Space Agency 2018, Agriculture in the satellite age, http://www.asc-csa.gc.ca/eng/satellites/everyday-lives/agriculture-in-the-satellite-age.asp, accessed 2019.

Commonwealth of Australia 2013, Australia's Satellite Utilisation Policy, https://www.industry.gov.au/sites/g/files/net3906/f/May%202018/document/pdf/australias_satellite_utilisation_policy.pdf, accessed 2019.

Commonwealth of Australia 2016, Australian Industry Report 2016, https://publications.industry.gov.au/publications/australianindustryreport2016/assets/Australian-Industry-Report-2016.pdf, accessed 2019.

Commonwealth of Australia 2018, Budget Paper No. 2., https://www.budget.gov.au/2018-19/content/bp2/index.html, accessed 2019.

Creagh, B 2018, Hitachi's automation plan with Whitehaven Coal and beyond, https://www.australianmining.com.au/features/hitachi-collaborates-whitehaven-coal-automation-maules-creek/, accessed 2019.

CSIRO Futures 2018, Space: A Roadmap for unlocking future growth opportunities for Australia, https://www.csiro.au/en/Do-business/Futures/Reports/Space-Roadmap, accessed 2019.

Dougherty, K 2017, Lost in space: Australia dwindled from space leader to also-ran in 50 years, https://theconversation.com/lost-in-space-australia-dwindled-from-space-leader-to-also-ran-in-50-years-83310, accessed 2019.

IBIS World 2018, Satellite Communications and Astronautics: Australia Market Research Report, https://www.ibisworld.com.au/industry-trends/specialised-market-research-reports/technology/satellite-communications-astronautics.html, accessed 2019.

Infosys 2018, Asset Monitoring & Advanced Maintenance, https://www.infosys.com/industries/aerospace-defense/industry-offerings/Documents/asset-monitoring.pdf accessed 2019.

International Efficient Agriculture Solutions and Standards Association 2016, Variable Rate Fertilization, http://ieassa.org/en/variable-rate-fertilization/, accessed 2019.

Kornhauser, A L 2006, Global Navigation Satellite System (GNSS), https://www.princeton.edu/~alaink/Orf467F07/GNSS.pdf, accessed 2019.

Manicaros, A 2017. '$235m plan to launch space industry in NT', The Nothern Star, 24 July, https://www.northernstar.com.au/news/235m-plan-launch-space-industry-nt/3203973/, accessed 2019.

McGarry, D, Tullberg, J N & Yule, D F 2003, 'On track' to sustainable cropping systems in Australia, http://www.micromanage.com.au/actfa1/further_reading/On_track_ISTRO_Knote.pdf, accessed 2019.

Morgan Stanley 2017, Space: Investment Implications of the Final Frontier,
https://fa.morganstanley.com/griffithwheelwrightgroup/mediahandler/media/106686/Space_%20Investment%20Implications%20of%20the%20Final%20Frontier.pdf, accessed 2019.

Morgan Stanley 2018, Space: Investing in the Final Frontier,
https://www.morganstanley.com/ideas/investing-in-space, accessed 2019.

Organisation For Economic Co-Operation And Development 2014, The Space Economy at a Glance 2014, OECD Publishing, Paris.

Prescient & Strategic Intelligence n.d., Remote Asset Management Market Size, Share, Development, Growth and Demand Forecast to 2023
https://www.psmarketresearch.com/market-analysis/remote-asset-management-market, accessed 2019.

Sadlier, G, Flytkjær, R, Sabri, F & Herr, D 2017, The economic impact on the UK of a disruption to GNSS,
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/619544/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Full_Report.pdf, accessed 2019.

Schuman, A W & Hostler, H K 2008, Variable rate fertilization — getting started,
https://crec.ifas.ufl.edu/extension/trade_journals/2008/2008%20Jan%20variable%20rate%20fertilization.pdf, accessed 2019.

Shoker, I 2018, Remote Monitoring for Improved Asset Management,
https://www.arcweb.com/blog/remote-monitoring-improved-asset-management, accessed 2019.

Smart, M 2016, Old vs New: the next generation of the space industry,
https://theconversation.com/old-vs-new-the-next-generation-of-the-space-industry-64793, accessed 2019.

South Australian Space Industry Centre 2017, Timeline of Space Activity in South Australia,
https://www.defencesa.com/upload/brochures/Timeline%20of%20Space%20Activity%20Sept%202017.pdf, accessed 2019.

Space Angels 2019, Space Investment Quarterly Q4 2018.

Space Exploration Technologies Corp. 2017, Reusability,
https://www.spacex.com/reusability-key-making-human-life-multi-planetary, accessed 2019.

Space Safety Magazine 2014, Space Economy,
http://www.spacesafetymagazine.com/space-on-earth/space-economy/, accessed 2019.

Strada, G M & Sasanelli, N 2018, Growing the Space Economy: The Downstream Segment as a Driver,
http://www.piar.it/report09today/Strada2018.pdf, accessed 2019.

The Allen Consulting Group 2008, Economic benefits of high resolution positioning services, for Victorian Department of Sustainability and Environment and the Cooperative Research Centre for Spatial Information,
https://www.crcsi.com.au/assets/Resources/ffa927a7-55d1-400a-b7d6-9234f4fe4ad2.pdf, accessed 2019.

The University of Southern Queensland 2018. USQ Space Sciences.

Weinzierl, M 2018, 'Space, the Final Economic Frontier', Journal of Economic Perspectives, 32(2), pp. 173-192.

End notes

1. In this context, the space industry is more tightly defined than the space economy, where the former focuses on the sub-sectors considered to be in the 'core' of the space industry while the latter includes the broader upstream and downstream industries that sell to and buy from the 'core' space industry (e.g. advanced manufacturing).
2. OECD, 2014
3. Smart, 2016
4. Weinzierl, 2018
5. Bryce Space and Technology, n.d.
6. OECD, 2014
7. Space Safety Magazine, 2014
8. Ibid
9. Space Exploration Technologies Corp., 2017
10. Morgan Stanley, 2017
11. Ibid
12. Ibid
13. Bryce Space and Technology, Global Space Industry Dynamics, 2017
14. Bryce Space and Technology, Start-up Space, 2017
15. Dougherty, 2017
16. South Australian Space Industry Centre, 2017
17. Australian Academy of Science, 2017
18. Australian Space Agency, 2018
19. Australian Government Department of Industry, Innovation and Science, 2018
20. Ibid
21. Commonwealth of Australia, 2018
22. Australian Government Department of Industry, Innovation and Science, 2018
23. Ibid
24. Commonwealth of Australia, 2016
25. ACIL Allen, 2017
26. ACIL Allen, 2017
27. ACIL Allen, 2017
28. Space Angels, 2019
29. Ibid
30. Australian Bureau of Statistics, 2017
31. Morgan Stanley, 2018
32. Australian Government Department of Industry, Innovation and Science, 2018
33. IBIS World, 2018; ACIL Allen, 2015

34. Morgan Stanley, 2018
35. IBIS World, 2018
36. Morgan Stanley, 2018
37. IBIS World, 2018
38. Manicaros, 2017
39. Tullberg et al, 2003; Schofield et al, 2007 as seen in The Allen Consulting Group, 2008
40. International Efficient Agriculture Solutions and Standards Association, 2016
41. Schuman and Hostler, 2008
42. Canadian Space Agency, 2018
43. ACIL Allen, 2017
44. Jones and O'Halloran, 2006 as seen in The Allen Consulting Group, 2008
45. Jaroz and Finlayson, 2002 as seen in The Allen Consulting Group, 2008
46. Seymour, 2005 as seen in The Allen Consulting Group, 2008
47. Creagh, 2018
48. Hughes, 2002 as seen in The Allen Consulting Group, 2008
49. The Allen Consulting Group, 2008; Hughes, 2002 as seen in The Allen Consulting Group, 2008
50. Seymour, 2008 as seen in The Allen Consulting Group, 2008
51. The Allen Consulting Group, 2008
52. McNab and Garcia-Vasquez, 2012 as seen in ACIL Allen, 2013
53. Sadlier et al, 2017
54. Kornhauser, 2006
55. Sadlier et al, 2017
56. CSIRO Futures, 2018
57. Commonwealth of Australia, 2013
58. Australian Government Space Coordination Committee, 2018
59. ACIL Allen, 2013
60. Ibid
61. Ibid
62. Ibid
63. Ibid
64. Ibid
65. Ibid
66. ANZLIC, 2017
67. ACIL Allen, 2013
68. Ibid
69. Ibid
70. ACIL Allen, 2013; The Allen Consulting Group, 2008
71. ACIL Allen, 2013
72. Ibid
73. ACIL Allen 2015

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