A Study of the Economic Potential of the Local Space Sector

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Throughout history the study of astronomy has fascinated humans. Space exploration commenced in 1957 with the launch of Sputnik 1. Since then a global industry has developed and today, the space economy involves not only governments and scientific research organisations but also opportunities for the economic exploitation of space have been made possible by technological advances, which are making space technologies accessible not only to large businesses but also to an increasing number of small enterprises and start-ups.

The international space economy continues to grow at an impressive rate and recent estimates indicate that global space industry revenues increased from $323 billion in 2015 to $329 billion in 2016. The growing importance of space-related products and services is demonstrated by the fact that currently the major part of these revenues belongs to the commercial sector, which contributes slightly more than three quarters of all global economic activity in space. These upstream and downstream activities are an integral part of the space economy and they include businesses that do not usually regard themselves as being part of the space sector but that rely on space applications to produce their products and services.

Australia uses space-related technologies in virtually every sector of the economy. It has been estimated that the output of the Australian space sector is in the range of $3-4 billion, with a workforce of between 9,500 and 11,500 employees. At present, the Australian space sector is considered to be underdeveloped and it represents a clear case of unfulfilled potential. In fact, it is estimated that the space sector in Australia contributes for approximately only 0.8 per cent to the global space economy, while Australia's share of the overall world economy is 1.8 per cent. Since the downstream sector is fundamental for the Australian community and its importance will only increase in the future, satellite services will continue to play a key role. Currently, however, with the exception of domestic telecommunications services, the data on which downstream space technologies are based are entirely provided by other countries' satellites. A national strategy to reduce Australia's dependence could be a key result of the recently announced Commonwealth Government decision to establish a national space agency. It is now accepted that the creation of an internationally recognized and permanent institution to oversee a national space program will play a key role in the development of the space sector in this country. As well as reducing dependency, a national space program should aim to improve access to high quality data, improve Australians' quality of life, and contribute to building a long term national strategic resource.

The description of the Australian space sector and the explanation of the importance of the downstream segment in the economy serve as introductory concepts to the main purpose of this report, that is to scope the current level of space sector activity in South Australia and its growth potential. In this report we aim to measure the size of the South Australian space workforce, its growth rate and its contributions to the Australian space sector. Our findings show that the space workforce in the State is of the order of 800 employees, working in private companies, the Defence services, universities, research organisations, government departments, industry associations and private consultancies. If we think that only 7.15% of the Australian population lives in South Australia, and that the Australian space workforce has been estimated to be in the range of 9500-11500 employees, then South Australia has a higher per capita space sector work force compared to the national average. Contributing to this result is the fact that by global standards the South Australian space sector has a relatively large number of start-up enterprises that are still small in size.

In our analysis we considered 32 private companies operating in the space sector in South Australia, employing 460 full time equivalents (FTEs) in space-related jobs. More than two-thirds of these companies have been founded since 2000, and almost half of them have been founded only in the last five years. There has been an impressive growth rate in the sector, with 30% of companies founded only in the last three years. The steep increase in business formation provides some evidence that the market for space related products and services is not saturated yet, and there are many more opportunities for new businesses to establish in the state.

In order to understand the growth potential of the Australian space sector, an attempt has been made to determine the size of the domestic space market. By using a conservative approach, we estimated a market size of approximately 1400 companies, which is a measure of the number of companies potentially interested in using space technologies to improve their services and products. Considering this demand for space technologies, and the fact that the number of consumers that buy space technologies is bound to increase as space products and services become cheaper, it is reasonable to assume that the market size will increase in the foreseeable future.

The majority of private companies that currently constitute the space sector in South Australia are small and medium size enterprises (SMEs). New and more affordable space technologies reduce the importance of economies of scale, and therefore the potential contribution of smaller firms is enhanced. In this report it is estimated that in numerical terms 48 per cent of space companies are micro businesses, almost 50 per cent are medium and small enterprises, and only a very small share of 0.07% is represented by large companies.

Therefore, it was important to assess the implications of such a high number of micro and SMEs in the space sector. For this purpose, a comparison was done with the case of Germany. The space sector of Germany and Australia are dominated by SMEs, which in both countries account for over 99 per cent of companies, more than in any other industrial nation. However, in Germany they make up a significantly higher share of employment and a higher contribution to GDP. These differences are mainly due to the fact that the Australian space sector is characterized by a much larger proportion of micro enterprises, for whom investing in innovation activities and becoming more internationally focused is more difficult compared to medium size enterprises. Additionally, Germany is incorporated in a triangular system which allows for a division of responsibilities and project support between national government space agencies, the European Space Agency (ESA), and the European Union, whereas Australia currently lacks an industry/government eco-system that is comparable in size and importance compared with the system in Europe.

South Australia has developed a skilled space workforce of considerable size. The enabling factors present in the region, such as a leading university system in the field of STEM-related subjects and strong State Government support, have made this growth possible and paved the way to a new role for South Australia, as a leading centre of space expertise and innovation for the country.

INTRODUCTION

The aim of this report is to measure the importance and the growth potential of the space sector in South Australia. In pursuit of this objective, we analysed the private companies belonging to the space industry in South Australia, the number of their workers employed in space-related jobs, the trend of the space industry in the last two decades and its contribution to the national space economy. Since the majority of the businesses operating in the South Australian space sector are SMEs, the case of Germany has been analysed as an example of best practice for Australia. In fact, the German Mittlestand is the engine of the German economy and it shows how SMEs can drive innovation and economic success. Therefore, the study of the German model can provide useful insights to the Australian economy.

Overall, the investigations made in this report present an interesting and detailed picture of the actual status of the space economy in South Australia. Given the growing importance of space for modern societies, the developments of the space industry in South Australia appear to be of crucial importance for the country, and provide a good starting point for further improvements of the national space economy.

The analysis has been carried out partly through an in-depth study of the actual structure of the Australian space economy, with particular focus on the state of South Australia. We aimed to provide a detailed list of the enabling factors which investments in the region will be able to benefit from. We integrated this information with the results of a survey sent to 32 companies operating in the space sector in South Australia, information from online sources (LinkedIn and the companies' official websites) and with local industrial knowledge.

Chapter 1 provides an overview of the global space activity. After defining the problems related to the difficulty of providing a clear and exact definition of the space economy, the growing importance of the commercial applications of space technologies is examined. Space-based services are applied to various commercial activities and the technological advances in the space industry has made space technologies accessible not only to large businesses and governments, but also to developing countries, small companies and enterprises. Today, satellite data can contribute to a wide range of societal and economic benefits and they provide an essential support in achieving some of the biggest challenges of modern societies.

Chapter 2 represents the heart of this report. After describing the position of Australia in the space economy, its policy framework and its dependence on space, it depicts how South Australia has built on its position in the space sector. The chapter provides a detailed analysis of what made South Australia an ideal location to invest in space related activities. In particular, leading-edge education in the field of technologies and sciences and strong government support to foster the local space economy and business innovation were identified as crucial enabling factors in the rise of a dynamic and growing space industry in the region.

Finally, in *Chapter 3* the space economy of Germany is analysed, and how the German experience can be related to Australia is discussed. The chapter aims to present some interesting food for thought as to how Australia can advance in space through the support to its small and medium size sector.

1 OVERVIEW OF THE GLOBAL SPACE ACTIVITY, PRODUCTS AND SERVICES.

1.1 Space Economy

"*Space economy is the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space*" [1].

As suggested by the definition above, the Space Economy is a broad topic, with boundaries that are difficult to identify clearly. The global space industry includes a large variety of sectors and firms, both public and private, and it is particularly difficult to determine an accurate definition of its limits. The complexity of providing an accurate definition has risen in the past few decades, as space systems started to play an increasing role in the functioning of modern societies, their economic development and their strategies. As scientific and technological innovations are becoming more accessible, they are also leading the way to social and economic growth. In fact, space technologies are not simply used to explore and investigate *space*, but they are also becoming crucial assets of the *economic* growth of countries. Today, space applications are commonly used by public administration offices and private firms to improve decision making processes, assess the costs and benefits of their operations, access more and better quality information and optimize their crisis response. Thus, space technologies are becoming an increasingly important part of everyday life. For example, if we start to think about the theoretical implications of living in a world without satellites, we would notice that weather forecasting, air traffic control, global communications and broadcasting, and many other essential activities would completely disappear.

Although an increasing number of countries are developing space applications, there does not exist an internationally agreed definition of the exact compilation of the space sector. In broad terms, the space economy can be defined as: *the full range of activities and the use of resources that create value and benefits to human beings in the course of exploring, researching, understanding, managing, and utilizing space*[2]. These benefits are today larger than in the past and they involve a broad range of sectors. In fact, over the last 50 years we have witnessed a growth in the application of space-based services in various commercial activities. Thus, the space economy is wider than the traditional space sector (e.g. rockets and launchers) and it involves an increasing number of new services and product providers (e.g. geographic

[1] Space Safety magazine, (2014). *Space Economy*. Retrieved from: http://www.spacesafetymagazine.com/space-on-earth/space-economy/.
[2] Space Safety magazine, (2014). *Space Economy*. Retrieved from: http://www.spacesafetymagazine.com/space-on-earth/space-economy/.

information systems developers, navigation equipment sellers) who are applying space systems' technologies to create new services and products.

Recent estimates indicate that the global space industry increased from $323 billion[3] in 2015 to $329 billion[3] in 2016. The revenues from commercial sectors represent slightly more than three quarters of all global economic activity in space. Commercial space products and services, which includes satellite communications and Earth observation, constituted the largest sector at $126.62 billion[3] in 2016, essentially unchanged from the year before. Commercial infrastructure and support industries, including the manufacture of spacecraft, as well as launch services and insurance, totalled $126.26 billion[3] in 2016, representing a 5.3% increase. Global government space budgets declined by 0.3% in 2016, as spending totalled $76.43 billion[3].

Traditionally, the space industry can be divided into two main categories: the upstream and the downstream sectors. The **upstream sector** is comprised of the companies responsible for the design and assembly of spacecraft destined to be sent into space and for the purpose of space exploration. On the other hand, the **downstream sector** utilizes the research and technology from upstream products to a range of different applications. The former comprises manufacturing of satellites, parts, subsystems, launch vehicles while the latter relates to services based on satellites, such as broadcast services and satellite communications. The companies involved in the downstream sector are not traditionally part of the space community, as they only use space signals and data in space-related products and services. Therefore, the downstream sector forms as a consequence of the products and services flowing from the upstream sector.

In 2013, the OECD categorises the space economy into *three main segments*: consumer services, space manufacturing and services from satellites operators. The first of these categories belongs to the downstream sector, while the latter two are part of the upstream sector.

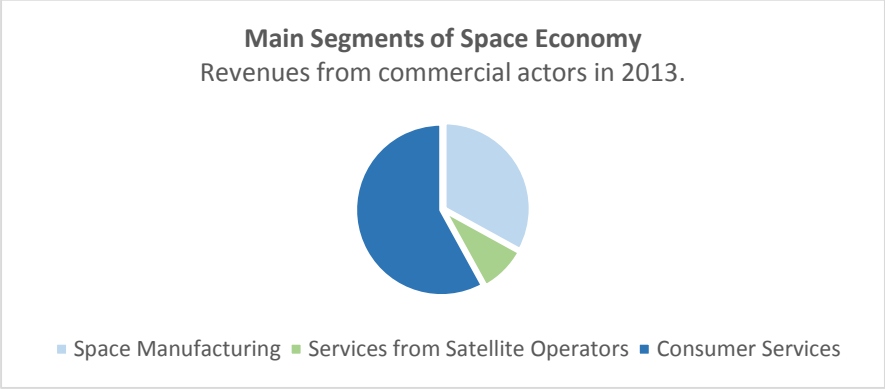

Figure 1.1: "Main Segments of Space Economy"[4].

The biggest share is represented by the **consumer services**' segment, which accounts for more than half of the total. This segment has been derived from governmental driven research and development.

[3] Space Foundation (2017). The Space Report 2017, *The Authoritative Guide to Global Space Activity.*
[4] *Source:* OECD, (2014). *The Space Economy at Glance 2014.* OECD Publishing, Paris.

Consumer services include participants, usually outside the space community, who rely on space applications to provide part of their products and services to the final consumers. These downstream activities are an integral part of the space economy, although their share is the most difficult to assess.

Space manufacturing, with a 34 per cent share, is the second most important segment of the space economy. The manufacturing segment refers to the supply chain and it is composed of prime companies that design and produce complete spacecraft system. These companies are categorised as follows:

- **Prime** companies, responsible for the design and assembly of complete spacecraft systems.
- "**Tier 1**" companies, responsible for the design, assembly and manufacture of major subsystems, such as satellite structures, propulsion subsystems, payloads.
- "**Tier 2**" are manufacturers of equipment to be assembled in major sub-systems.
- "**Tier 3** and **Tier 4**" include producers of components and sub-assemblies, specializing in the production of specific electronic, electrical and electromechanical components and materials.

The space manufacturing supply chain includes a broad range of clients: government, research centres, space agencies, international organizations and private companies. These participants engage prime suppliers to develop spacecraft, satellites and launchers for commercial and scientific use. Depending on the country, the government demand may be much more important in terms of revenue generation, compared to commercial demand. The customers of the space industry are also the final consumers that of space-related products and services from the downstream companies.

The remaining 8% is represented by **satellite operators**, mainly providers of telecommunications, fixed and mobile satellite services, satellite radio services, and remote sensing. Consumer services include participants, usually outside of the space community, who rely on some satellite capacity for part of their revenues. They encompass direct-to-home satellite television service providers, satellite navigation consumer equipment and value-added services. These are important participants, as they service public and private customers who operate outside of the space sector (e.g. providing bandwidth, imagery), so they tend to encourage innovation by space manufacturing suppliers to respond to market needs by lowering costs (e.g. development of broadband via satellite).

1.2 From Exploration to Exploitation

The first era of space, Space 1.0, was represented by the early study of astronomy. After that, space activities started to be developed primarily for strategic and military purposes, instead of for economic or societal gains. This was the second era of space, when nations were engaging in space races and that led to the first moon landings. Over time this perspective has slowly changed with the growing application of space-based services to various commercial activities. The technological advances in the space industry have led to what have been called a *democratization of space*[5], meaning that technologies once reserved solely for large businesses and governments, are today much more accessible to developing countries and small start-up enterprises. The availability of smaller and less expensive satellites paved the way for more

[5] Dave Baiocchi, William Welser IV (2015). *The Democratization of Space*. Foreign Affairs Magazine.

and more companies to use them to create a growing number of space-based products and information for their activities. As space started to be conceived as a market opportunity and to manifest its potential on sectors not strictly related to space, investment in order to exploit the new space-related technologies increased. The national space agencies and the ESA encouraged investments in the space-economy by entities willing to exploit the commercial use of the space applications. As societies started to evolve into massive consumers of space-dependent goods and services, it was also clear that space activities were gaining a new role in modern societies, and they were evolving from simply being a fascinating field of research into a source of economic and societal benefits. This is the third era of space, characterized by the economic exploitation of space technologies. Space 4.0 represents the latest improvement and it is characterized by the interaction between government, private sector, society and politics, so that space becomes fully integrated into society and economy. It can be used as a tool to tackle global challenges such as climate change, demographic development, migration, shortage of resources, conflicts and catastrophes, energy, digital divide, health and curiosity[6].

1.2.1 The downstream sector

Satellites have strategic as well as economic value. Around 940 satellites are currently operating in orbit, with more than two-thirds being communication satellites[5]. Satellites are at the centre of three critical space-based technologies for the economic, societal and strategic well-being, specifically: Earth Observation from Space (EOS), Satellite Communications (SATCOMM) and Position, Navigation and Timing (PNT)[7].

- *Earth observation from space* is defined as the gathering of information about the planet where we live via remote sensing technologies supplemented by the efforts of analysts and service providers who create tailored products to meet specific needs.
- *Satellite Communication* refers to an artificial satellite that relays radio telecommunications signal via a transponder that creates a communication channel between a source transmitter and a receiver at different locations on Earth.
- *Positioning, navigation and timing* is a combination of three different capabilities used in conjunction with map data and other information, producing the Global Positioning System (GPS) technology used so widely today.

Space products and services can have a strong and positive impact on environmental monitoring, agriculture, meteorology, and communications. For example, remote sensing is useful in monitoring the shoreline changes and mapping coastal features. EO imageries can be used to track natural disasters, to provide efficient and effective responses to minimize damage and in most cases it is the only means we have to effectively monitor land use and chart wildlife habitats. Remote sensing has been also successfully used for mapping soil properties and monitoring crop growth conditions. The Global Information and Early Warning System (GIEWS) of the Food and Agriculture Organization of the United Nations (FAO), monitors

[6] ESA, 2016. *Ministerial Council 2016*. Retrieved from: http://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0.

[7] Australian Government, The Department of Industry, Innovation, Science, Research and Tertiary Education, (2013). *Australia's Satellites Utilization Policy.*

food supply and provides timely warnings of imminent food shortages, droughts, and hunger at individual country or sub-regional level[8] on the basis of the information received from satellites. Another useful application of space technologies is in the field of weather forecasting. Meteorologists throughout the world use the Global Positioning System (GPS) to derive information on the state of the atmosphere. The improvements in GPS technology over the past few decades offer system users the ability to *navigate* precisely, determine the *exact position* of objects on the Earth surface and to synchronize operational systems for unprecedented efficiency. In other cases, space products have been shown to be useful in providing means of monitoring vehicle emissions and the overall level of air pollution. For example, satellite data has been used to investigate changes in the nitrogen dioxide (NO_2) and to infer ground-level NO_2 emissions over Shanghai[9]. Without satellites it would not be possible to provide communication capabilities to remote areas of the Earth, or to ships, airplanes and other mobile vehicles. Satellite communications are also important for providing services in urban regions, bringing connectivity to consumers and to networks of machines.

Therefore, it is clear that satellite data can contribute to a wide range of *societal and economic benefits*. High quality data is crucial to driving greater organizational success in support of fact-based decisions. Satellite data are complete, accurate, valid, consistent and timely and therefore governments and companies can improve their organizational processes through informed, satellite-driven decisions. In other worlds, space technologies provide us with the tools to address key global challenges. One of the best ways to assess the importance of satellite data in people's life is to measure their impact on the Millennium Development Goals (MDGs) set by the United Nations in 2000 and that are supposed to be achieved by 2030.

The Millennium Development Goals for the World Community are[10]:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equity and empower women
4. Reduce childhood mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases.
7. Ensure environmental sustainability
8. Develop global partnership of development

Space technologies have a clear impact on each one of these goals.

[8] Oscar Rojas (2014). *Earth Observation for Monitoring Agriculture – FAO's Global Information and Early Warning System* (GIEWS), 20th WORLD CONGRESS OF SOIL SCIENCE.

[9] Zheng, Qianjin, (2017). *Investigation of NO2 Air Pollution over Shanghai, China, Using Satellite Remote Sensing and Ground-Level Observation*, Texas A&M University

[10] *"United Nations Millennium Development Goals". Retrieved from:* https://www.un.org/millenniumgoals/poverty.shtml

Figure 1.2: Millennium Development goals, United Nations.

1. *Eradicate Extreme Poverty and Hunger*

Satellite data can improve agriculture and help countries to meet their food needs. They can provide an effective tool to reduce famine and help small farmers all over the world to access precious information about their crops.

2. *Achieve Universal Primary Education*

Governments in low and middle-income countries trying to determine the literacy rates of their population can obtain this information by using satellite imageries to identify correlations between geospatial elements and well-being outcomes. In this way, policymakers can measure the size of illiteracy and implement policies to reduce it accordingly.

3. *Promote Gender equity and Empowerment Women*

Some of the most innovative applications of space technologies involve the adoption of satellites to close gender data gaps, promote expanded and unbiased gender data collection, and use gender data to improve policies, strategies, and decision-making. The previous point explained a way to obtain information from satellites in order to determine the literacy rates. In this way researchers can also map the literacy rate for women across the entire country and policymakers can implement policies to reduce the gap.

4. *Reduce Childhood Mortality*

One of the main reasons of the high rate of child mortality in the less developed countries is the lack of food. The improvements in agriculture can assist to overcome this problem, by making the production of food processes more efficient. In addition, the interested areas can be easily monitored using space imageries, making intervention more timely.

5. *Improve Maternal health*

Data related to the Earth's surface can be used for public health purposes. Space agencies have a long history of collaboration with public health agencies. One public health application of space technologies is telemedicine or tele-health, which can be used in remote locations and can link health experts with other health professionals or patients anywhere in the world via satellite communications. Also, devices

developed for space missions, such as the robotic arm that was used to assemble the international space station, have been adapted into a smaller robotic device for use in surgery.

An interesting application of space technologies that targets mothers is *Inmarsat - Nigeria Maternal Health Pilot Programme.* In Nigeria, Inmarsat is partnering with MAMA to deliver maternal and child health services to 50 remote, rural communities. Called The MAMA Connect Project, the onsite system is pre-loaded with a MAMA's evidence-based, culturally-sensitive health information. The satellite network updates the content and provides real-time connectivity for pregnant and new mothers to interact online.

6. *Combat HIV/AIDS, malaria and other diseases*

Enabling innovation and access to health technologies remains a key strategy in combating infectious diseases in low and middle-income countries. An unfortunate side-effect of increased, faster, and cheaper travel worldwide is the very much increased speed with which epidemics spread across distant parts of the Earth. This requires increased and effective vigilance supported by accurate, continuous, and speedy collection and processing of data across the globe. Space assets, infrastructures, and expertise, in particular, Earth observation, ground-positioning, and communication satellites and associated applications, are becoming key tools towards strengthening preparedness, improving surveillance, and providing effective early-warning.

7. *Ensure Environmental Sustainability*

Remote sensing is useful in monitoring the shoreline changes, track sediment transport and map coastal features. Thus, the data provided by satellites can be used to prevent coastal erosion and to map the state of the coasts. At the same time, remote sensing has been shown to be useful in monitoring ocean circulation, measuring ocean temperature and wave heights, and tracking the level of ice in oceans. These data are very useful to understand how to best manage ocean resources and understand how they change over time. Earth observation is also fundamental in tracking natural disasters, such as: hurricanes, earthquakes, erosions, and flooding. Satellite data can be used to assess the impacts of a natural disaster and respond in the most efficient and effective way to minimize the damage. Finally, remote sensing is in most of the cases the only means we have to effectively monitor land use and chart wildlife habitats. The information provided by satellites can be used to minimize the negative impact that urban growth has on the environment, and help to adopt the best strategy to protect Earth's natural resources.

8. *Develop Global Partnership of Development*

Collaboration among different countries is crucial to achieve the MDGs. Data and infrastructures should be shared in order to save time and to better exploit all the advantages of the terrestrial applications of space.

2 THE SPACE SECTOR IN AUSTRALIA

2.1 The Importance of the Space Economy for Australia

"Our public and private sectors are fundamentally dependent on EO which is entirely provided by other countries. These data and services are recognised as essential to our public and private infrastructure with numerous national reviews showing that Australian governments and industry are critically dependent on EO to maintain our economy and societal wellbeing "[11].

Australia relies on space-related technologies for a wide variety of activities and they are used in virtually every sector of the economy. As already explained in the previous chapter, sizing the space economy is difficult. Attempts to measure the size of the sector have been made in the past. Some analyses have focused on the output of the Australian space industry, which is estimated to be in the range of $3–4 billion, with export revenues constituting roughly 8 per cent of this figure, and between 9500–11 500 fulltime equivalent staff[12]. It is worth noting that, at present, the Australian space sector is considered to be underdeveloped, and it represents a clear case of unfulfilled potential. In fact, the space industry in Australia contributes for approximately only 0.8 per cent to the global space economy, while Australia's share of the overall world economy is 1.8 per cent[12].

In the past, the Australian Government has been taking its first steps toward the recognition of the importance of space services on which the nation relies, and the growing importance they will have in the future. In 2013, the Government started to develop a coordinated space policy, with the release of the *Australia's Satellite Utilization Policy*. The document refers to all the space capabilities, such as the operation of orbiting satellites and their networks, as well as the ground systems and expertise used to access the data emitted from satellites for the benefit of users, that the nation uses. The policy is a clear consequence of the growing interest of the Government in the topic of the space economy, and it shows a new awareness of the strategic and economic importance of the satellite services' industry.

The policy offers 7 principles[13] that the government will use to ensure continuing and affordable access to space capabilities:

1. *Focus on space applications of national significance*
2. *Assure access to space capability*
3. *Strengthen and increase international cooperation*

[11] Space Industry Association of Australia, (2017). *SIAA White Paper: Advancing Australia in Space*.
[12] Australian Government, The Department of Industry, Innovation, Science, Research and Tertiary Education, (2017). *Review of Australia's Space Industry Capability. Issues paper – August 2017.*
[13] Australian Government, The Department of Industry, Innovation, Science, Research and Tertiary Education, (2013). *Australia's Satellites Utilization Policy.*

4. *Contribute to a stable space environment*
5. *Improve domestic coordination*
6. *Support innovation, science and skills development*
7. *Enhance and protect national security and economic wellbeing*

Achieving these goals will contribute to five key benefits for Australia[14]:

- *Improved Productivity*: space capabilities such as satellite imagery and high accuracy positioning deliver information that brings about greater efficiencies and encourages innovation.
- *Better Environmental Management*: satellite information enables effective environmental management across Australia's extensive and often inaccessible land and ocean territory.
- *A Safe and Secure Australia:* space capabilities are important contributors to national security, law enforcement and to the safety of all Australians in disasters.
- *A Smarter Workforce:* space capabilities help to transform existing industries and build new ones that provide quality jobs.
- *Equity of Access to Information and Services:* satellite communications enable high-speed, universal access to TV broadcasting, internet and telephone services.

Australia itself recognizes that the obstacles to increase Australian involvement in space activities are not technical and that, given sufficient investment, Australia could achieve capability of excellence[14]. As a consequence of this view, in July 2017 the Australian government has established an Expert Review Group to review the Australia's space industry capability and in September 2017 the Government announced the establishment of an Australian Space Agency, which is likely to commence operating in July 2018.

2.1.1 Building an Australian Space Agency

Since the downstream space sector is fundamental for the Australian community and its importance will increase over the years, it is assumed that data from space satellites will continue to play a key role. Attempts have been made in the past to boost the space industry. For example, in 2017, the Australian Government announced the $100 million Advanced Manufacturing Fund which will support the manufacturing sector to move to other high technology advanced manufacturing areas. In fact, the production of sophisticated space components represents a new market opportunity that could assist in the revival of the manufacturing industry in Australia. The aim of the new fund is to boost innovation, skills and employment, and support Australian businesses to improve their performances on the global stage.

The creation of an internationally recognized and permanent institution will play a key role in the development of the space sector in Australia. The Agency will be responsible for setting and administering civil space legislation and rules, to provide policy advice to the government and to formulate a national strategy to fully exploit the potential of the Australian space industry.

[14] Australian Government, The Department of Industry, Innovation, Science, Research and Tertiary Education, (2013). *Australia's Satellites Utilization Policy*

2.2 Investing in the Space Sector in Australia

The are many drivers for the Australian Government commitment to the development of the space sector in Australia. Space capabilities are already playing an important role in the country, enabling communications, emergency management, weather forecasting, banking, transport, environmental management and national security. Their importance is bound to increase even more in the future, as it has been already explained how the space industry is emerging as one of the fastest-growing sectors of the global economy.

The list below provides some of the main reasons why an active role in the space economy is desirable:

- *Reduce dependency from other countries' satellite data*: As already noted by other authors[15], every sector of the Australian industry relies, more or less directly, on space technologies in order to perform their business. Currently, however, with the exception of domestic telecommunications services, the data on which downstream space technologies are based are entirely provided by satellites owned by other countries. Becoming more autonomous would have a direct and positive impact not only on the companies that are dependent on space technologies but also on safety and security. In fact, national security is increasingly reliant on space capabilities, which contribute in detection of illegal immigration, preventing cross-border organised crime and fighting piracy.
- *Unique geographic features*: This reason refers to two different geographic features of the Australian territory. First of all, it refers to the exploitation of a *geographic advantage*. From physics, we know that the closer the launch site is to the Equator, the heavier loads rockets can carry[16]. Therefore, the Northern Territory appears to be a particularly favourable location to launch satellites into space. In fact, the territory is currently negotiating a deal that could see Darwin becoming the first rocket-launching site in Australia. Secondly, it refers to the fact that Australia's *environmental responsibilities* extend to beyond the Australian land mass to its oceans and territories, including almost half of Antarctica. Space-related technologies appear to be the only available technology to control such a wide and remote land.
- *Source of High Quality Data*: Satellites can make Australian industries more productive and competitive by providing high quality data that is unobtainable in any other way. High quality data is crucial to driving greater organizational success because of the reliance on fact-based decisions. Satellite data are complete, accurate, valid, consistent and timely and therefore companies can improve their operational processes though informed, satellite data-driven decisions.
- *Improve Australians' quality of life*: in addition to being economically important, satellite data provide enormous societal benefits to the community and the environment. Remote sensing is useful in monitoring the shoreline changes, tracking sediment transport and mapping coastal features, and it has been shown to be useful in monitoring ocean circulation, measuring ocean temperature and wave heights, and tracking the level of ice in oceans. Satellite data can be used to assess the impacts of a natural disaster and in most of the cases the only means we have to

[15] Space Industry Association of Australia, (2017). *SIAA White Paper: Advancing Australia in Space*.
[16] Bin Li, (2017). *The Economic Reasons Why Australia Needs a Stronger Space Industry*. The Conversation.

effectively monitor land use and chart wildlife habitats. Satellites provide communications to remote areas of the Earth, to ships, airplanes and other mobile vehicles. They also provide services in urban regions, bringing connectivity to consumers and to networks of machines. In some circumstances, satellites are the only method of communication in cases available. Satellite phones are widely used by the emergency services. They also find uses at sea and in remote areas of the country. The improvements in GPS technology over the past few decades offer system users the ability to navigate precisely, determine the exact position of objects on the Earth surface and to synchronize operational systems for unprecedented efficiency.

2.3Investing in the Space Sector in South Australia

"South Australia is undergoing an economic transformation – moving away from traditional manufacturing towards high value-added, sophisticated activities that will transform our economy, generate new investment and create the jobs and industries of the future. Using advanced technologies and digital disruption will help to ensure an innovative, creative and prosperous economy for South Australia".[17]

South Australia offers many advantages as a place to do business - access to a skilled workforce, high quality infrastructure, available and affordable land, and a government that supports new businesses[18]. Out of all Australian states, South Australia leads the way on business investment and Adelaide has recently become one of the main innovation hotspots in Australia[19]. Investors feel confident to invest in South Australia, since the state holds a sustained AAA credit, which shows the stability and strength of the economy of the region. Overall, South Australia provides an ideal environment for investing in innovative businesses. Among such businesses an important role is played by the companies participating in the space industry, whose number and economic importance is growing year after year.

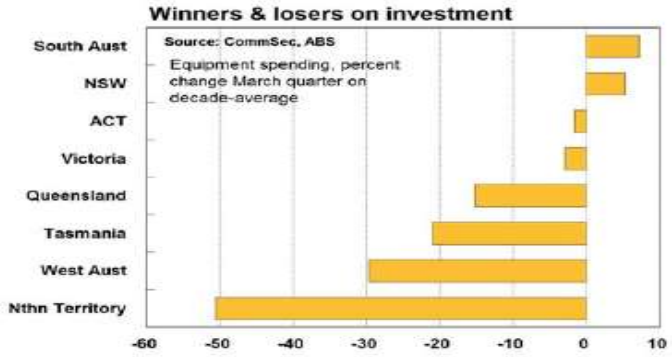

Figure 2.1: Business Investment, Australian States, 2017[20]

[17] Source: http://innovation.sa.gov.au/about/.
[18] Government of south Australia, (2016). South Australia. The place where people and business thrive.
[19] CommSec, (2017). *State of the states, Economic performance report*.
[20] CommSec, (2017). *State of the states, Economic performance report*.

There are numerous reasons why South Australia represents a good place to invest in the space industry. South Australia's strong knowledge-based economy and track record of innovation and commercialisation is backed by strong space science and technology research capabilities with the presence of leading universities, most notably the University of Adelaide, the University of South Australia and Flinders University. There are more than 60 organisations already working in the space sector in South Australia, many of whom are listed in the South Australian Space Capability Directory[21]. A number of these organisations are making impressive progress especially in the field of small satellites industry.

The new South Australian Space Industry Centre (SASIC) has been established to promote the space economy in South Australia. This Office was established with the goal of positioning South Australia as the national hub of space activity where entrepreneurs, universities and research centres are actively involved in developing a vibrant space innovation ecosystem. The Office has developed the Space Innovation and Growth Strategy (South Australia): Action Plan 2016-2020[22], which details the State's vision through three pillars:

- Grow South Australia's economy through space activity;
- Invigorate South Australia's space innovation ecosystem by stimulating capabilities and expertise in South Australia and strengthening the commercialisation of research results in the space industry;
- Engaging international cooperation with lead countries by growing a network of strategic partnerships in the space sector.

2.3.1 South Australia's Strengths

Investments directed to the region would benefit from the following enabling factors:

Expertise and Universities

South Australia can be considered as a hub of leading edge education. The University of Adelaide, Flinders University and the University of South Australia are consistently recognised for their academic excellence and they offer a unique opportunity for students to improve their expertise and succeed in their future careers.

The *University of Adelaide* is a member of the Group of Eight, a coalition of research-intensive universities in Australia. The University has a proud history of excellence in research and conducts research and innovation development in engineering and science, including: sensing systems, image and signal processing, software, robotic and communication systems, range safety, test and evaluation. The University has relevant research infrastructures and test capabilities through such areas as: The Institute for Photonics and Sensing (IPAS), the Adelaide radar Research centre, acoustic and vibration testing, wind tunnel and laser diagnostics. One of the research projects in the School of Computer Science of the

[21] South Australia Space Industry Centre (SASIC), (2017). South Australian Space Capability Directory.
[22] Defence SA, Space Industry and R&D collaborations, (2016). Space Innovation and Growth Strategy (South Australia) Action Plan 2016-2020.

university involves the study of machine learning. The Machine Learning Group[23] focuses on core machine learning theory as well as wide ranges of applications such as image understanding and text analysis.
Flinders University is a modern research-intensive university with key space-applicable capabilities in a wide variety of areas including materials science, nanotechnology, robotics, mechatronics, earth observation, science education and policy, geospatial sciences, space heritage, and medicine. Flinders is an institutional member of the International Astronautical Federation and the Space Industry of Australia. Flinders Centre for nanoscale Science and Technology researches and produces innovative materials and coatings with relevance to the space industry. The Centre scored a top ranking of 5 in the most recent Excellence in Research for Australia (ERA) assessment. A Flinders research group is studying the interaction between bacteria and mineral surfaces using advanced synchrotron Nano spectroscopic techniques. The University's Physics Group has a long tradition of innovative space physics research. Flinders also conducts innovative research in haptics and telecommunications that are space-capable and presents a flourishing internationally recognized school of Space Archaeology.

The *University of South Australia*'s Institute for Telecommunications Research (ITR) has more than 25 years' expertise in satellite communications applied to telecommunication services, earth observation, remote sensing and defence. ITR developed and operates ground station equipment and communication pay-loads on board satellites. Key expertise include: telecommunications, geospatial science, remote sensing, imaging and positioning, as well as planetary and space science. The University of South Australia has a planetary space science activity focusing on the observation and investigation of terrestrial planets in the solar system, using data from the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA).

The *Southern Hemisphere Space Studies Program* is conducted each year in Adelaide by the International Space University in partnership with the University of South Australia. The program is an intensive, five-week live-in experience in the southern hemisphere summer. The program provides an inter-disciplinary understanding of the following subjects: space science and exploration, space applications and services, human spaceflight and life sciences, space systems engineering and technologies, space policy and economics, space business and project management and space law and regulatory issues.

Other important centres of expertise are the *Mullard Space Science Laboratory* (MSSL) and the *Defence Science & Technology Groups.* MSSL undertakes a broad program of space related research across a broad range of science themes: astrophysics, planetary sciences, solar physics, space plasma physics and climate extremes. The group has participated in over 200 sounding rockets and over 40 satellites and space probes. Its world-leading science program is supported by extensive technology capabilities applicable to space research including cryogenics, detector physics, electronic engineering and manufacturing, imaging, mechanical and thermal engineering and manufacturing, software engineering and computing, optics, cleanliness and contamination control, quality assurance, project management, systems engineering and test and calibration. MSSL Australia has specific expertise in management of space instrumentation

[23] Source: https://cs.adelaide.edu.au/research/mlearn/.

projects, systems engineering and detector development. It develops concepts, designs and manufactures scientific instrumentation for scientific spacecraft from all the major space agencies.
The *Defence Science & Technology Group* provides research and development and science and technology advice to the Defence industry with respect to space-based capabilities across Earth observation, satellite communications, and national space-based position, navigation and timing (PNT), which play a crucial role in applied space research.

Manufacturing

Traditional manufacturing industries are following a downward trend in Australia. Nevertheless, the country possesses the skills and capacity to play a leading role in the high-tech manufacturing industry. The revival of the manufacturing industry, that is evolving into a more sophisticated and technology-advanced industry can act as enabler for the nascent South Australian space industry and sustain its development throughout the provision of complex pieces of machinery.

Space Infrastructures

In South Australia there is one of the largest and cleanest defence test ranges left in the free world. *The Woomera Range Complex* is an Australian Strategic national asset, located in the north-west pastoral region of South Australia, which principle capabilities include facilities for the launch of high-altitude sounding rockets. The complex could become a strategic asset for the development of the space industry by improving its launch capabilities and by rendering it compatible with the launch of satellites.

Industry presence

Some of the world's leading space companies, such as the British BAE Systems, our Speedcast, the American Lockheed Martin and Northrop Grumman, and the German Airbus Defence & Space are located in South Australia. These global players of the space sector represent an important source of investment and job creation. The American multinational Boeing has recently opened a new office in Adelaide's CBD and signed a partnership agreement with the South Australian Government. The company will support some of the largest and most complex defence projects in Australia and in 2017, Boeing Defence Australia have invested $7,000[24] in the Defence Honours Scholarship Program, to support higher level education in the South Australian region.
In addition to those global leaders, there is a copious group of small and medium size enterprises (SMEs) that plays an important role in the economic growth of the space sector. The majority of the South Australian companies that operate in the space industry belongs to the SMEs group. In fact, the new technologies reduce the importance of economies of scale and therefore the potential contribution of small enterprises is enhanced. This is also consistent with APAC's findings in its 2015[25] study where over the 50 per cent of the Australian space companies interviewed were identified as SMEs.

[24] *Boeing Grows Defence presence in South Australia* (2017). Article retrieved from: http://www.boeing.com.au/news/releases/2017/april/boeing-grows-defence-presence-in-south-australia.page.
[25] Asian Pacific Aerospace Consultants Pty Ltd, (2015). *A Selective Review of the Australian Space Capabilities: Growth Opportunities in Global Supply Chains and Space Enabled Services*.

Government Support

The Government have demonstrated a supportive approach to business, industry, young innovators, researchers, universities and investors by encouraging commercial activities in the space sectors. In September 2017, the *South Australian Space Industry Centre* (SASIC) was established, with the aim of fostering the local space economy and create future high-tech jobs. Other governmental bodies that provide expertise and capabilities to be used in the development of the space sector are: *The Department of Defence Capability, Acquisition and Sustainment Group* and *The Department of Environment, Water and Natural Resources*.

Particularly important for its financial support and the provision of expertise to the space industry, *The Investment Attraction South Australia* aims to capture foreign investment and to direct it to the most promising and value-adding industries in South Australia.

The governmental projects currently underway specifically to promote the space sector are:

- the *Space Innovation Fund*, that aims to enrich the South Australian Space Ecosystem with new start-ups and change the culture towards NewSpace 4.0;
- the *Cooperative Research Centre (CRC) For Innovative Space Solutions,* that aims to facilitate technological transfer from Research Organisations to Private Companies, including national and international stakeholders with a budget provided by Federal Government;
- the *Aerospace Innovation Complex*, that aims to provide facilities for launch testing and UAV testing, in conjunction with a consortium of start-ups.

The South Australian Government recognises that innovation drives economic growth. The main national funding opportunities for research and development in space as well as in high-tech sectors are:

- the *National Innovation and Science Agenda*, with almost $1.1 billion funding available in the next four years, representing an opportunity to promote business-based research, development and innovation and investing in STEM;
- the *Next Generation Technologies Fund* that provides for $730 million over the next decade to invest in strategic technologies, with space capability as one of the main priority areas;
- the new *Centre for Defence Industry Capability* that provides for $230 million over the next decade, including the Defence Innovation Portal that will facilitate engagement between Defence and innovation activities;
- the *Defence Innovation Hub* with $640 million available over the next decade to facilitate the engagement between industry and Defence sectors;
- the *Australian Research Council (ARC),* that funds research under the National Competitive Grants Program through its two main projects: Linkage and Discovery.

Additionally, there are State Government programs to encourage innovation:

- the new Premier's Research and Industry Fund Research Consortia Program in South Australia encourages collaboration between researchers and entrepreneurs, and investment in key science and research areas that have the potential to generate significant economic, social and/or environmental benefits for the state;
- the Innovation Voucher Program;

- South Australian Early Commercialisation Fund;
- South Australian Venture Capital Fund;
- Space Innovation Program (Scholarships, Incubator and accelerator initiative in Space);

These represent a pool of opportunities, particularly for the South Australian SMEs involved in the state's potential space and Defence industry cluster:

- the SA Export Partnership Program, which creates opportunities for the local space industry to be engaged internationally with new markets, increasing the export value of their products and services
- the Investment Attraction South Australia agency, which aims to encourage investment in South Australia.

Industrial Associations

In South Australia there is an important network of industry associations, which main scope is to promote the growth of the space industry. They identify and bring together companies with relevant capabilities within the space sector, they represent their interests and provide access to market opportunities. These associations are: The *American Institute of Aeronautics and Astronautics* (AIAA), the *Defence Teaming Centre* (DTC) and the *Space Industry Association of Australia.*

International Engagement

In terms of potential international partnerships in space SASIC has started to establish collaborations with some national space agencies, such as: CNES in France, ASI in Italy, DLR in Germany, KARI in Korea, JAXA in Japan, and NASA in the United States. SASIC will continue to foster international cooperation with lead countries, taking into account opportunities such as:

- the new Premier's Research and Industry Fund Research Consortia Program in South Australia along with national programs such as Cooperative Research Centres, Australia Research Council Industry Linkage Grants, the Australia-China Science and Research Fund, the Australia-India Strategic Research Fund, and the Australian Astronomical Observatory, that can all provide valuable support for international R&D collaboration;
- the SA Export Partnership Program, which creates opportunities for the local space industry to engage internationally with new markets and increase the export value of their products and services.

2.4 An Economic Analysis of the South Australian Space Activity

The scope of this analysis is the comprehension of the South Australian space activity and its growth potential. In particular, we aimed to measure the *size* of the workforce, its *growth rate* and its *contributions* to the Australian space sector.

A clear characteristic of the South Australian space economy is that it is a very dynamic industry in terms of business operations. The sector is subject to major transformations, with companies being sold, bought

or merged very frequently. We analysed 32 private companies that operate in South Australia[26] employing 460 full time equivalents (FTEs) in space-related jobs. More than two-thirds of space companies have been founded after 2000, and almost half have been founded only in the last five years. There has been an impressive growth rate in the sector. In fact, between 2000 and present the number of companies more than tripled, rising from just 9 in 1999 to 32 in 2017, with 9 new companies founded only in the last three years.

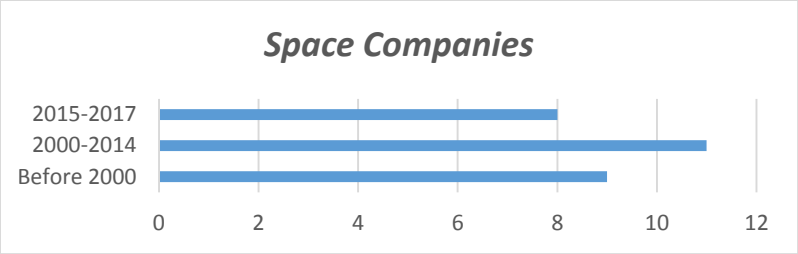

Figure 2.2: Space Companies in South Australia by Year of Foundation

We estimated that the companies considered in the analysis employ 462 FTE staff in space-related jobs, with 40% of these positions created only after 2000. When we include also the people employed by industrial associations, private consultancies, universities, research organizations, and government departments that operate in the space sector[27], the number increases to 794. This is a conservative estimate of the work force, since the companies included in the capability directory are not necessarily all of the South Australian space companies operating in the state.

According to the 2015 APAC study the Australian total workforce in the space sector has been estimated to be in the range of 9,500-11,500 employees[28]. If we think that only 7.15% of the Australian population lives in South Australia, and that almost 800 workers are employed in the space industry, it means that, on average, the state is contributing more than the others in terms of per capita space sector workforce. This result is particularly remarkable if we think that the South Australian space industry is relatively young and composed by enterprises that are still very small in size.

Finally, it is worth noting that it has been estimated that there are 11 space start-ups in South Australia[29]. At present, we know of only 34 space start-ups in the whole of Australia[30]. This means that a third of the Australian space start-ups are located in South Australia. This is an impressive result, that demonstrates how the South Australian space sector is a dynamic and fast-growing industry.

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[26] The analysis is based on the results of a questionnaire, that has been sent to 31 companies operating in the space sector in South Australia (*South Australian Space Companies Survey, 2017*), the information founded online (LinkedIn and the companies' official websites) and with local industrial knowledge.

[27] As listed in: South Australia Space Industry Centre (SASIC), (2017). South Australian Space Capability Directory.

[28] Asian Pacific Aerospace Consultants Pty Ltd, (2015). *A Selective Review of the Australian Space Capabilities: Growth Opportunities in Global Supply Chains and Space Enabled Services*

29 Jim Plouffe, (2017). South Australia looks for accelerators and incubators to support space industry startups. The Lead.

[30] Source: SIAA Australian Space Capability database.

Additionally, the companies have space capabilities in all the main space segments, of: *space systems*, *launch activities*, *ground systems*, *space enabled services* and *support services*. Only 15% of companies operate in all the business lines, while 30% of companies operate in four business lines and another 30% operate in two business lines. A smaller proportion of companies have operations in three business lines and a remaining 7% have operations in only one line.

Space Systems	Launch Activities	Ground Systems	Space Enabled Services	Support Services
20	12	18	22	9

Figure 2.3: Space segment served by the South Australian companies[31]

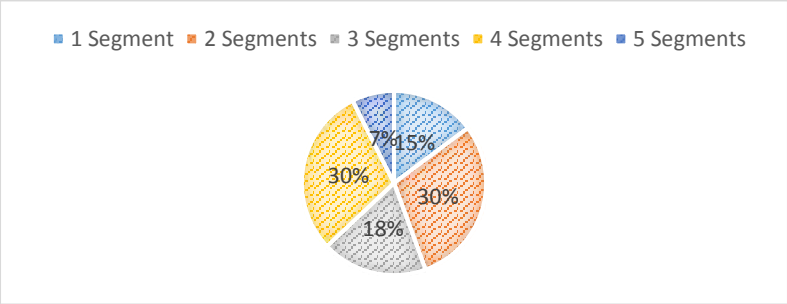

Figure 2.4: Level of diversification of the South Australian companies[32]

2.5 Forecasting the Downstream Space Market Size

Determining the space downstream market size is fundamental to understanding the current and future importance of the space industry in Australia.

The ideal customer is a public or private company that can benefit from space technologies. In the previous chapter, we have discussed about the broad range of social and economic benefits of space technologies, so that they can be applied in potentially every industry sector in the economy. In the following table there are some examples of applications of space technologies, which identify an ideal target consumer for each sector:

[31] South Australia Space Industry Centre (SASIC), (2017). South Australian Space Capability Directory.
[32] South Australia Space Industry Centre (SASIC), (2017). South Australian Space Capability Directory.

Sectors	*Application*
Agriculture	Increase production and profitability for farmers, agronomists and food manufacturers.
Mining	Location of tracks and inhabited areas exploration, location of potential access corridors, support of mineral exploration projects.
Electricity, Gas & Water Supply	Reduction of security issues for pipeline corridor planning, monitor electric transmission and vegetation intrusion.
Construction	Assessment of construction and engineering projects.
Education and Training	Implementation of distance education options thanks to technologies such as: videoconferencing and virtual classrooms.
Health Care and Social Assistance	Provision of health services and telemedicine over a distance.
Arts and Recreation Services	Delivery of television programming to viewers by relying on communication satellites orbiting the Earth.
Federal Government & Defence	Enhancement of security programs which can enable local governments to protect property, monitor its boarders and the movement of people.
Information Media & Telecommunications	Enable weather forecasting; essential communications-related businesses such as phone, TV and Internet service providers.

Table 2.1: Potential Customers

For each of the sectors identified above, the following table displays the number of companies operating in Australia for the years 2013 and 2016. These are all the target customers potentially in need of space technologies.

Sectors	***2013***	***2016***
Agriculture, Forestry and Fishing	187,691	177,012
Mining	8,340	7,915
Electricity, Gas & Water Supply	5,802	6,306
Construction	336,229	358,466
Accommodation & Food Services	81,694	90,284
Transport, Postal and Warehousing	126,117	133,093
Information Media & Telecommunications	18,671	20,024
Financial & Insurance Services	169,261	193,489
Rental, Hiring and Real Estate Services	226,615	240,509
Public Administration & Safety	7,345	7,288
Education & Training	25,923	28,399
Health Care & Social Assistance	107,812	123,416
Arts & Recreation Services	26,047	26,418
	1,327,547	1,412,619

Table2.2: Counts of Australian Businesses by Industry Division, years 2013-2016[33]

In theory, most companies for each one of the sectors mentioned above would benefit from buying space services. Nevertheless, in practice, few of them have the combination of financial resources and business practices required to make space services a worthwhile investment. This limits the penetration rate to large organizations, that we can consider to be less than 1%. However, this is still more than what a start-up can effectively pursue. The availability of smaller and less expensive satellites is paving the way for more and more companies to use in their business activities. As space started to be conceived as a market opportunity, with space technologies able to provide high quality data that can directly improve efficiency

[33] Source: Australian Bureaus of Statistics

in operations, investment to exploit them started to increase. Therefore, it is reasonable to assume that the share of target customers is bound to rise in the future, as more and more companies are becoming aware of the benefits of using space technologies in their everyday business. If we assume that the market penetration rate is 0.01% (quite conservative), the market size would be 14126 companies according to the following formula:

Domestic Market Size *(2016) = Number of target customer X penetration rate = 14126 X 0.01= 1412.6*

This means that there are more than 1400 Australian companies per year potentially interested in using space technologies to improve their services and products.

In this analysis, we have only considered the domestic market of space technologies. Companies that export their services overseas would face an even broader market. Considering how many different businesses are potentially in need of space technologies and that the amount of actual consumers that buy space technologies is bound to increase, as space products and services become cheaper and awareness on their benefits arises, it is reasonable to assume that the market size will increase in the future.

3 A COMPARISON BETWEEN THE GERMAN AND AUSTRALIAN SPACE SECTORS

3.1 The German Successful Experience in the Space Industry

"Both in Europe and world-wide, Germany has won a reputation as a reliable supplier of fine technology, and a welcome co-operation partner. For many years and in many fields, moreover, German space technology has been making essential contributions towards enhancing our standard of living, progress in science, and security in Germany and Europe. It has become an engine of our country's economic development and an important factor in promoting Germany as a business location"[34].

In the last decade, the status of the space activity in Germany greatly improved. The main reason of the shift toward a more developed space sector has to be linked to the substantial effort made by the Government to encourage the industry. The Federal Ministry of Economics and Technology has recognized that space is a key element to solve some of the most important global challenges[35]. Space technologies provide a set of tools that are essential to achieve social, economic and scientific development in modern societies and the German government took important actions to exploit their full potential. The latest government space strategy was published in 2010[35]. Since then, Germany committed to exploit the opportunities represented by space, achieving a number of significant successes. The government expenditure on space has constantly increased, and Germany continued to encourage the development of technological skills necessary for achieving a leading position in the space industry. Today, Germany can claim to have assumed a leading position in at least two fields connected with space technologies, that are: Earth observation and laser communications[35]. In 2006, space was the biggest single field in financial terms. Since then, the German space budget has constantly increased, showing the particular importance given to the space sector by the Federal Government. In 2016, Germany's spending on space activities totalled €1.43 billion, while the country's contribution to the European Space Agency (ESA) has been €872.6 million[36]. This means that Germany was among the countries with the highest space budgets, and its generous amount of funding to the ESA makes it the most important contributor.

The German industry is characterized by the production of high-technology components and systems, with a particular emphasis on satellite manufacturing. Some of the largest space companies, estimated at about 80 in number[37], are located all over the country. The majority is concentrated in Bavaria and Baden-Wuerttemberg in the South, and in Bremen in the north-west. Other than relying on a broad range of

[34] Retrieved from the German Aerospace Center space administration website: http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10002/
[35] Federal Ministry of Economics and Technology, (2010). *Making Germany's Space Sector Fit for the Future*.
[36] Space Foundation (2017). The Space Report 2017, *The Authoritative Guide to Global Space Activity*
[37] OECD (2014). *The Space Economy at Glance 2014*. OECD Publishing.

large companies active in the space sector, the participation of *small and medium size enterprises* (SMEs) is essential since they are crucial in the development of many downstream services and applications, with satellite navigation and Earth observation service industries that are mainly made up of SMEs and start-ups.

Most of Germany's business is conducted by small and medium-sized enterprises (SMEs), and the space sector makes no exception. These companies form the so-called *Mittlestand* and they can be seen as the engine of the German economy. It has been estimated that the German Mittelstand contributes to almost 52 per cent of GDP in Germany[38] and they are considered indispensable for growth, jobs and innovation in the country.

The Mittlestands can rely on a set of favourable elements. They are characterized by being:

- *family-owned*, with many SMEs directly managed by their owner. One key element of these small enterprises has to be found in the benevolent attitude of the companies' owners toward their employees, whom in turn feel particularly motivated to perform well in their jobs. Close relationships with the employees are made possible by the small size of the company, which allows for direct and more personal relationships among the employees, compared to big companies;
- able to develop *strong regional ties* and at the same time to maintain an *export oriented set of mind*. Their businesses abroad tend to prefer small companies, to specialize in one segment and to always keep an eye on quality;
- very *innovative,* especially for what concerns product, process and service innovation;
- incredibly *stable financially*, with the main source of investment being equity capital and own resources (54 per cent) and bank loans (29 per cent)[39]. The economic robustness and a cautious approach to expansion enable these companies to undertake medium-term and long-term investments, even in times of crisis.

3.1.1 Bremen

Bremen is the smallest federal state of Germany and it's the fifth-largest German industrial location. In the early 1980s the city of Bremen entered an economic crisis that was closely linked to the collapse of the city's largest employers: the shipbuilding companies[40]. After the crisis, the city underwent a process of economic transformation which lead the region to emerge as one of the leading technology locations in Germany. The strong focus on science and knowledge creation has been a decisive factor in the economic recovery of Bremen. The city demonstrated its capacity for innovation and a unique entrepreneurial spirit. Today, the region plays a leading role in particular in: maritime economy, wind energy, automotive and aerospace.

[38] Federal Ministry of Economic and Technology (BMWi), Public Relations Division, (2012). *German Mittlestand: Engine of the German Economy.*

[39] Germany Trade and Invest, (2013). Mittelstand in Germany: well-financed, innovative, export-oriented.

[40] Ploger Jorg, (2007). Bremen City Report. CASE reports, CASE report 39. Centre for Analysis of Social Exclusion, London School of Economics and Political Science, London, UK.

The process of economic restructuring included the development of the *Bremen Technology Park,* location of over 500 companies, with a workforce of around 7500 employees. The park is the site of centres of production technology, microsystems technology, material sciences, aerospace engineering, environmental research, information and telecommunications technologies and informatics.
Another important element of the reconstruction process has been the reform of the *university system,* with a strong focus on engineering and high-tech sciences. Bremen is home to leading research universities in Germany: The University of Applied Sciences (UAS) and the founded private International University Bremen (IUB). These universities prepare highly-skilled professionals and represent the scientific and expertise base of a growing sophisticated industry.

A highly efficient model for *cooperation* also ensures the region's success. The research institutes work in close collaboration with businesses and many of the products are the result of close cooperation between the business sector and scientific institutes. These are the German Research Centre for Artificial Intelligence, the German Aerospace Centre (DLR), the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, and the Centre of Applied Aerospace Technology and Microgravitation (ZARM).

At Bremen it seems that there is everything that a hub for the space industry needs. For many decades, the aerospace industry has enjoyed close links with Bremen, which is the second-largest German production and development location within the European Airbus family. In the region are located around 140 companies and 20 research institutes in aviation and space industries, which employee about 12.000 people[41]. The revenue of the aviation and space sector in 2016 was about 4 billion €. One of the city's particular strong points is mobile multimedia communications, with some 50 companies representing this central business area. It is not without good reason that Bremen was chosen as one of the Universal Mobile Telecommunications System (UMTS) pilot regions for Germany.

3.2 Similarities and Differences

The reason why the space economy of Germany has been analysed is due to the possibility of using Germany as an example of best practice for a successful space economy in Australia. Given that the scope of this report is the comprehension of the Australian space activity and its growth potential, the analysis of the differences between the German and Australian space sectors seems particularly useful. In fact, the German and Australian economies show important similarities. In both countries the majority of companies that constitute their economies are small and medium size enterprises (SMEs). Over 99 per cent of all companies belong to the small and medium size sector, which is more than in any other industrial nation. In addition to that, the two countries share similar business cultures. In fact, even if every system is unique in terms of approach to do business and to innovation and willingness to take risk, important similarities have been found between the Australian and German entrepreneurship culture[42].

[41] Information about the Bremen space economy is provided by the German Federal State Bremen Ministry of Economic Affairs, Labour and Ports Director Foreign Trade Promotion and International Affairs.

[42] Geert Hofstede is a Dutch social psychologist who conducted a pioneering study of cultures across modern nations. H. found out that the German and Australian Business Cultures are not that far from each other in most

On the other hand, the German model cannot be transferred 1:1 to Australia. The differences between these two social and economic environments cannot be ignored and they have to be taken into account when determining good practices for Australia, based on the German case. For example, Germany is incorporated in a triangular system which allows a division of responsibilities between National agencies, the European Space Agency (ESA) and the European Union. National Agencies promote and support national strategic goals, qualify national industries and scientific institutions for competition, prepare projects for the ESA and for the European Union programs. On the other hand, the ESA encourages cooperation among the European state members, implement the European space program and a range of activities that go beyond the scope of any single member. Most importantly, ESA highly contributes in terms of job generation in the European space sector. Finally, the European Union is responsible for flagship programs such as Galileo, global monitoring of environment and security. The cooperation of this three pillars is essential in shaping the German space policy.

By contrast, Australia cannot rely on the same degree of cooperation among space organizations. In addition to that, without considering the government, it cannot rely on an employer comparable in size and importance to the ESA. Collaborating through various programmes with ESA is an integral part of driving innovation and research in the European countries, and a considerable stimulus for the development of the space industry. Such stimulus could be replicated in a similar way in Australia only by establishing a national space agency. In fact, an internationally recognised and permanent institution would play a key role in the development of the space sector in Australia.

Finally, differences between Germany and Australia are also determined by a different level of government engagement in space activities. When measuring the government engagement, a first indicator to consider is the amount of laws and regulations relating to the exploration and use of outer space. As shown in the figure below, the legal frameworks of Australia and Germany looks rather dissimilar. In fact, the German legal framework appears to be more articulated and comprehensive.

Australia	Germany
• *Space Activities Act 1998* • *Space Activities Regulations 2001*	• *Law governing the transfer of responsibilities for space activities* • *Act to give Protection against the Security Risk to the Federal Republic of Germany by the Dissemination of High Grade Earth Remote Sensing Data* • *Law governing the transfer of administrative functions in the sector of outer space activities* • *Satellite Data Security Act*

Table 3.1: Laws and Regulations Related to the Exploration and Use of Outer Space[43]

dimensions. Within both Australian and German organizations hierarchy is established for convenience, but both managers and employees and employees expect to be consulted and information is shared frequently. The main differences concern the level of individualism, the relationship versus task focus business, and the level of indulgence.

[43] United Nations, Office for Outer Space Affairs (UNOOSA). National Space Law Collection. http://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/index.html

A second important difference relates to the space budgets of the two countries. In 2009 Germany's space budget was estimated to be around USD 1660 million, considerably higher than the Australian space budget, estimated to be only USD 5 million[44].

The detailed analysis of the region of Bremen, which is playing a leading role in the field of the space industry in Europe, is instead mostly motivated by the fact that the region's performance in the space sector can serve as an inspirational model for South Australia. The Bremen's space industry started to develop in the last 3 decades, offering a good case to analyse the potential of the South Australian space economy if it will continue to develop along a similar path. As a result of space-related expertise and industry, both regions have developed into important space centres. Another thing they have in common, is that they have been both directly involved in the International Astronautical Congress. The world's largest space conference has been held in Adelaide in 2017, while Bremen has been selected as the next location for the year 2018. In September 2017, these strong similarities stimulated the interest of the city of Bremen and the of the South Australian Government, represented by SASIC, to jointly sign a Letter of Intent to manifest the reciprocal interest in the implementation of collaborative activities in the areas of space research and development[45]. Collaborative efforts in the space sector between South Australia and Germany have been also demonstrated by a second Letter of Intent, also signed in September 2017, by SASIC and the German Aerospace Center (DLR)[46].

3.2.1 Australian and German SMEs compared

The space sectors of both Australia and Germany are dominated by small and medium size enterprises (SMEs). The new and more affordable space technologies reduce the importance of economies of scale in the space sector, and therefore the potential contribution of smaller firms is enhanced. On the other hand, the traditional difficulties faced by SMEs, mainly problems related to the access to financing, information infrastructure and international markets[47], often require government intervention. SMEs often have trouble obtaining financing because banks and traditional lending institutions are averse to risky ventures. In view of the SME role in the space sector, governments that support SMEs by promoting entrepreneurship, facilitating firm start-up and expansion, and improving access to venture capital and other types of financing, are also supporting the rising space industry.

In Germany, over 99 per cent of companies are SMEs. This is exactly the same proportion of SMEs that populate the Australian economy. Nevertheless, in Germany they make up a significantly higher share of employment and a higher contribution to GDP, as shown in the table below.

[44] OECD, (2011). The Space Economy at Glance 2011. OECD Publishing, Paris.

[45] *See Annex 1*: Letter of Intent for Cooperation in the Space Sector between the Free Hanseatic City of Bremen and The Government of South Australia Represented by South Australia Space Industry Centre.

[46] *See Annex 2*: Letter of Intent for Cooperation in the Space Sector between German Aerospace Center, DLR, and The Government of South Australia Represented by South Australia Space Industry Centre.

[47] OECD, (2000). Small and Medium-sized Enterprises: Local Strength, Global Reach. OECD Publishing, Paris.

	SMEs		
	Workforce	%GDP	Share
Germany[48]	61.30%	52	99.7%
	>	>	=
Australia[49]	45%	33	99.8%

Figure 3.1: Australian and German SMEs compared.

When compared to the German Mittlestand, Australia SME's sector is characterized by a much larger proportion of micro-enterprises, which explain the considerable difference in terms of workforce.

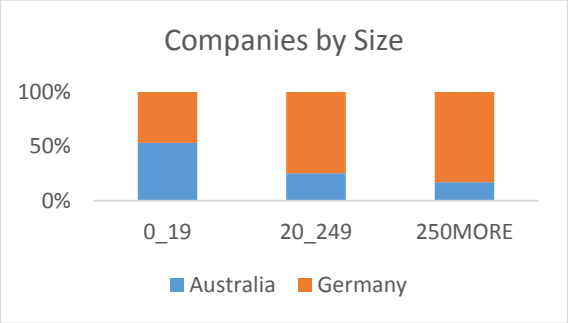

Figure 3.2: Company Size, year 2014[50].

In a OECD Policy brief[51] some crucial variables regarding SMEs have been analysed. They are:

1. *Participation in Global Markets*

The German Mittlestand enjoy a relatively strong position on foreign markets and they account for 19 per cent of total exports by German firms[52]. By contrast, in Australia, the contribution of SMEs to the total value of export is relatively small. In fact, it has been estimated that medium and small businesses account for only 4.9 per cent of total exports[53].

2. *Innovation*

As well as being strongly export focused, the German Mittelstand is also characterized by high levels of innovation. In order to maintain their competitive position, these small and medium size companies invest

[48] Source: Federal Ministry of Economic and Technology (BMWi), Public Relations Division, (2012). *German Mittlestand: Engine of the German Economy;* KfW, (2015). SME Investment and Innovation France, Germany, Italy and Spain.
[49] Source: The Australian Small Business and family Enterprises Ombudsman, (2016). Small Business Counts.
[50] Source: OECD Database.
[51] OECD, (2000). Small and Medium-sized Enterprises: Local Strength, Global Reach.
[52] Federal Ministry of Economic and Technology (BMWi), Public Relations Division, (2012). *German Mittlestand: Engine of the German Economy.*
[53] The Australian Small Business and family Enterprises Ombudsman, (2016). Small Business Counts.

strongly in research and development activities. It has been shown that 19 per cent of total innovation expenditure comes from the SMEs. Even if only 10 per cent of them invest in R&D, 26 per cent have been found to conduct innovative practices in their businesses[54].

To a certain extent, small businesses, start-ups in particular, are always innovative. However, the propensity to engage in innovative activities normally increases with size. In fact, large companies usually have more resources to invest in research projects. Medium sized companies have greater capacity to conduct innovation activities. The very high number of micro-enterprises in Australia is the main reason of the disparity in terms of innovation activities between Germany and Australia.

	Australia	Germany
Higher SMEs concentration	✓	✓
Reliance on an Extensive Network of space Organizations		✓
Higher Space Budget		✓
Higher Contribution to GDP		✓
Higher Share of Employment		✓
Higher Proportion of Small and Micro Enterprises	✓	
Higher Participation in Global Markets		✓

Figure 3.3: Similarities and differences between the German and Australian Space Sectors

3.2.2 The Role of SMEs in South Australia

SMEs are non-subsidiary independent firms, that employ a limited number of employees. In Australia, the upper limit for the medium companies is 200 employees, small businesses employ up to 20 employees and microbusinesses have between 1 and 4 employees[55]. These thresholds are not universally set, and the size of medium companies range between 200 and 500, depending on the country. The size is what most commonly describes SMEs, but sometimes financial definitions are also used to define them. Over 99 per cent of Australian companies are SMEs, which account for 45 per cent of total employment[56].

Almost half of the space companies considered in the analysis of the South Australian space sector, 48 per cent, are micro businesses (less than 10 employees). Medium and small enterprises account for almost half of the share, each of these categories contributing for an equal amount. Finally, the smallest share, 0.07 per cent, is represented by large companies.

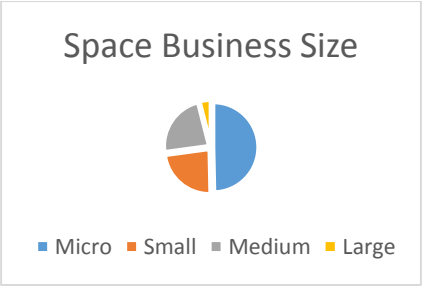

Figure 3.3: Space business size measured by employment, South Australia, 2017.

[54] KfW, (2015). SME Investment and Innovation France, Germany, Italy and Spain.
[55] Australian Bureau of Statistics, (2001). Small Businesses in Australia.
[56] The Australian Small Business and family Enterprises Ombudsman, (2016). Small Business Counts.

In Bremen, there are 20 space companies which employ around 2000 people in space-related jobs[57], while in South Australia there are 32 space companies, as reported in the Capability Directory[58]. Even if the number of companies is considerably higher than the companies operating in Bremen, they employ only 800 workers. Again, these remarkable difference has to be linked to the differences in the size of companies. Such disparity is mainly due to the fact that the South Australian space economy is younger than the Bremen's space industry, and therefore characterized by a high share of start-ups, that are still very small in size.

3.2.3 Spill Over Effects

Germany is a successful example among the space economies, and the country hosts a wide range of small and medium-sized companies that are extremely productive. Small companies constitute the backbone of the national space economy, both in Germany and in Australia. The great success experienced by Germany can provide useful insights for Australia and it can be considered as an example of best practice in the space sector. The importance of Germany as a comparison lies in the similar economic structure of the two countries, both based on SMEs enterprises.

SMEs are equally important in terms of share of businesses in Australia and in Germany. Overall, they contribute for a very high share of total companies, the highest among the developed countries. However, German companies employ more people and their contribution to the national GDP is higher. The main reason for these differences is attributed to different sizes of companies composing the SMEs sector. In fact, in Australia there is a considerably high number of micro-enterprises, for whom investing in innovation activities and becoming internationally focused is more difficult compared to medium size enterprises.

The space economy is a young sector of the Australian economy, and the majority of the companies composing it are still small and micro businesses. From our analysis, SMEs operating in the space sector in South Australia are already performing very well, and even above the global standards of SMEs, for several indicators. In fact, while it is sometimes believed that small and medium companies are incapable of penetrating foreign markets, and that smaller firms focused only on domestic markets, this does not seem to be the case for the SMEs operating in the space sector in South Australia. For example, some of the companies belonging to the micro size group already conduct operations overseas[59]. The date of foundation is not a good indicator of the company's activism in international market. In fact, the results of the survey show that while there are companies that started their operations several years ago and that are still selling their space services and products only to domestic clients, there are also younger businesses that have already started to export their products overseas. This means that these types of companies were born global, or, in other words, they started to export from the very beginning. With respect to innovation, the South Australian space companies of small and medium size that conduct R&D

[57] Information provided by German Federal State Bremen Ministry of Economic Affairs, Labour and Ports Director Foreign Trade Promotion and International Affairs.

[58] South Australia Space Industry Centre (SASIC), (2017). South Australian Space Capability Directory.

[59] South Australian Space Companies Survey, 2017.

activities are 31 per cent, in line with the proportion of German enterprises that innovative practices in their businesses.

However, the case of Germany provides some insights beneficial in terms of export and innovation. The problems affecting the SMEs sector of the Australian economy in general, have a spill over effect on the space sector in particular, and they may prevent the space industry in exploiting its full potential. Given that the SMEs operating in the space sector are already innovative and export oriented, an environment more conducive to economic growth for the small and medium size enterprises similar to Germany would provide an additional boost to the space economy.

CONCLUSIONS

The South Australian space industry is a fast-growing sector, currently employing almost 800 workers. Entrepreneurs deciding to establish their business in the State can benefit from a broad range of enabling factors, such as a leading university system in the field of technology and science-related subjects and strong government support. South Australia appears to be one of the most favourable environments to start a new business in the country, as shown by the fact that a third of the Australian space start-ups are located in the region. There has been an impressive growth rate of the space sector. In fact, between 2000 and present the number of private companies belonging to the space industry more than tripled, rising from only 9 in 1999 to 32 in 2017, with 9 new companies founded in the last 3 years.

South Australia has developed over time expertise and a skilled work force of considerable size. The performance of South Australia is impressive, especially considering the fact that the South Australian space sector is rather young and that the majority of companies are very small in size. On the other hand, the high proportion of young businesses and enterprises may in part explain the high level of innovation and creativity of the industry. The enabling factors underlined in this report suggest that in South Australia there is a high potential for the further development of the space industry. In particular, governmental support to small businesses to help them to grow in size and the establishment of a national space agency will be decisive inputs that have the potential to drive a booming South Australian space industry.

ANNEXES

ANNEX 1

Letter of Intent for Cooperation in the Space Sector between the Free Hanseatic City of Bremen and The Government of South Australia Represented by South Australia Space Industry Centre.

CONSIDERING, in particular, the friendly relationship between the Free Hanseatic City of Bremen and South Australia;
CONSIDERING that the global space sector has undergone significant evolution in technological development, knowledge dissemination and size in recent years;
CONSIDERING the reciprocal interest in the space industry and research collaboration; have come to the following understanding:

1. The purpose of this Letter of Intent (hereinafter also referred to as "LoI") is to develop a closer understanding and greater cooperation through the pursuit and promotion of joint activities in the areas of research and development, academic exchange and industry collaboration in the space sector;
2. The Sides have preliminarily identified the following areas for the implementation of the collaborative activities:

a) Promotion of cooperative relationships between academic and research institutions in Free Hanseatic City of Bremen and South Australia;
b) Identification of common goals with the view to developing a forward program of joint collaborative activities;
c) Facilitation of joint research projects and training activities in mutually agreed areas;
d) Support of the exchange among universities including expanding the professional competencies of early career graduates and researchers;
e) Promotion of the collaboration between startups, small and medium businesses enterprises in the space sector, up- and downstream products as well as applications with particular emphasis on cross-sector business cases, through the exchange of best practices, technology development, technology transfer and oriented mission;
f) Support of the involvement in commercial, trade fairs and conferences of the space community of both countries, with the goal of sustaining the volume of business and the quality of research.

3. By mutual agreement the Sides may identify projects to be conducted under the auspices of this LoI by means of separate project agreements that provide details concerning the specific commitments and obligations made by each Party
4. The Parties concur that this LoI does not constitute any commitment of resources of either Side or establish any legal relationship or legally enforceable rights between the

two Sides, and each Side will pursue the goals set out above on a best effort and good will basis using its own resources as opportune;

5. Each Side's rights, title and interests in its intellectual property and confidential information remains unaffected by the existence of this LoI;
6. Each Side will bear its own costs of and costs incidental to its negotiation, preparation and execution, including any costs incurred in relation to the negotiations that are contemplated by it.

This Letter of Intent will be reviewed by the Parties at least annually.

Signed in Adelaide, Australia, September 25th 2017.

ANNEX 2

Letter of Intent for Cooperation in the Space Sector between German Aerospace Center, DLR, and The Government of South Australia Represented by South Australia Space Industry Centre.

CONSIDERING, in particular, the friendly relationship between Germany and South Australia;
CONSIDERING that the global space sector has undergone significant evolution in technological development, knowledge dissemination and size in recent years;
CONSIDERING the reciprocal interest in the space industry and research collaboration;
Convene on the following:

3. The purpose of this Letter of Intent (hereinafter also referred to as "LoI") is to develop a closer understanding and greater cooperation through the pursuit and promotion of joint activities in the areas of research and development, academic exchange and industry collaboration in the space sector;
4. The Parties have preliminarily identified the following areas for the implementation of the collaborative activities:
   g) Promotion of cooperative relationships between academic and research institutions in Germany and South Australia;
   h) Identification of common goals with the view to developing a forward program of joint collaborative activities;
   i) Facilitation of joint research projects and training activities in mutually agreed areas;
   j) Support the exchange among universities including expanding the professional competencies of early career graduates and researchers;
   k) Promotion of the collaboration between small and medium businesses enterprises in the space sector through the exchange of best practices, technology development, technology transfer and oriented mission;
   l) Support the involvement in commercial, trade fairs and conferences of the space community of both countries, with the goal of sustaining the volume of business and the quality of research.
7. By mutual agreement the Parties may identify projects to be conducted under the auspices of this LoI by means of separate project agreements that provide details concerning the specific commitments and obligations made by each Party
8. The Parties agree that this LoI does not constitute any commitment of resources of either Party or establish any legal relationship or legally enforceable rights between the two Parties, and each Party will pursue the goals set out above on a best effort and good will basis using its own resources as opportune;
9. Each Party's rights, title and interests in its intellectual property and confidential information remains unaffected by the existence of this LoI;

10. Each Party will bear its own costs of and costs incidental to its negotiation, preparation and execution, including any costs incurred in relation to the negotiations that are contemplated by it.

This Letter of Intent will come into effect on signature of both Parties and, unless brought to an end earlier, will continue for a period of five years. It may be amended end extended at any time, by mutual written consent of the Parties. This Letter of Intent will be reviewed by the Parties at least annually and may be brought to an end by either Party at any time within the five-year period by giving at least six (6) months notice in writing to the other.

Signed in Adelaide, Australia, September 25th 2017.

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