

# INSIGHTS REPORT

Understanding the Challenges and  
Opportunities in Singapore's  
Space Ecosystem



October 2020



## Editor's Note

When OneWeb filed for bankruptcy earlier this year, it seemed like an omen for numerous space start-ups that were navigating COVID-19 but were low on cash. However, the effects were ultimately muted, with investments in some sectors even rising. This was, in part, due to government intervention at some level, be that through support packages, investments, or contracts. For an industry that is still largely intertwined with the government, viewing it from a policy perspective is necessary to see how it can be nurtured and grown.

When analysing and suggesting policies to solve issues that are inherent to your local context, it is necessary to know what are the issues that plague your local ecosystem. When we first started out with the expectations of writing a policy paper that would address some industry need, we came across a problem – we didn't know what challenges beset the industry. Based on our prior experiences and conversations with the industry, we had anecdotal evidence of certain issues. However, we weren't able to find a recent, relevant report that highlighted the major issues for us. Technically, there were reports that discussed problems within the American or European space ecosystem, but weren't transferrable to Singapore. Without knowing what issues challenged Singapore, how could we suggest effective policies? We couldn't.

As a result, we decided to create a report of our own to understand the local ecosystem better. We felt that this report should marshal honest opinions of the various stakeholders of the Singaporean space industry. With that aim, we managed to interview over two dozen stakeholders from different areas of the industry. We also felt that our personal biases and opinions should be separated from those of our interviewees and, therefore, we have opted to report on the insights that were shared to us without filters, resisting the temptation of adding our own thoughts on the feasibility or accuracy of the comments. Consequently, this report reflects the viewpoints of our interviewees. While some of that information may be subjective, we have chosen not to alter them (where appropriate) for the sake of personal objectivity. The report also contains some preliminary information on the global space industry as a whole but that isn't the purpose of this report (feel free to skip ahead if you're familiar with the space industry). It is also not the purpose of this report to provide its readers with a substantial amount of quantitative data on the Singaporean space industry.

*The true purpose of this Insights Report is to inform local (and foreign) stakeholders about how the space ecosystem is viewed from different perspectives within the industry.* Through that we not only hope to bring to light the challenges faced by the different stakeholders, but also the opportunities they foresee. Ultimately, the *Insights Report* hopes to provide insights to policy makers, entrepreneurs, business leaders, investors, academics, students, and anyone else who can derive value from it. Similar to how geospatial information gathered by Earth observation satellites can be utilized for more meaningful purposes, we too are providing the synthesized information that can, hopefully, be well utilized to make Singapore's space ecosystem more vibrant and successful.

**Arka Ray**

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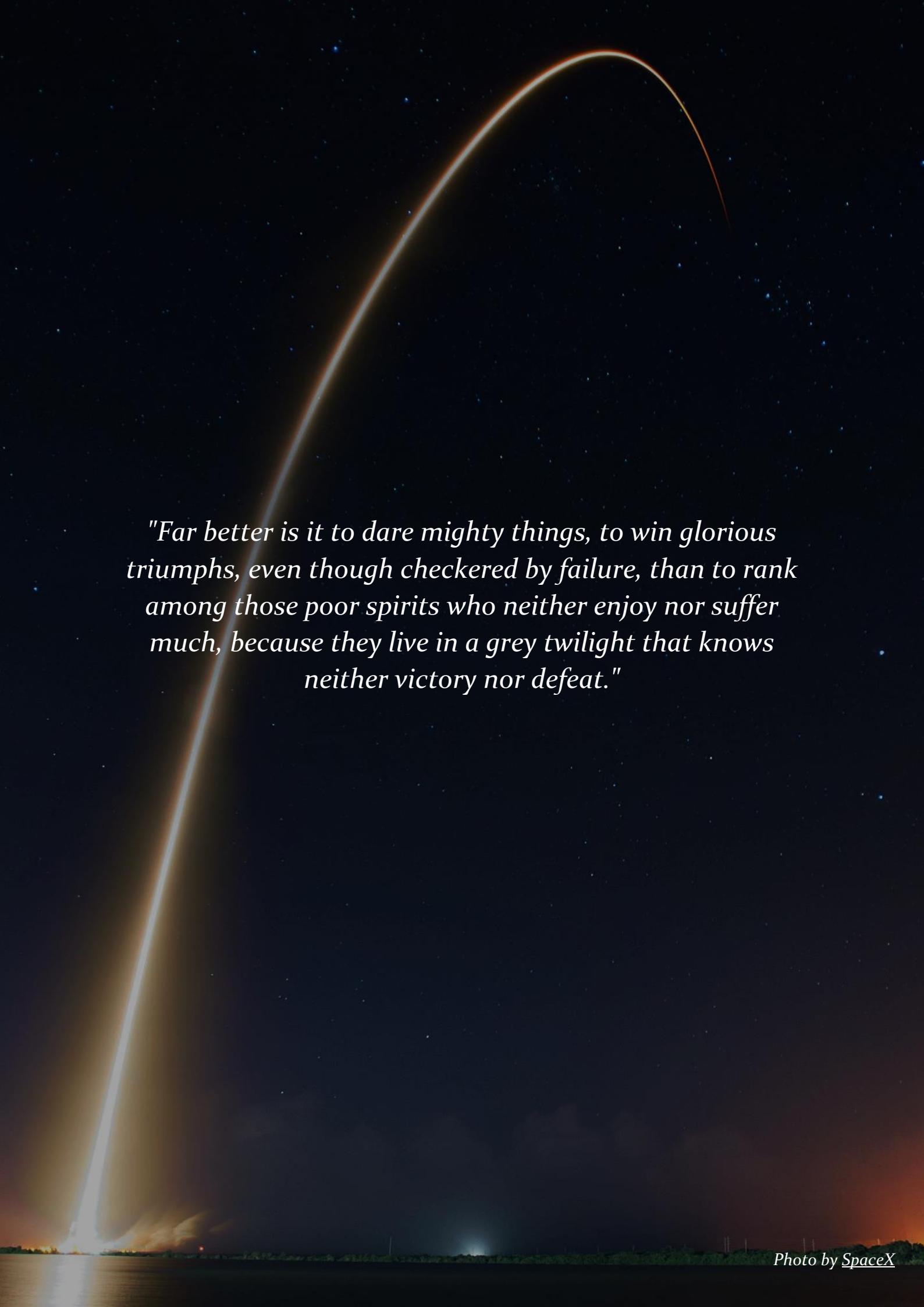
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## Glossary of Abbreviations

IoT	Internet-of-Things	NTU	Nanyang Technological University
IP	Intellectual property	SSTL	Singapore Space and Technology Ltd
R&D	Research and development	GNSS	Global Navigation Satellite System
ITU	International Telecommunication Union	NASA	National Aeronautics and Space Administration
IMDA	Infocomm Media Development Authority	CNSA	China National Space Administration
GLC	Government-linked corporation	ESA	European Space Agency
NRF	National Research Foundation	JAXA	Japan Aerospace Exploration Agency
MOE	Ministry of Education	ISRO	Indian Space Research Organisation
OSTIn	Office for Space Technology and Industry	OECD	Organisation for Economic Co-operation and Development
VC	Venture Capital / Venture Capitalist	UNOOSA	United Nations Office for Outer Space Affairs
EDB	Economic Development Board	COPUOS	Committee on the Peaceful Uses of Outer Space
NUS	National University of Singapore	AI	Artificial Intelligence
MAIT	Manufacturing, Assembly, Integration, and Testing		

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*"Far better is it to dare mighty things, to win glorious triumphs, even though checkered by failure, than to rank among those poor spirits who neither enjoy nor suffer much, because they live in a grey twilight that knows neither victory nor defeat."*

## Our Approach

In writing the *Insights Report*, the team had to carry out numerous forms of data collection, compiling, and review. This not only provided the team with an in-depth assessment and understanding of the industry, but also helped them formulate and facilitate the stakeholder interviews in the later stages of the projects.

While the team thoroughly researched both the global and local aspects of the space ecosystem, and conducted further research for clarifications beyond the interview stage, not all the background research has been included in this report. That is by design. The true purpose of this report is not to serve as a primer or an overview on the global space ecosystem, nor is it to provide industry data, like revenue or funding rates, on local companies. The real purpose of this report is to inform readers of the varying opportunities and challenges present within the industry, from the perspective of stakeholders themselves. This report is a grassroots approach to understanding the underlying issues so that relevant bodies can try to address them.

A brief description of the two key parts of the report are described below:

**Global Overview** – In this half of the report, we present the context in which we're operating globally. Feel free to skip ahead if you have a basic understanding of the global space industry.

- This section covers an introduction to the space economy, our roles within it, the different industries of interest, the main players, and the space community at large.
- The research for this section was almost completely based on frameworks which were heavily focused on desk-research followed by internal discussions.

**Local Insights** – In this half of the report, we discuss the findings based on our interviews with 28 organisations.

- The questions asked were in the following areas: Regulations, Government Support, Competitiveness, Talent, Financing, Technology Capabilities, The Future
- Given that we were trying to get broad and diverse perspectives, our line of questioning for each of the above topics typically started with: “What are your views on [topic] in the context of Singapore?” Thereafter, based on the answers given, we would drill slightly deeper where appropriate to better understand the interviewee's point of view.
- The different groups of interviewees were as follows:
  - The ‘Company’ group – Organisations which operate primarily in the commercial space sector, such as satellite MAIT or space exploration companies.
  - The ‘Ancillary’ group – Entities which typically operate ancillary to the commercial space sector, such as research institutes or investors.
  - The ‘SEDS’ group– Our views that are based on our research and conversations with external entities, such as government representatives and global space enthusiasts.
- Responses have been kept anonymous as a general rule, but the list of interviewees or their companies can be found at the end of the report.

We encourage you to read our detailed methodology in the Appendix to get a better understanding of how we carried out our interviews and the approach we took in analysing the responses objectively.

## Introduction

Humanity is currently at the tipping point in the history of its global space industry. Today, we are seeing our daily lives becoming increasingly intertwined with our activities in space, with new applications of space being discovered to improve our lives here on Earth and to understand our place in this Universe.

From high-resolution data that allows us to understand the changes of our Earth at near real-time speed, to providing internet coverage to the remaining half who are still unconnected as they live beyond the reach of a network, our quality of life will only improve as private companies and nations alike increase their investment and activities in this next frontier of exploration and development.

Singapore has made great progress with its efforts in space since the launch of its first locally designed and built satellite, X-Sat, that was launched into space back in 2011. Since then, several local companies have been established to participate in this emerging industry. At the same time, overseas companies have also chosen to set up their operations here. In 2013, the Singapore Economic Development Board (EDB) created the Office for Space Technology and Industry (OSTIn) with the aim of growing a globally competitive local space industry to be a pillar of Singapore's economic development. These trends demonstrated the potential of a robust and vibrant space industry in Singapore and is a testament to our potential to be a significant beneficiary and participant of the global space industry.

A few years ago, the Minister of Trade and Industry at the time, Mr S. Iswaran, recognised the importance of making advances in space. He said, "While our space industry has made progress, it is important that we continue to innovate and chart new frontiers." Hence, with space being one of the key industries with the potential to widen the economic and social gap between nations, it remains imperative for Singapore to continue to advance our capabilities in the sector to remain relevant in the future.

## Our Role as SEDS

In the book "How to Make a Spaceship: A Band of Renegades, an Epic Race, and the Birth of Private Spaceflight", author Julian Guthrie described that back in 1980, when Mr Peter Diamandis was an undergraduate at MIT, he and his friends sought to establish a space initiative for students run by students. They settled on the name Students for the Exploration and Development of Space (SEDS) as it best explains the mission of the organization. In the first-ever meeting of the organization, Mr Diamandis explained why the time was right to have a student space organization, as they needed students to take charge of their future in space. He didn't want bureaucratic and myopic politicians to chart the future for them, and he believed that an engaged student population would be able to enlighten the government, private industry and the general populace on the far-reaching benefits of space.

Back in 2019, Singapore became the 24th nation to establish a SEDS chapter. One year later, SEDS has grown by leaps and bounds, with presence in over 30 nations and territories all over the world today. This ongoing momentum is kept alive with greater collaboration between the various chapters of SEDS Earth.

As members of SEDS, we continue to persist by being a conduit between students and the larger space economy. Our activities are organized with the ultimate goal of democratizing space opportunities to students and to benefit the greater space ecosystem—all with the desire to set out and achieve the thriving future out in space that was outlined by Mr Diamandis some 40 years ago.

## **Our Roles as Scientists and Researchers**

Research forms one of the key foundational pillars of a nation's space expertise. Research provides a platform through which research institutions, universities, government agencies and students can work together to advance and push the frontier of space science and technology. These academic institutions play a pivotal role in developing the talent of Singapore with real-world projects that involve both undergraduate and graduate students. Research groups within these universities, coupled with the support and direction set out by the National Research Foundation Singapore (NRF), has led to the development of cutting-edge technologies. It has also led to entrepreneurs who have demonstrated proof-of-value and clear business models spinning off start-ups from their research groups.

Scientific research aside, other forms of research are also growing in prominence and importance. While scientific research leads to the creation of new technologies, a myriad of other research leads to the development of enabling policy, business opportunities, and industry development. No ecosystem can grow without holistic support from these diverse segments.

As aspiring researchers and scientists in Singapore, we play an important role in discovering and discussing the newest opportunities. Our research is done with the central aim of facilitating conversations such that they will lead to the creation of more opportunities, growth, and value for Singapore.

## **Our Role as Citizens**

Space has always been a field that seemed elusive and out of reach to the general public—hence the common phrase "it's rocket science", which is used to describe things that are difficult to achieve and understand. However, space is going to play a larger role in all of our lives than ever before, whether the general public makes an effort to understand it or not. Having a better understanding of the domain would simply allow us all to reap the benefits from it.

Space was once thought of as a domain for nations before private companies entered to democratize humanity's access to space by driving down the cost. Similarly, opportunities to be involved in space has also seen a paradigm shift. What was once a predominantly STEM dominated field, has largely changed into one that is all encompassing with a large influx of roles ranging from lawyers, artists, journalists, financial analysts and public policy makers, to name a few. The general public often overlooks the non-STEM aspects of space, without which, many of humanity's greatest achievements in space would not have been possible. Therefore, by engaging the general public about the benefits and opportunities in space and changing the public perception of space, we would be able to put the Arts in STEM to encompass a STEAM driven effort towards space.

As citizens of a country with diverse groups of people – old and young, STEM and non-STEM, space-literate and space-ignorant, etc — we want to engage the public by making space

accessible, relatable, and exciting. That is one of the main goals that led to the establishment of this report.

## The Insights Report

Through initiatives at SEDS Singapore, we aim to improve the skills and knowledge of students interested to explore and provide value to the space industry. We are also providing the research and opinions that make our space ecosystem unique and full of potential. Finally, we also aim to improve the public conversation about this emerging industry. This *Insights Report* is one such initiative, aimed at helping its readers — investors, entrepreneurs, policy makers, and more — gain a deeper understanding of the issues and opportunities that affect Singapore.

With that understanding and the responsibilities the above roles entail, this report sets out to understand the local space community better. In this report, we explore Singapore's space ecosystem through discussions with local stakeholders. Through that, we will be able to ascertain the issues as they appear to different stakeholders and discuss where a better conversation needs to be facilitated in order to effectively grow the ecosystem.

## Definition

In an effort to understand the *space economy*, especially within the context of a small country like Singapore, it is important we define what exactly we mean by the term itself. The report employs the following working definition of the space economy, taken from the OECD Handbook on Measuring the Space Economy, as it is used quite extensively:

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

Not only does defining the term provide all readers an understanding of the bounds of our research, it also starts the process of acquainting us to looking at Singapore in a more global context — with a global definition.

It is important to understand this in a global context. Many of the countries which have interests in space have varying definitions of the space economy. As a result, using the OECD definition seemed adequate for all intents and purposes.

Given the definition, which includes upstream and downstream elements, the scientific community, and society at large, we have taken the liberty to use the terms ‘space economy’, ‘space ecosystem’, and ‘space industry’ interchangeably<sup>1</sup>.

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<sup>1</sup> This is an important point to note due to the fact that different readers may perceive the ‘ecosystem’ as encompassing a larger group of entities than the ‘industry’. Alternatively, some may perceive the ‘industry’ as being part of the ‘economy’, which in itself is part of a larger ‘ecosystem’. In order to avoid the ambiguity, and only leave the subtlest of nuances to the reader, the terms are being used interchangeably through the report.

## Value Chain

The space industry value chain, like most industries, consists of the upstream, midstream, and downstream sectors<sup>2</sup>.

The *upstream sectors* include activities that result in an operational space system. That includes manufacturing space infrastructure as well as related subsystems and components, such as rockets and satellites parts. It also includes launch services and additional activities, typically provided by space agencies.

The *midstream sectors* include activities related to operating in-orbit satellites, management of the missions, and the transactions of satellite capacity and data. Support activities, such as user transmission equipment manufacturing, like dishes and sat-phones, are also part of the midstream. Associated services that exploit space systems, such as data storage, processing and dissemination are also included.

The *downstream sector* includes activities related to exploiting the space-infrastructure and end-user application provisions in a diverse range of industries.

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<sup>2</sup> While this definition of a value chain is fairly common, especially among consultancy firms (that advise governments on space projects), there is no globally accepted, formal definition of the term in the context of the space sector. Hence, the definition used is from [a report](#) by PWC titled “Our service offering for the Space sector”. PWC is fairly reputable in the space consulting sector, having published noteworthy research and consulted important players.

## Industries and Subsectors of Relevance

### Satellite Manufacturing, Assembly, Integration, and Testing

Satellites play a critical role in a world increasingly connected wirelessly. The number of operational satellites on orbit grew by over 20 percent to 2100 with over 300 satellites being launched in 2018, according to the Satellite Industry Association. This increasing satellite production is credited to smart manufacturing, which lowers costs through utilising internet-of-things (IoT) and artificial intelligence (AI) capabilities. Smart manufacturing, among other things, consists of system miniaturization and standardization. In fact, Frost & Sullivan's 'Future of Space (2030 and Beyond)' report found that the increased demand volume along with decreasing timelines between space missions is driving a shift to automotive-style supply chains and serial production, especially with respect to small satellites. Correspondingly, this had led to a transformation of the small satellite supply chain, mainly due to the scalability and cheaper costs of CubeSats. This has also led to the emergence of high throughput satellite communication with new collaborative business models (between upstream and downstream participants) that lower overall costs to bring about better internet connectivity and broadband. The lower requirements for small satellites are also paving the way for new technologies, like all-electric satellites<sup>3</sup>.

Another element crucial to the production of effective satellite systems is the assembly, integration, and testing that takes place after the manufacturing of the satellite components. A satellite is supposed to be designed to withstand numerous trials during its journey to space and while in operation. These include, but are not limited to, mechanical shock, strong vibrations, relatively extreme temperatures, and signal interruptions. Assembly, integration, and testing are thus necessary to certify the integrity of the satellites before they're sent into space. While there are many companies that provide these services, some government entities like the Malaysian Space Agency have dedicated centres for it.

Frost & Sullivan foresees that small satellites, nano-satellites in particular, will make up the majority of missions by 2029 – and with that will come the demand for dedicated services for the small satellite subsector and the miniaturization of payloads and systems.

Satellite manufacturing, assembly, integration, and testing is generally the area in which Singaporean companies appear most frequently. This could be due to the overlap between telecommunications and the space industries.

### Satellite Operations

Satellite operations are a critical part of maintaining existing satellite infrastructure and keeping it operational for commercial or scientific purposes. Satellite operators monitor satellites, typically all the time and via ground stations. The operators provide command and support to their clients' in-orbit missions when needed, as not all satellite service users and providers may have the infrastructure nor human resources to actively manage their existing fleets. Other than in managing the operation of a satellite, these operators also tend to aid in managing the missions that the satellite has set out to complete. In terms of applications globally, Earth

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<sup>3</sup> The first such all-electric satellite was the Eutelsat 172B, launched by Eutelsat and built by Airbus, on 2 June 2017.

observation missions were the most common satellite missions in 2016, at 35%. It was followed by communications at 22%. Ground stations, a key element in satellite communication and data transmission, is also a key infrastructure that will grow in sync with increasing satellite operations. Companies like Atlas Space Operations and Kongsberg Satellite Services, which operate ground segments, have been enhancing their small satellite operational capabilities. That being said, new ideas are emerging in this arena. One such idea includes the use of space-based relay stations which would provide continuous communications to satellites over a longer range, reducing the number of ground stations needed<sup>4</sup>.

Frost & Sullivan predicts that several Earth observation companies and a few communication companies will contribute to the installation of more than 2600 small satellites by 2023. With this increase in small satellite missions, the expected increase in demand for satellite operators will be similar.

## **Downstream Services**

Downstream services refer to all activities based on space technology, particularly services provided by a network provider to a customer. The demand for such services is driven by the extent of our hyperconnected world. Frost & Sullivan found that the demand is further driven by an expected 1.75 billion new internet users by 2027, further increasing the need for better IoT infrastructure and architecture to lower costs. The obvious beneficiary of more upgraded capabilities will be the telecom consumer due to the high volume of affordable connectivity services that will enter the market.

Other than communication, navigation systems will also be greatly enhanced by the growth in satellite services and missions. The European Global Navigation Satellite Systems Agency estimates that there will be 7 billion GPS receivers operational globally by 2022. The key impacts of increased navigation services would be greater accuracy, more reliable services, and better safety and time savings due to improved efficiencies across navigation-reliant industries.

The outsized benefit, which has yet to be fully exploited, lies in the end-user applications of the downstream services. With increasingly data-heavy business models, the potential that lies in the usage of satellite data is enormous.

Realtime information and data can be utilized for new value propositions in multiple industries, such as:

- Surveillance – End-user specific services and integrated platforms are helping industries that rely on timely information, like the aviation and maritime industries.
- Smart City Connectivity – With the advent of IoT and smart city capabilities, like autonomous public transport, mapping data and augmentations systems will be beneficial.
- Disaster Management – A combination of high-throughput satellites, weather information, and real-time analytics would help agencies be more efficient in times of disasters.

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<sup>4</sup> The start-up that proposed this “radical” idea – Audacy – defaulted to debt in 2019, bringing light to the highly capital-intensive nature of space infrastructure projects.

- National Security – Situational awareness and enhanced tracking are simply two of the uses of current space infrastructure that will improve greatly with better data processing and satellite services.

Most nations are unable to participate in the traditional space industry of satellite operations, launch services, or advanced technology creation. However, the availability of data has liberalised the downstream playing field to a large extent, allowing companies from around the world to participate and unlock value from existing space infrastructure.

## **Launch Services**

Launch service providers (LSP) are companies which specialise in launching spacecraft at all stages of its production. The Institute of Defense Analyses 'Global Trends in Small Satellites' report found that launching miniature satellites (which weigh below 100kg) is set to become a USD 15 billion industry by 2027, fuelled largely by CubeSats. This is partly accredited to the necessity of replacing old small satellites which have driven recurring demand up. In turn, this has increased the need for small satellite LSPs. Moreover, the increasing privatisation of space has led to a significant increase in connecting more operators and service providers through strategic partnerships for more timely launches. This has led to increased investment, industry consolidation and multiple business models.

A niche but emerging trend within the launch services sector is air-launched rockets: the launching system where a spacecraft is hauled by an aircraft and launched mid-air in its journey to orbit. This concept or practice is not new, as demonstrated by the Pegasus Rocket by Northrop Grumman, which has been in action since the 1990s. However, the Pegasus uses a solid rocket motor, whereas conventional systems consist of a liquid engine. Hence, the Pegasus sacrifices safety for a simpler and more effective design. While the area is certainly nascent, it provides a more scalable business model where access to space is made cheaper.

Given Singapore's inherent limitations with regards to size and geographical land space, launch services are not a traditional sector for Singapore's space technologies. Equatorial Space Systems is a unique example of a company defying these norms by working to provide dedicated nanosatellite launch services, by proposing use of sea launch architecture for its future operations.

## **Space Exploration and Management**

When it comes to space exploration, most nations currently participate in a research capacity. However, the idea of commercial applications resulting from space exploration is also a much-discussed topic. While the feasibility of any commercial space exploration activities is yet to be proven, limited largely by costs and technology, several daring entrepreneurs have explored and raised funding in this sector. Resource mining remains one of the key objectives of space exploration, as the National Aeronautics and Space Administration (NASA) estimates USD 700 quintillion worth of natural resources, such as nickel, platinum, iron and cobalt, are present in asteroids and could theoretically be recovered. Other projects include space tourism, which has seen the largest number of new entrants in the sector of space exploration. Frost & Sullivan estimate that, by 2025, the space tourism market will be worth USD 1.2 billion. Other objectives include new scientific discoveries and to develop a more distinct human presence in our solar system. Space management, which includes emerging areas of opportunity like space debris, congestion, and situational awareness, are other important pain points within the space industry, which will only get more pressing as the number of satellites increase.

As research and development efforts in the space industry persist, potentially spilling over to other industries, costs are estimated to decrease and these bold objectives will become more achievable.

## Ancillary Services

With the advent of any new and high-tech industry, there is a corresponding rise in several ancillary services which operate to benefit and improve the industry itself. Space is no different. Several ancillary services that add value to the space ecosystem are as follows:

**National Space Agencies** – Space agencies play a crucial role in the development of a country's space programme and its role in the global space scene, where agencies are paramount in policy decisions regarding space. The major paradigm shift regarding agencies is the increasing collaboration between public space agencies and private corporations. NASA's 'Tipping Point' awards are an exemplary example of the evolving public-private sector relationship between public space agencies and private space companies. CNBC reported that NASA's 'Moon to Mars' initiative saw 14 US companies, like SpaceX and Blue Origin, win USD 43 million to develop new technologies with NASA in a collaborative effort.

**Non-profit/Non-governmental Organisations** – The main objectives of non-profits are to raise awareness about space-related endeavours to the general public. Moreover, they often have collaborations with national space agencies in order to improve public awareness of the benefits of space technology and exploration. One such example is the 'Space Certification Program' that the Space Foundation has launched in collaboration with NASA. The program certifies products and businesses with viable links to space technology with a "seal of approval". Being granted one signifies that the product or business has attained a certain standard that involves innovation, comfort, convenience and dependability. This group also include organisations that act as pseudo-trade associations and provide brokering or consultancy services.

**Investors** – Investors in the space industry range anywhere from angel investors to multinational corporations and governments. The increasing privatisation of space has been synonymous with the general trend of investors whose interest is gradually moving away from consumer start-ups to deep tech start-ups, whose disruptive technologies can solve problems. Space Capital, a New York-based investment firm with a focus on space technology, reported that space companies received USD 5.8 billion across 198 investment rounds in 2019, topping the USD 5.1 billion record that was set in the year before.

**Academia** - The academic sector involves scholars, scientists, engineers, policy makers, and more. It plays a large role in supplying talent towards the space industry's science and technology programs. With the rise of the importance of STEM in education and increasing privatisation of the space industry, new jobs are being created. There is an increasing demand for a skilled space workforce, thus increasing the viability of pursuing jobs in space-related industries. In order to meet this demand, some universities, like the University of Michigan, have rolled out dedicated space degree programs.

## Main Players

### Governments

The global space economy reached nearly USD 350 billion in 2017, having grown on average by 6.7 % p.a. between 2005 and 2017, almost twice the 3.5 % average yearly growth of the global economy, as reported by the European Investment Bank's 'The Future of the European Space Sector' report. Bryce found that close to 50 nations have government space budgets, nine over USD 1 billion, and nearly 20 under USD 100 million in their report titled 'Global Space Industry Dynamics'.

The United States and China are the world's top geopolitical and economic powers and they possess the full range of space capabilities necessary to preserve and enhance their military and economic power and prestige. In the first space race, between USA and the USSR, government agenda was motivated by space supremacy over the enemy. While the recent resurgence in space is also taking place at a similar time as US-China tensions rise, a large amount of credit for the developments go to the private companies for pushing prices in the sector down.

Other space powers like Europe, India and Japan possess technical capabilities that rival and, in some cases, surpass those of the top space powers in areas such as global navigation satellite services (GNSS), imagery intelligence gathering, and space situational awareness. However, their programs are smaller in scale and budget. Of the major space powers in the world which have full launch capabilities to transfer heavy payloads in geosynchronous orbits, can launch multiple and recoverable satellites, deploy cryogenic engines, and operate extra-terrestrial exploration missions, three are Asian: China, Japan, and India.

**United States of America** – USA accounts for approximately one-third of the operational spacecraft currently in orbit around Earth. The national space exploration efforts of the country are led by the National Aeronautics and Space Administration (NASA), who also carried out the most prolific event in space history – the moon landing under the Apollo missions. Other famous missions and projects under NASA include the Skylab, the International Space Station, the Space Shuttle program, and the Mars Exploration Rovers.

The United States leads in government spending when it comes to space, with an estimated USD 48 billion spread among 11 agencies and offices. The United States is significantly increasing government funding to both civil and military space programmes. As an illustration, the unclassified Space Budget for 2019 stated that the US Air Force could potentially invest about USD 44 billion over five years in space systems (mainly R&D) between 2018 and 2023.

**China** – China owns and manages the second largest fleet of spacecraft in orbit, currently operating several constellations of navigation satellites, remote sensing satellites, communication satellites, surveillance, and spacecraft. China is one of three nations with the capability to recover satellites and conducting a manned space flight. China's major missions include the Tiangong-1 space station, Shenzhou manned space flight programme and the Chinese Lunar Exploration Programme. The United States-China Economic and Security Review Commission stated that the Chinese National Space Administration (CNSA) handles the planning and development of national space programmes, while state-owned China Aerospace

Science and Technology Corporation is the prime contractor responsible for the design and development of launch vehicles and satellites as well as commercial launch services. China has the second largest government spending at USD 11 billion, with the budget allocated to the military and civil space agency supported by a single contracting entity called China Aerospace Science and Technology Corporation.

**Europe** – The European Space Agency (ESA) currently has 22 Member States, unlike most other nations which primarily operate within the country's borders. The ESA has several programs, such as the space flight programme (via the International Space Station), uncrewed exploration missions to celestial bodies, Earth observation, science and telecommunications, and a major spaceport - the Guiana Space Centre at Kourou, French Guiana. The agency also works closely with NASA on projects like the manufacturing of the Orion Spacecraft service module.

ESA's budget for the year of 2020 was earmarked as EUR 6.7 billion (nearly USD 8 billion), with the largest proportions being allocated to Earth observation and space transportation (23% for each). Navigation, human and robotic exploration, and scientific purposes were the next largest groups in terms of funding.

### Other Noteworthy Players

**Japan** – The Japan Aerospace Exploration Agency (JAXA) is responsible for research, technology development and launch of satellites into orbit, and is involved in many more advanced missions such as asteroid exploration and possible human exploration of the Moon. JAXA has designed and carried out several missions in the areas of planetary exploration and solar sail research. The Japanese government also has ambitious hopes for the local space entrepreneurship scene and has offered USD 940 million to fund space start-ups in a push to grow the industry.

**India** – The Indian Space Research Organisation (ISRO), under the Department of Space, is responsible for operations, manufacturing, research and development, with multiple facilities across the country. India's space program focuses on technology development, space applications and scientific advancement. Recently, ISRO has successfully deployed its regional GNSS system (NavIC), augmentation system, launcher, and Mars missions. Other than prospective space exploration missions, India's first manned space mission is also scheduled for 2022, with a budget of USD 1.5 billion behind the whole project, as reported by the OECD.

**Russia** – Russia's Roscosmos State Corporation for Space Activities coordinates space activities in Russia. Under the activities it takes part in are numerous civilian activities, such as the astronaut programs and Earth observation, as well as military launches. While Roscosmos has waned in significance since the fall of the Soviet Union, they have played an important role in international cooperation, such as by facilitating foreign launches and being a major participant in the International Space Station. That being said, they have managed their own initiatives as well, such as the Baikonur Cosmodrome and the upcoming ExoMars missions (in collaboration with the ESA).

**Luxembourg** – As one of the smallest, but wealthiest, countries in the world, Luxembourg has thrust itself to the centre of space development. The Luxembourg Space Cluster states that it unites highly specialised companies and government research agencies focusing on space

telecommunications, GNSS and location-based services, earth observation, maritime safety and protection, and space technologies. Its recent Space Resources Act made it the second country in the world, after the US, to provide a comprehensive legal framework for the exploitation of resources beyond our planet. Since the 1980s, successful experiences in near-space, orbital satellite networks set a precedent for the government to launch initiatives in the NewSpace era. As a result, Luxembourg aimed to create a vibrant space ecosystem by launching several initiatives in the areas of regulation, taxation, R&D, competitiveness etc. Unlike the US, Luxembourg's space framework had some important differences aimed at encouraging all innovation. For example, American law requires companies to have more than 50% of US-backed equity for certain initiatives, while Luxembourg has no such limitation. Luxembourg's Space Resources Act opened a floodgate for investment, with investments in revolutionary companies like Planetary Resources<sup>5</sup>. A Financial Times report found that the space and satellite sector in Luxembourg currently makes up almost 2% of Luxembourg's GDP, having grown from virtually nothing three decades ago.

**Southeast Asia** – Southeast Asia's different space programmes are motivated less by flashy projects and more by socio-economic needs and a desire to increase self-reliance in the area of security. Euroconsult found that, in 2012, Vietnam was the largest spender within the ASEAN group with an expenditure of USD 93 million on space programmes, followed by Laos (USD 87 million) and Indonesia (USD 38 million). The Observer Research Foundation's report on the region, titled 'Southeast Asian Space Programmes: Capabilities, Challenges and Collaborations', states that some of these countries, which are relatively poor as compared to the rest of the region, are investing in the applications of space technology, rather than focusing on academic research. The applications could have wide-ranging benefits in the areas of disaster management, agriculture, conflict zones, and tourism. Unlike the ESA, no formal joint agency exists in Southeast Asia. As a result, most countries in the region are involved in largely developing their own capabilities, with occasional regional collaborations within the ASEAN nations or with other countries, like Japan.

## Private Industry

Most people know about Elon Musk's Space Exploration Technologies Corporation, better known as SpaceX. However, as mentioned earlier, it is worth noting that space companies (as a whole) raised USD 5.8 billion in private investments over 198 investment rounds in just 2019, a record-breaking year, with investments totalling to nearly USD 26 billion since 2009.

Many have drawn parallels between the current development of the space industry to the past development of the internet, where increasing competition and falling barriers to entry spurred enormous growth from the fast-moving private sector. Start-ups, in particular, are continuing to emerge with over at least 500 small companies created in the past 5 years, as per OECD's findings. While some provide solutions in areas traditionally controlled by the government sector, like launch services, there are many innovative and highly-risky ventures popping up as well, such as asteroid mining and deep space exploration. Given the risk profile of the inchoate subsectors of space, private industry has greater liberty to experiment and, probably, fail in the early stages of development. However, many smaller companies have yet to bring their products to market. That being said, they have already disrupted larger aerospace incumbents, who were

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<sup>5</sup> It may be worth noting that after months of financial uncertainty, a blockchain-based production studio, ConsenSys, acquired Planetary Resources through an asset-purchase transaction.

grounded in their slow and uninspired developments. Due to the increasing competition and activity, private ventures are expected to drive commercial innovation within the industry in the coming decade.

While there are many innovative and impressive companies worth discussing, Space Capital reported that SpaceX, Blue Origin, and OneWeb<sup>6</sup> were the largest companies in this area, capturing the lion's share of investments in 2019.

## Policy Developments

Given that different nations may see things in different lenses, motivated by their own interests, the United Nations Office for Outer Space Affairs (UNOOSA) – part of the UN Secretariat – is responsible for promoting the peaceful use and exploration of space through international cooperation. As a result, they endeavour to work with any of the 193 UN Member States to establish or strengthen the legal and regulatory frameworks for space activities, and assists developing countries in using space science and technology for sustainable socioeconomic development. As the secretariat of the Committee on the Peaceful Uses of Outer Space (COPUOS) – a committee set up to discuss the scientific and legal aspects of exploring and using outer space for the benefit of humankind – the Office is responsible for helping implement the five international treaties, five legal principles, and related General Assembly resolutions that together comprise space law.

However, nations (or more specifically, UN members) are no longer the only significant stakeholders when it comes to making developments in space. As the private industry starts to play an increasingly significant role in the development and commercialisation of space, new markets are expanding and new innovations are being made faster than policies can keep up. While there is a perennial debate about how much public policy should intervene in the market, a complete lack of policy in space, where boundaries and ownership are undefined, could easily lead to disagreements and chaos. Moreover, as technologies, such as 5G, IoT, and high throughput satellites, combine to solve new problems, policy may play an important role in enabling the transition for existing firms while also encouraging entrepreneurship.

Different countries have different approaches to space policy, with some examples given in the ‘Governments’ subsection above. While several countries have updated their space policies recently, such as the UK’s Space Industry Bill, one of the most seminal policies that were released in 2020 was the Artemis Accords. The Artemis Accords are a set of bilateral agreements with other space agencies that want to participate in the Artemis program and underscore the principles that NASA has determined to be critical for effective space governance and exploration.

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<sup>6</sup> OneWeb filed for bankruptcy in March, 2020. By then, OneWeb had already burned through USD 3.4 billion, which it had raised from a diverse group of investors, including Airbus, Softbank Group, and the government of Rwanda. Britain has agreed to pay USD 500 million for a 45 percent stake in the company, which has launched 74 satellites (out of the 650 it had planned to launch). Bharti Airtel, a telecom company based in India with more than 400 million subscribers, is also taking a 45 percent stake.

## The Emergence of NewSpace

Traditional space, which primarily catered to governments, had certain weaknesses in it, such as a lack of transparency in pricing or highly monopolistic supply chains. However, in the emerging space model, often cited as NewSpace, several private ventures with unique and creative business models have popped up in the past few years, addressing the whole value chain from upstream to downstream. Such NewSpace players are distinguished by their propensity to step away from the conventional strategy of massive, high-performance spacecraft with strong risk reduction, developed, operated and utilized by various agencies towards low-cost, easily replaceable satellites deployed in constellations. Such a vertically integrated approach allows NewSpace participants to focus on the downstream segment and usage of satellite data to create additional value on existing infrastructure. The reduced risk (in a traditionally risky domain), shorter-cycle ventures (where traditionally long timelines were typical) are particularly appealing to investors and conventional companies. That has led to a massive influx of capital into the industry.

Increasing end investments from private companies have opened up a multitude of opportunities and gaps in the space industry that many wish to capitalise on. From automotive giants such as Audi, tech giants such as Google, Facebook and Tesla to multinational corporations, these gaps are slowly being filled up with new business models as old incumbents and new entrants initiate new strategic partnerships.

NewSpace is greatly propelled by advancements in *deep tech*, which broadly refers to cutting-edge technologies that are proprietary and provide innovative solutions to problems. Around the world, governments have launched initiatives that provide capital investment to such deep-tech start-ups. An example would be the Singapore government's start-up investing arm, SGInnovate, which launched the 'Deep Tech for Good' initiative that provides seed investments. Deep tech has also been an area of much interest to venture capitalists since 2015, as VC investments in deep tech are growing 3 times faster according to a global survey by Wavestone.

Bryce's 'Start-up Space' report also found that industrial consolidation has occurred, as horizontal and vertical integration of new entrants and incumbents has allowed for added value and lower costs across the space supply chain. Moreover, a start-up invasion has occurred, with an increase of 34% in the number of space start-ups from the previous year, and there was a 61% increase in total start-up space investment.

Space entrepreneurship, a key driver of NewSpace, has gained traction in recent years as many governments and private investors continue to fund deep-tech start-ups. Space Capital argues in their industry report, titled 'U.S. Government Support of the Entrepreneurial Space Age', that another benefit of government funding is that it reduces barriers to entry, decreasing the risk of starting a company while increasing the number of start-ups that may succeed. They also found that since 2000, commercial space companies have received USD 7.2 billion in government investments. In Singapore, start-ups that are classified 'deep tech' are eligible for a government grant that provides 70% funding in the initial round investment of SGD 500,000. Coupled together, the higher availability of grants, greater private capital investment, and the recent successes of companies like SpaceX and Blue Origin have increased investor confidence in the budding space industry, creating more opportunities for space entrepreneurs to venture into the space industry.

Thanks largely to NewSpace, the global space economy is projected to grow from USD 340 billion in 2019 to USD 1 trillion over the next 20 years, as per findings by Australia's Department of Trade, Business and Innovation. In 2019, investments totalling USD 5.7 billion was made across 178 commercial space start-ups worldwide, breaking the previous 2018 ceiling of USD 3.5 billion, as reported by Bryce in their 'Start-up Space' report. Communications, satellite servicing, human spaceflight and in-space manufacturing are key areas of growth, where there is a greater push by commercial entities and the convergence of multiple emerging technologies across the industry.

Ultimately, the space industry still has many challenges and questions that require answers. Regulatory differentiation in countries' space laws offers varying degrees of attractiveness to stakeholders, but also presents a new set of challenges of global standards. As the pace of the industry picks up, policy has to stay relevant and keep up as well. New position papers, like the Artemis Accords, which outline recommended guidelines and principles for NewSpace, show the importance of having progressive space agendas to tackle new-age issues<sup>7</sup>.

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<sup>7</sup> While more issues will be raised later in the report, an example of a contemporary issue, as discussed by PWC, is relevant here. The issue is on space situational awareness, where space debris from old satellites are threatening sustainability. Currently, there is no law that mandates that these satellites must be cleared up by the ones who first put them there. Thus, challenges and gaps in international space law remains a pressing issue that needs to be resolved, mainly (1) "Flag of Convenience" dilemma which slackens regulatory laws in exchange for an edge in the space race, (2) Laws regarding colonisation of other planets (for its resources), (3) Militarization of Space, (4) Commercial Space Flight (Insurance, Safety, etc). While the issue has similarities to other segments of law, the context it is placed in makes solutions that worked on Earth highly challenging to implement in space.

## Community

The community at large plays an important role in the future of the space industry. Universities conduct research, student groups introduce students of all ages to the space industry, and other organisations host industry competitions such as business case competitions and engineering competitions. Members of the space industry host workshops, seminars and forums discussing space law and policy. These programs provide an insight into the space industry and help create a talent pipeline for the industry.

### **Academia and Institutes of Higher Education**

Academia and institutes of higher education consist of universities and their academics, as well as their student body. Academics conduct research and push the boundaries of the space industry. Institutes of higher education, likewise, put in place initiatives that allow the research scene to thrive and to introduce students to the space industry.

#### Case Study: MIT Media Lab Space Exploration Initiative

Seeing that many organizations already tackled engineering and scientific challenges in this area, the Media Lab is distinct in its freedom to imagine, to build and deploy bold visions that venture beyond the rational constraints of most academic grants. In essence, it hopes to take an interdisciplinary approach, combining art, science and engineering to conceptualize innovative ideas that could one day change the world.

#### Project: The Telemetron Orchestra

The MIT Media Lab team, using its interdisciplinary approach, questioned the feasibility of Earth's musical instruments in space. In order to explore this question, Nicole L'Huillier, Sands Fish, and Thomas Sanchez Lengeling are building the Telemetron Orchestra, a collection of novel musical instruments designed explicitly to be performed in microgravity. The Telemetrons take advantage of the poetics of the weightless environment to create a musical performance based on motion in space. The instruments are both devices and sculptures at once. According to MIT Media Lab, the instruments are both kinetic and aesthetic experiments, as well as explorations of interaction design in an environment where the gravitational rules we are used to do not apply.

During the zero-gravity flight test of the first Telemetron, L'Huillier and Fish recognized the unique agency that objects in microgravity possess. There were interesting questions to ask about the dance between a human and a non-human body, and work continues to define a new body language for performance in weightlessness. As of writing this report, the Telemetron has not been fully developed, but it has opened up an avenue of questions and interest about the arts and culture in space.

Besides academic initiatives, some institutes of higher education have started space research centres. For example, the University of Leicester in the UK launched its Space Research Centre in 1998 with a focus on developing novel sensors and optics for high energy astrophysics, planetary landers and orbiters and interdisciplinary research in conjunction with the life sciences and medicine.

In addition, some higher education institutes have even gone as far as establishing a Faculty or Department of Space. One such institute is the University of Osaka, which established its Department of Earth and Space Science in 1995. The department focuses on the scientific aspects of space research, such as space phenomena and planetary science.

In Singapore, academia has played a crucial role in the early development of space interests within the community. Two of our local Universities are leading the development of Small Satellite research with the Satellite Research Centre (SaRC) and the Satellite Technology and Research Centre (STAR) at Nanyang Technological University and the National University of Singapore respectively. Another research centre, the Centre for Quantum Technologies (CQT) is also achieving ground-breaking developments in quantum computing.

## **Student Organisations**

Since the late twentieth century, student organisations have been created to promote various industries. The space industry is no different. These student organisations play an important role in introducing students to the space industry and generate more interest in the industry.

The focus of each student organisation varies. Some organisations may focus on promoting the exploration and development of space, while others focus on the engineering aspects of space travel. For instance, John Hopkins University has a myriad of space-related student organisations. It has an Aerospace Medicine Interest Group, created to generate interest and inspire careers in aerospace medicine. The University is also the home to the AstroJays Rocketry Team, a student-led rocketry team established to compete in the Spaceport America Cup. These organisations show that the interest in space is not exclusively for scientists, but for people from every possible discipline.

### **Case Study: Students for the Exploration and Development of Space (SEDS)**

SEDS pursues its mission by educating people about the benefits of space, by supporting a network of interested students, by providing an opportunity for members to develop their leadership skills, and inspiring people through our involvement in space-related projects.

#### **Competition: Taking Out the Trash (SEDS USA 2020 Competition)**

One of the ways SEDS engages its members is through annual competitions. The topic for 2020 is titled “Taking Out the Trash”, which discusses the problem of space debris and its solutions.

In this competition, teams were tasked to research the problem of space debris, which consisted of three segments: the impact, the policies in place, and the technologies that can solve it.

Based on the above, students were expected to design comprehensive plans to tackle the issue. Engaging students early on with such meaningful and important problems help them to be a more active member of the emerging space community.

## Industry Competitions

Industry competitions are often held to inspire new ideas for the future of space. Students are usually the target participants, although often members of the public are allowed to take part in them. These industry competitions cover various topics, ranging from engineering to law and policy.

Example: Spaceport America Cup

Spaceport America Cup is a competition designed in conjunction with the Intercollegiate Rocket Engineering Competition for student rocketry teams from all over the country and around the world. It has been held every year since 2017. Over 150 teams from around the world have participated, and the competition continues to grow every year. Students have launched solid, liquid, and hybrid rockets to target altitudes of 10,000 and 30,000 feet.

The Spaceport America Cup is an excellent example demonstrating how competitions are used to challenge and inspire students to come up with solutions for our future in space.

Competitions are also present in other disciplines, such as the Manfred Lachs Space Law Moot Court Competition, organised by the European Centre for Space Law and the Mars City State Design Competition hosted by the Mars Society.

Other well-known competitions include the Ansari X Prize, which offers a USD 10 million award for spectacular innovations in affordable spaceflight. The Google Lunar X Prize was also intended to award "the first privately funded teams to safely land a robot on the surface of the Moon and have that robot travel 500 meters over the lunar surface and send images and data back to the Earth" USD 30 million. While not part of the private industry, NASA's Centennial Challenges program also offers up to USD 2 million to support innovations which are of interest to the agency. They have also allocated USD 30 million in contract funds for winning lunar bots that meet key objective of the Lunar X Prize.

## Non-Governmental Organisations

Humanity's dream of space exploration and discovery is not a simple one. It has its risks and unintended effects and a community which provides outside support can be beneficial. As a result, non-governmental organisations (NGOs) were created to promote space-related causes. A paper by Lukaszczuk and Williamson found that NGOs have a variety of missions as well, from education to sustainable space development. They also found that NGOs tend to play a unique role in international affairs, providing access to resources and expertise.

Some notable NGOs are as follows:

Secure World Foundation      Has a mission to promote secure and sustainable use of the space domain.

Space Foundation      Training and educating the next generation of space leaders through certifications and workforce development programmes.

Space Safety Coalition      Promotes responsible space safety through the adoption and development of international standards, guidelines and best practices.

Mars Society	The world's most influential space advocacy organization dedicated to the human exploration and settlement on the Planet Mars.
The Planetary Society	Advocates for space and planetary science funding in government, educates the public on space-related topics, and funds ground-breaking space science and technology.
National Space Society	Promotes social, economic, technological, and political change in order to expand civilization beyond Earth, and to settle space and use the resulting resources to build a hopeful and prosperous future for humanity.
Space Generation Advisory Council	Aims to represent university students and young space professionals ages 18-35 to the United Nations, space agencies, industry, and academia. Holds the status of Permanent Observer at the UN COPUOS and regularly takes part in the annual meeting, as well as its Legal and Scientific and Technical Subcommittees.



Photo by Elina Sazonova

## Singapore

In 2019, Singapore registered to become a member of the United Nations Committee on the Peaceful Uses of Outer Space, becoming the sixth ASEAN country to join, after Indonesia (1973), the Philippines (1977), Vietnam (1980), Malaysia (1994), Thailand (2004).

Before OSTIn came into action in 2013, there was fairly little to talk about in terms of Singapore's space landscape. In comparison, there has been a lot more activity aimed at cultivating an industry in the past few years.

OSTIn was created to help the nation capture the economic opportunities that were emerging in the global space arena while also helping Singapore build a thriving space industry. At its inception, OSTIn was described as being a national office which would collaborate closely with both local and international players in the satellite industry in order to help them realise their initiatives in the Asian market. Beyond that, OSTIn is also meant to help develop key research capabilities in the industry and plan all civil space matters in Singapore.

While Singapore does not yet have a public space agenda, she has supported many innovative companies and initiatives in the sector. She has done so with:

- At least 9 company programmes
- 13 satellites launched (since 2011) and growing
- A satellite industry development fund worth SGD 90 million (between 2013 to 2018)
- 13 start-ups, and growing, across the satellite value chain
- Over 30 local and international companies engaged in multidisciplinary activities in the sector
- More than 1,000 professionals employed in the sector

That can be seen as a further sign of support for the emerging industry and if the industry continues to grow or is of strategic interest, policies will likely adapt to create a more conducive environment.

Government involvement and advocacy aside, private organisations, like Singapore Space and Technology Ltd, and non-profits, like SEDS, are also championing greater engagement and collaboration in space.

In this *Insights Report*, we spoke to more than 30 representatives, on behalf of a total of 28 entities, about their views on Singapore and the space industry. These entities comprise of:

- 18 companies, which are primarily in the commercial space sector, henceforth known as the '**Company**' group
- 9 organisations, which are ancillary to the commercial space sector, henceforth known as the '**Ancillary**' group
- A variety of other sources, including international SEDS chapters, members of government and foreign space professionals, henceforth known as the '**SEDS**' group<sup>8</sup>.

In the following sections, we discuss the key talking points and views that were raised.

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<sup>8</sup> They are labelled as 'SEDS' because these views are based on our own secondary research as well as our own interpretations of the conversations we have had with different sources.



*Photo by Tingey Injury Law Firm*

## REGULATIONS

Do regulations stifle innovation? That has been a question that is likely as old as the Code of Hammurabi itself. Classical economic theory suggests that regulations can impose a cost burden on firms, which makes them reallocate their spending away from investments in innovation. On the other hand, proponents of regulation argue that it is a necessary step to protect the consumer and maintain trust between market participants. The Porter Hypothesis, which traditionally relates to environmental regulation, goes further to posit that well-designed regulations could actually encourage innovation. As the space industry develops into a larger part of the global and local economy, regulations are likely to increase and gravity may not end up being the only force preventing companies from achieving lift-off. Singapore's challenge, much like most other countries, is to strike a balance between a regulatory regime that reasonably protects the interests of all stakeholders while allowing sufficient room for literal moonshots.

In this section, respondents were asked for their opinions on the regulatory environment in Singapore, both in terms of space-specific and general regulations. The responses were generally positive but certain interviewees brought up difficult experiences that they had faced and hoped would be solved.

In general, the 'Company' group provided more responses which contributed to this section. While the 'Ancillary' and 'SEDS' groups did also have their fair share of responses, it seems logical that the 'Company' group would likely have had the most unique experiences in dealing with the regulations that affect the local industry.

## Non-Space Specific Regulations

When it came to general regulations that affected them, most interviewees felt that Singapore's regulatory regime was generally conducive. The areas where there was some disagreement was related to navigating through foreign regulations and technology transfer.

### General Policies and Regulations

All three groups of respondents were in agreement that the general policies and regulations in Singapore in relation to the setting up of a company and the running of a business was commendable. One point of tension was highlighted but that was more due to comparisons with other systems, rather than a comment on the system itself.

Most interviewees found Singapore to be very business-friendly and this is reflected in its policies and regulations. This is so even at the beginning stages of a starting a business. Start-ups have found that the method of incorporating a company is clear and relatively simple.

Several companies felt that Singapore is in a strategic location and has done a good job in remaining neutral in its policies notwithstanding the current global climate where countries constantly take sides. One interviewee found this neutral branding important for commercial space activities especially those that require international collaboration. The interviewee found that Singapore's neutrality is essential when working with foreign companies (American, European, Chinese, Japanese, and Korean companies). Another interviewee found that this trait allows Singapore to be a good space hub and that if there were more collaboration with Singapore as a centralized location, the region would be able to achieve much more together.

Interviewees generally agreed that Singapore's general business environment and the surrounding regulations were rather friendly. However, one interviewee said that the legal infrastructure for venture investing still seemed to be developing with there being a lack of legal counsel who can manage deals comfortably. Points were also raised about how coordinating with the public registrar was more difficult as compared to similar processes in the US.

We too have seen that the business environment is generally conducive. In fact, Singapore has consistently ranked among the top 3 in the world for ease of doing business over the past 15 years, as per the World Bank Group's annual 'Doing Business' Report<sup>9</sup>. As such, some of our interviewees believe that it has led to Singapore attracting a fairly high number of regional headquarters for companies. Some respondents felt that this translates into greater ease of finding partners for collaboration.

Companies

Ancillary

SEDS

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<sup>9</sup> Singapore has ranked 2<sup>nd</sup> in terms of 'Ease of Doing Business' for the past 4 years (2017, 2018, 2019, and 2020) on the 'Doing Business' report, while New Zealand has consistently ranked 1<sup>st</sup> over the same period. Prior to 2017, Singapore was consistently 1<sup>st</sup> from 2007 onwards.

### Laws and Regulations of Other Countries

Besides domestic laws and regulations, foreign regulations and international standards also have affected the setting up and running of businesses in Singapore. For example, the United States International Traffic in Arms Regulations (ITAR)<sup>10</sup> and Export Administration Regulations (EAR) renders the satellite technology export controlled, which affects what kind of operations local space companies can undertake. Interviewees that raised these points generally agreed that these could prove to be barriers.

One interviewee has found that the above-mentioned United States regulations prevent some foreign companies from bringing in satellite manufacturing and research and development (R&D) work into Singapore. Hence, these foreign companies have Singapore offices only to conduct sales and marketing work in the region, or for more downstream outputs such as data analysis and computer vision. It is perhaps for this reason that one company found that there is more red tape for hardware focused companies as compared to software focused companies.

Another interviewee averred, from the perspective as a satellite operator, that regulations in the region are “largely more complicated than it could be as compared to places in Europe.” There was a sense that the countries are very protective of their local industry and required many licenses in order to operate in their country, sometimes requiring local partners before such licenses would be given out. However, the same interviewee noted that this state of affairs appears to be changing, with countries like Thailand opening up when previously it was more closed off to foreign companies.

An interviewee also raised the issue of regulations like ITAR, finding that they make it legally complex to set up certain businesses. However, the interviewee noted that given the US’s standing as the largest market for space technology, navigating through the complexities is necessary. That also implies that any country that wants to tap into the opportunities within the US, would need to be credible in this space. A company seeking to expand its reach to the United States while remaining ITAR compliant may do so by having an entity set up within the US itself. Interviewees helpfully mentioned examples of companies like Rocket Lab which have done precisely that. An interviewee stated that one reason for this could be that most lawyers in this region are not equipped to easily handle some of these regulations.

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<sup>10</sup> In a paper titled “An Overreaction That Destroyed An Industry: The Past, Present, And Future Of U.S. Satellite Export Controls”, Kurtis Zinger explained the unintended effects of ITAR. In 1998, the US Congress reclassified satellite technology as a munition and returned it to the control of the State Department under ITAR. This made cooperation and sales between US manufacturers and countries like China particularly difficult. ITAR was also seen as “destroy[ing] an industry,” reducing the market share of US satellite makers by almost 25% from 1997 to 2007. Some companies supposedly developed ITAR-free satellites, without any restricted components, and allowed them to be launched on Chinese rockets. However, they were challenged, and subsequently fined, for it by the US. Aeroflex, for example, had to pay a USD 8 million fine. Thales Alenia Space, a company that was forced to discontinue its ITAR-free satellite products, claimed that “every satellite nut and bolt” was being classified as ITAR-restricted and disadvantaging US satellites. Meanwhile, China has been able to sell their technology globally by bundling Chinese satellites with Chinese rockets, completely avoiding ITAR.

### **Intellectual Property Regime and Technology Transfer**

An issue that both the ‘Company’ and ‘Ancillary’ respondents raised was in relation to intellectual property (IP) that is spun-out of university labs. When research is initiated in the university context, and the university has expended resources in assisting the project, the IP<sup>11</sup> is usually assigned to the university. There was a consensus that the process could be streamlined and that the Technology Transfer Office’s<sup>12</sup> self-interest was also understandable. Points of tension arose in regards to whether or not the current licensing schemes hindered the commercialisation process, with both the ‘Company’ and ‘Ancillary’ respondents reflecting that the process is not straightforward and may pose some issues. However, alternative reasons were also raised as to why IP might be underutilized.

An interviewee opined that technology transfer offices often want a larger stake in the company in order to maximize the capitalization of the IP the university owns. Hence, a licensing agreement with a university may be quite onerous on the spinoff and may involve the procurement of both equities and royalties. While early phase companies may find such agreements to be the path of least resistance, it may pose problems later when the companies seek funding (e.g. Series A or Series B funding). Even with such agreements, the university is still not out of the picture and in order to completely break free from this university ecosystem, lawyers (such as those specializing in patents) are required.

However, while acknowledging the difficulties that university spinoffs face, some interviewees also recognized that universities are protective of IP that is developed using its resources for good reasons. An interviewee found that a university’s attempt to maximize the capitalization of IP is reasonable given that the university has to be held accountable for the use of its funds. Nonetheless, on a more positive note, it has been averred by one interviewee that the Intellectual Property Office of Singapore and the patent system in general appears to be becoming more amenable to such transfer of IP rights.

Similar to the ‘Company’ group, ‘Ancillary’ group interviewees noted that many of the funds used to develop the IP originate from the government. That makes it taxpayer money which carries with it the consideration of how this IP can contribute back to the economy, society, and the university. Given all the resources that were channelled by the university into the development of the IP, interviewees opined it was likely fair that the university would want to extract sufficient value for themselves.

Interviewees all acknowledged the importance of robust technology transfer agreements. One interviewee said that the agreement must be well-defined and that limited legal documentation would definitely be a barrier for interested investors and entrepreneurs. Interviewees also claimed that the models that top foreign universities from the United States, United Kingdom, or Israel adopted for their own technology transfer offices had proven itself to be a cost-effective way of spinning out IP. They recommended that universities ought to follow those models in order to increase the ease of licensing.

<sup>11</sup> Intellectual property is an important area of law in the context of the space industry. For example, patent law is important in protecting the design of satellites; copyright is important in safeguarding the information that is transmitted through telecommunications; and, of course, trademarks are important in the maintenance of a space company’s brands.

<sup>12</sup> Universities are well known to be the incubators of great innovations, often licensed to enterprise companies (or students) through the university’s technology transfer office. Each local university has a technology transfer office (e.g. Industry Liaison Office, NTU’s Innovation & Technology Transfer Office, SUTD’s Office of Technology and Enterprise Management) which is responsible for such technology transfer and the commercialization of university research.

A report by Greenberg Traurig LLP found that nearly 90% of American patents do not earn any return i.e. they are massively underutilized. While not necessarily as extreme, this issue was found to resonate in many knowledge-based economies, where universities produce a fair amount of IP. Some of our respondents reflected that they are familiar with the issues regarding the overly bureaucratic processes that surround university licensing schemes, which may result in an underutilization of university IP.

Based on our understanding, one respondent felt that the underutilization of IP in Singapore could be because of the risk appetite of the professors in relation to whether they thought it would be worthwhile to commercialize IP they have developed. Truly enough, these individuals have to make important decisions, taking bets on their careers and jobs in order to start these spinoffs. The respondent opined that if such a person is willing to make a jump, the hurdle of IP licensing would not in and of itself hinder such an endeavour. As part of the discussion, the suggestion of focusing on identifying people who are willing to make such jumps and supporting them was raised. That could be considered instead of necessarily looking to make substantive changes to the IP licensing regime. This is not to say that such processes cannot be further streamlined.

SEDS

Locally, SpeQtral is one of the more well-known cases of successful licensing of technology from the Centre of Quantum Technologies. The company did not face too many difficulties in licensing owing to the professionalism of the Industry Liaison Office at NUS. One respondent also explained that companies would likely have a smoother licensing process should the professor involved in the spin-off have some prior experience in the relevant procedures. On a separate but related note, a respondent noted that the process might be more difficult when an external start-up is trying license the IP.

We found that by the year 2000, IBM's annual patent-licensing royalties were at USD 1 billion<sup>13</sup> (approximately USD 1.53 billion in 2020 prices). When we asked some of our respondents, they too agreed that IP holds great potential for those who license it out. In the case of many interviewees in the 'Company' group, that IP holder is a local university-based research institute. Like any other asset, we believe that IP utilisation should be of concern to all parties who can stand to benefit from it – which includes the research institute, the start-ups, and the government (via the economic machine).

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<sup>13</sup> For context, a (mostly) free cash flow of USD 1 billion at the time represented one-ninth of IBM's annual pretax profits.

## Space-Related Regulations

While interviewees from all three groups found general business regulations to be favourable, there were more mixed feelings towards regulations that specifically related to the space industry. There were general comments about the current space-specific regulations, as well as more specific comments on regulations relating to satellites, outer space objects, launch services, and geospatial technology.

### General Comments

Overall, the all three groups of respondents were of the opinion that there was a dearth in regulations relating specifically to the space industry and that the existing regulations could be clearer.

Several interviewees found that there were no regulations that were completely specific to the space industry in Singapore, save perhaps for international norms that are set out by treaties such as the Outer Space Treaty which guide how nations should behave in relation to space activities.

The dearth of regulations in this area has led some companies to wonder if this means they have free reign to do whatever they want or whether they are not allowed to do anything at all. That said, companies are of the view that there is much development that could take place in this area and that the government is adopting a ‘wait-and-see’ approach—choosing to set up appropriate regulations only after seeing what other players do in this space rather than prematurely doing so.

Furthermore, some interviewees felt that regulations that are not specific to but that concern the space industry are relatively unclear. One interviewee found that the small local space ecosystem meant that there are not many people who can share their experience. And even the founders of the few start-ups here may be working on different kinds of projects and their experience may not be entirely relevant nor helpful. All in all, there are not many people who are knowledgeable about the regulatory aspects of the space industry.

Some interviewees were of the opinion that the lack of clearly defined rules or guidelines in the space industry, coupled with the general ease of doing business, provided participants with ample room to experiment and set standards. However, most interviewees raised that the lack of a formal regulatory regime in this area was actually a hindrance which made venture investing and coordination between entities difficult.

Our discussions with several respondents showed us that regulations relating to the space industry did tend to be somewhat unclear and vague. We found that this wasn't a phenomenon specific to the space industry. Instead, this seemed to affect any emerging area where the rules were continuously evolving. Member of Parliament Melvin Yong raised a similar point about the discrepancies in terms of regulations, albeit in the context of COVID-19 restrictions for businesses, in a parliamentary session in June. It seems to be that this process of navigating regulations is likely to be harder for start-ups.

One respondent suggested that for a start-up applying for filings, it might be useful to approach relevant persons in universities who are experienced in navigating through regulations. Given that some local universities have already launched a handful of satellites, there would likely be some people who know the intricacies of this process. We believe that a network to access such guidance could prove to be useful.

Based on our understanding, the government has worked with partner institutions in the past to make regulations clearer. However, Singapore is new to space and so companies would likely be expected to pull their weight and be knowledgeable enough so that they can navigate through some of the red tape (for example, when the ITU asks technical questions) with ease.

Regardless, the general opinion was that the expertise in this area will have to be built over several iterations and experiments.

## Satellites and Frequencies

Interviewees from the ‘Company’ and ‘Ancillary’ groups highlighted some of the issues in regards to satellites and frequency regulations. The ‘SEDS’ group found that this may be slightly complex in certain cases, but that there are solutions that can be considered.

One interviewee averred that the registration of satellites in Singapore is difficult. The interviewee found that while universities have been able to do so, the registration of commercial satellites appear to be tougher. This may be because there is currently no dedicated government body handling such registration. Instead, this falls within the purview of the Infocomm Media Development Authority (IMDA). However, because IMDA is not specialized towards the space industry, there is no personnel in IMDA who knows the requirements for such space activities.

The same interviewee described that it currently takes 1–2 months of back and forth correspondences with IMDA—a very slow and long process—in order to register a satellite, with the requirements for geostationary earth orbit satellites being even more stringent. However, it accepts that this might not just be an issue faced in Singapore. A second interviewee reported that their company had some difficulty in obtaining a frequency and spectrum license from IMDA in the initial stages, but that the issue was eventually resolved. The previous interviewee also pointed out that one of the key purposes of a space agency is precisely to help out with satellite registration and licensing, hinting that the setting up of such a government body would smoothen such kinks.

One interviewee noted that Singapore lacks some of the infrastructure or regulatory environment for satellite development and testing to begin with. Another interviewee mentioned that there was a notable lack of accessible legal guides on issues such as ownership of satellites, arguing that this could lead to a rather unorganized system.

One respondent noted that there was a distinction between the different kinds of entities that may be affected by satellite regulations—1) international satellite companies (e.g. Eutelsat; SingTelSat); 2) satellite start-ups; and 3) universities that build satellites.

Multinational companies have been able to navigate regulatory issues fairly easily and have not really had much regulatory issues. In any case, these companies do not manufacture satellites in Singapore. It was found that for those entities in the second and third cases, the main hurdle is likely to be in attaining permission from IMDA in order to register the required frequencies so that they can do a filing for those entities at the International Telecommunication Union (ITU)<sup>14</sup>. The universities have had experience with the registration of satellites and frequencies, and could be tapped on for assistance.

<sup>14</sup> ITU is the United Nations specialized agency for information and communication technologies and the global body in charge of global radio spectrum harmonization. The ITU’s regulatory procedures for satellites start with the submission of an advance publication information, after which the process can take from anywhere between 6 months to 7 years, according to the ITU themselves. Given how intertwined communication and radio spectrums are in today’s world, the ITU often opines on many emerging technologies, like AI or drones. However, there has been some debate about whether the ITU is using its time effectively by discussing policy issues in areas that are not part of their central mission. Michael O’Rielly, a Commissioner at the US FCC, argues that policies on such topics, especially those under the jurisdiction of national authorities, are a waste of the ITU’s time. That time could be better used in discussing spectrum policy, formulating ideas for proliferating broadband to remote areas, or even improving internal processes for faster action at the ITU.

### **Outer Space Objects and Launch Services**

Some companies felt that there are certain areas where regulations have yet to be implemented. However, the ‘SEDS’ group discussed how different consideration may result in some sectors receiving lesser attention during the early stages of development.

Companies

One interviewee noted that Singapore does not currently have a registry of outer space objects and no regulations on launch services. The interviewee felt that there is perhaps a need for these regulations and that the Economic Development Board’s (EDB) Office for Space Technology and Industry (OSTIn) is reportedly already looking into legal and regulatory structures. An interviewee suggested that an easy way to implement regulations would be to take the United States’ Federal Aviation Administration’s regulations and adapt them to the needs of Singapore and that this is what other countries have already done.

Some responses highlighted that different governments have different metrics for prioritizing areas of growth. One respondent stated how Indonesia’s ‘Multifunctional Satellite’ project was done to aid in their key focus of developing a digital start-up ecosystem by ensuring connectivity throughout the archipelago. Similarly, one can assume that Singapore too would likely prioritize certain sectors over others.

SEDS

As OSTIn or the Ministry of Trade and Industry have yet to announce a strategic direction, we believe that that is part of the reason why there are currently no specific regulations in place for launch companies here. In the past, launches have occurred in other countries and so, the handful of companies that endeavour to have launch activities would likely be the ones that face the most issues. One interviewee noted that Singapore’s airspace and maritime space are already extremely crowded, which could further complicate the development of regulations for facilitating launches in this area.

Companies

### **Geospatial Technology**

Another company felt that the government was to be commended for having foresight in emerging areas of space technology.

One interviewee praised the local government for being “forward-looking” in terms of geospatial technology. The interviewee stated that there were already personnel working on geospatial technology before the turn of the century and that this has allowed new companies to tap on existing talent. Additionally, the interviewee found that the Singapore Land Authority has been very supportive of geospatial imaging. Some hurdles that may have made such activities difficult have also been since removed. For example, the interviewee said that in the early 2000s satellite images had to be cleared by the Singapore Police Force and other relevant authorities, but this requirement has since been removed.



*Photo by Charles Deluvio*

## PUBLIC SECTOR, GOVERNMENT SUPPORT AND GRASSROOTS INITIATIVES

When John F. Kennedy said “We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard,” it emphasized the role of the government in developing a robust space program. The space program was an endeavour that seemed radical and achieving its intended goals seemed virtually impossible. However, that wasn’t the first nor last time that the government stepped in to aid in solving problems that seemed Herculean. Even today, with many private companies doing a significant amount of heavy lifting in terms of space innovations, the government remains a key part of the equation – often as a customer or a financier, or even both. As Singapore’s role in the global space story evolves, stakeholders would be wise to remain cognizant of how deeply the government is intertwined with the industry and how that spills over to other areas.

In this section, respondents were asked for their opinions on the government’s role and support in Singapore, in terms of economic support and facilitating communication. In addition, multiple suggestions were discussed regarding further support that can be provided by the government. Lastly, the issue of whether a space agency was needed in Singapore also attracted diverse opinions. In general, the responses pointed to good governmental support but also raised areas where improvements could be made for greater efficiency and development.

In general, the ‘Ancillary’ group provided more detailed responses in this section. This was somewhat surprising, initially, as one would expect the ‘Company’ group to have stronger opinions on the topic of government support. While this could potentially be credited to companies supporting a free market ideology, the more likely reason is that the ‘Ancillary’ group is better able to view the industry from a macroeconomic viewpoint. Hence, they can potentially see the gaps and bridges between the public and private sector better and, as a result, have more thoughts on it.

## Economic Support and Funding

Almost all respondents commended the ongoing efforts of the government to enable and facilitate the growth of the space sector. That being said, several interviewees did raise potential limitations that the industry faces currently and suggested measures that the government could take to help the sector further.

### Existing Support

Respondents from both the ‘Company’ and ‘Ancillary’ groups generally lauded existing governmental efforts. Most notable was EDB’s support, which extended to both start-ups as well as multi-national companies which sought to start operations here.

Many companies mentioned that they have received generous and structured support from EDB and that it has been useful for them. The government’s supportiveness has also been reflected in the implementation of several incentives and useful schemes in terms of grants and fund matching (e.g. EDB government schemes<sup>15</sup>). One interviewee opined that the government has placed a big focus on the space industry as an engine of growth for Singapore, putting in place a funding structure that is favourable for spinning off start-ups.

However, some interviewees felt that certain areas, such as the launch services industry have been overlooked, as they feel that Singapore’s space industry incentives for companies usually focus on satellites and launching hardware. It was also mentioned that Singapore typically focuses on smart city implementations and software uses following satellite launches, but much less so for software used in the satellite manufacturing phase.

Almost all interviewees were confident that the government has already helped to push Singapore in the right direction, with regards to the space industry. Several interviewees understood the uncertainty and decisions that were ahead of us, stating that this was “a new phase for the country”. Given that OSTIn seems to be coordinating these efforts, there was an impression amongst the interviewees that the focus of our push towards space would likely be more economic than academic. While they felt that the two areas could be aligned, they were hopeful to see this movement in the space scene.

In addition to OSTIn, interviewees felt that the appointment of our first UNOOSA delegate was an indication of Singapore’s interest in the global conversation on space. Generally, the interviewees welcome such action as they believe that the Singaporean government is capable of intervening strategically and achieving its targets.

Lastly, interviewees also discussed the role of government in growing an industry. In the case of space, one interviewee stated that fostering the improvement of critical infrastructure for space was something the government has done well. In addition to that, general schemes like the Entrepass, plans laid out by Enterprise Singapore, and the efforts of the EDB were also said to have been beneficial to growing the space industry.

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<sup>15</sup> The EDB has had several schemes through the years in order to attract companies to set up or develop their businesses in Singapore. In 2019, the EDB, through a combination of schemes and sources, attracted SGD 9 billion in Total Business Expenditure per annum. When the new projects are fully implemented, they will create 32,814 new jobs in the coming years with a projected contribution of SGD 29.4 billion in Value-Added per annum. The EDB’s current list of schemes, in the areas of Growth, Capability Development, and Productivity can be found [here on their website](#).

### **Area of Improvements and Limitations—Grants and Co-Investment**

Without prejudice to the government's efforts hitherto, interviewees from the 'Ancillary' group suggested that perhaps even more support could be given in the form of grants or co-investments. The 'SEDS' group, however, also expressed some potential limitations to such schemes.

Interviewees suggested areas of improvement when it came to government support. The same respondents did, however, appreciate that the government likely had to balance between funding for start-ups, research, and the government itself.

In the area of grants and funding, some interviewees note a lack of action. They claim that the lack of grant calls for space (where the last one was probably 5 years ago) could send the wrong impression – that we're not engaging in space research. However, it was also noted that there were funds for satellite development and to pursue pioneering technology. Even in the realm of start-ups, more funding would definitely be helpful. Several raised points on how the European Space Agency is far more liberal with grants for academia and industry. That being said, some start-ups have not had much issues getting funding. That led to another point being raised about what exactly the government considers fundable. Interviewees suggested that transparency on what ventures are supported would be helpful. Another respondent drew parallels to Singapore's struggle for food security<sup>16</sup> and how the government had more specific goals in that area, suggesting that similarly well-defined goals in the space sector would be beneficial.

Co-investment was raised as another government-initiated funding mechanism. Government investment firms have been known to employ this as a tactic in the past and one interviewee said that the government should limit itself to purely co-investing. They cautioned against trying to lead any investments, much less set any terms, due to the potential hazard of crowding out private investors.

Based on our understanding, the government is currently working with partner agencies to support companies on EDB's radar with grants where appropriate. That aside, agencies like Enterprise Singapore do already have several grants and schemes in place to help start-ups. Through their investment arm – SEEDS Capital – they also co-invest in *deep-tech* companies. Other government subsidiaries, like Heliconia Capital Management Pte Ltd, also attempt to catalyse growth capital in Singapore through initiatives like the 'Co-Investment Programme'.

However, one has to ultimately be aware that any support that is channelled towards the private sector from public coffers will likely be scrutinized to ensure that the taxpayer's money is being well spent.

Ancillary

SEDS

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<sup>16</sup> Originally the mandate of the Primary Production Department (formed in 1959), which went on to restructure into the Agri-Food and Veterinary Authority in 2000, was to ensure food supply resilience, food safety, animal health and welfare, and plant health. They do this by transferring technology to farmers after conducting R&D on breeding, nutrition, disease control, production systems, and post-harvest technology. The government's intervention in this area has been praised in many international settings. Dr Graziano da Silva, the Director-General of the Food and Agriculture Organisation of the United Nations said "The world can learn from Singapore's success stories. Singapore has made efforts particularly, to maximise productivity from very limited land resources. Commercial indoor and rooftop vegetable farms are opening and other urban and peri-urban agricultural initiatives are taking shape."

### **Areas of Improvements and Limitations—Government-Led Demand and Contracts**

Interviewees from the ‘Company’ and ‘Ancillary Services’ groups were of the opinion that government-led demand would be a great help for the budding space industry. The ‘SEDS’ group agreed but also highlighted some limitations in creating such demand might face.

Companies

One interviewee suggested that the government and government institutions would help greatly if they became clients of new space companies. For example, in the context of launch services, this might mean having more governmental demand for satellites to be sent up into space and to have more space exploration missions. Creating more business for the space sector in this way would be beneficial for the growth of the space ecosystem.

Ancillary

Many ‘Ancillary’ interviewees stated that government-led demand could be a key form of support. Having the government as an anchor customer would supposedly reduce the inherent risk associated with a company, as well as provide a revenue mechanism. This would be a more effective measure if start-ups had knowledge of the government’s needs. One interviewee cited the example of the US Air Force Demo Day, where start-ups get direct opportunities to plug themselves into the defence network. Another interviewee claimed that early adoption of quantum communications could occur within industries that were particularly interested in data security, making the civil sector a prime customer.

SEDS

One interviewee raised that internal competition for tenders from organisations like MINDEF, which usually is a large client for space technology, is difficult for start-ups. They felt so because a start-up has to bid for certain tenders against established companies like ST Engineering, which are more reliable and established, making it “close to impossible” for start-ups to get a tender. This leads to a perception that the government will contract companies which are more established and, hence, won’t go under during the project.

Singapore’s public sector has been known to employ new and innovative solutions as a means of demand generation in the past. While government lead demand is far more obvious in certain mature industries, like construction<sup>17</sup>, it has also been present in other high-tech industries. For instance, Ms Vivien Chow<sup>18</sup> has stated that if there are solutions available in the market, they would be adopted through the usual procurement procedure if suitable. One respondent stated that a government would want the whole ecosystem to grow, likely implying that both start-ups as well as “local champions”, like ST Engineering, would be equally eligible for contracts.

That being said, it is worth noting that a space agency or coordinating office would likely have limitations due to the fact that it is not a procurement agency for such contracts. Several respondents noted that when it comes to government contracts, there must be a real need for the company’s business and that the business must be cost-efficient. One respondent highlighted that, after all, EDB has a fiduciary duty to protect the taxpayer’s money. The interviewee commented that if a government agency does pursue policy in this area, there would likely be constraints on it and these government contracts would have to outline clear deliverables for the company.

<sup>17</sup> BCA forecasts that the public sector will continue to lead demand and is expected to contribute S\$16 billion to S\$20 billion per year from 2021 to 2024 with building projects and civil engineering works each taking up about half of the demand.

<sup>18</sup> Ms Vivien Chow, Director of Applied Innovation and Partnerships at GovTech Singapore, made these comments at the Supercomputing Asia Conference 2018.

**Areas of Improvements and Limitations—Early Stage Support for Start-ups**

Generally, the 'Ancillary' groups felt that early stage support was important but that the support should be meant for unforeseen circumstances.

Ancillary

Interviewees also stated that early stage support for space companies would be highly crucial, especially in such an economically tumultuous time. Many (hardware) companies in this industry are usually unable to overcome unexpected hurdles in their early days due to the high costs associated with the development of their solutions. However, the interviewees did note that the support should primarily be aimed at helping companies overcome unexpected hurdles quicker and that if a company couldn't survive without government support, they probably wouldn't survive anyway.

## Communication Between Institutions

Interviewees were keenly aware that space is a broad domain and no single entity could be expected to know how everything works. Indeed, communication was a particularly persistent topic that was raised by the interviewees. Hence, besides economic suggestions, some respondents also raised how greater communication could be facilitated between the major societal institutions – the government, industry, academia, and the public. The suggestions not only involve a top-down approach where the government takes the lead—for example, by providing insight it is privy to—but also a bottom-up approach where industry and those in academia facilitate better communication and collaboration. These communication-centric views, unsurprisingly, were largely espoused by the ‘Ancillary’ group, who often play the role of bridging the gap between different stakeholders.

### Communication Between Government and Non-Government Entities

The benefits of more open and deeper communication between entities was highlighted, with particular emphasis on how it would lead to better synergy.

Interviewees suggested that the government could also help by aiding industry in problem discovery. They pointed out that the government was uniquely positioned to be knowledgeable about not just space technology but the potential uses for it in other industries. Even otherwise, the government had the resources to investigate how best to apply certain, incredibly specialised data. One interviewee suggested that the government could play an active role in open-sourcing the data and allowing innovative minds to derive value from space industry data.

Interviewees also raised the point that large companies, especially government-linked corporations (GLC), should be more transparent about their decision-making process when it comes to working with companies – especially when IP is involved. They felt that unless a GLC is focused primarily on building a portfolio of IP, GLCs would benefit more greatly from actually communicating their own pain points for the researchers to tackle.

Some interviewees understood that OSTIn’s role was more as an office than an agency and so, it was unfair to expect them to lay out roadmaps. That being said, they claimed that OSTIn would still need to consult stakeholders deeply in order to set policy. This was particularly true because of the ambiguity of the space sector as compared to other initiatives like ‘Smart Nation’. In order to do so, interviewees felt that there should be a feedback avenue to OSTIn to keep them aware of the reality on the ground.

### Better Communication Across Entities

Some of the existing tensions within and between entities were raised, highlighting the inefficiencies that may be hindering the progress and accessibility of the space sector.

Some interviewees remarked that research efforts by local universities are often fragmented. There is minimal sharing and collaboration, leading to duplication and wastage of resources. They also mentioned that they would prefer it if facilities were centralized, as shared infrastructure, assets, and talent would make the industry more nimble, and that local collaboration should be a key first step prior to broader collaborative efforts with other countries.

Communication within academia, the funding agencies, and the government as a whole was described to have a hierarchical structure, where the information is passed through the senior management of the research institute. This was said to have been detrimental because by the time the senior management in universities are aware of the possible research topics the community is already lagging behind the rest of the world as the topics are no longer cutting edge. Interviewees stated that as senior management supervise the funding for many different research groups, it is difficult for them to have a deep and comprehensive understanding of every upcoming research field. This further supported the notion of a grassroots approach of communication between agencies and academia. Some interviewees also felt that the communication had to be particularly solid between the scientific community and the funding agencies themselves.

Communication between the industry and the public is also highly necessary. This has greater implications on the area of talent but interviewees raised the point that there should be more measures to enhance the population's appreciation of the role space and space technologies play in their lives<sup>19</sup>.

### **Public Buy-In**

Some interviewees argued that the public had to be a willing stakeholder in the development of the space sector, especially given the high cost and apparent inaccessibility of the industry.

The government's role was further reemphasized with regards to public buy-in for the sustainability of the space industry. One major reason stated for having the public's buy-in was to justify the cost of the space projects. One interviewee stated how the Hubble Space Telescope, in the US, was truly incredible in its own regard. However, when it published its first images, they were underwhelming for the public. This led to efforts to improve the quality of the images in order to justify the massive expenditure behind the project.

Another argument for seeking the public's buy-in would be to justify expenditures or strategies in other areas of research, like climate change, which would be extremely difficult without space technologies, like Earth observation satellites. It was noted that the media also plays a big role in this aspect by showing people the relevance to space and keeping people interested. However, the (perceived) lack of development in the area means that space is not covered frequently. This has an unexpected effect on the next generation of space industry workers.

One interviewee explained that a lack of positive coverage hurts the talent pool for the industry as Asian parents, who typically have a larger say in their children's careers than Western parents, don't see space as a flourishing or stable industry.

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<sup>19</sup> A common anecdote that is often cited is how GPS – a military invention that was originally hard to justify due to its high cost and low utility – has become ubiquitous in today's day and age. However, like the GPS, space-based technologies have time and time again produced inventions that have led to amazing innovations and an immeasurable amount of global economic value. Space Angels and the Silicon Valley Bank have [published a report](#) titled “The GPS Playbook: How a space-based technology generated the largest venture outcomes in history” which discusses the massive contributions and potential of space-based technologies.

## Grassroots Initiatives

Most interviewees agreed that a grassroots approach should be considered for collaboration and funding, citing that doing so would lead to more effective and efficient developments in the industry.

### Collaboration and Encouraging Shared Resources

Some interviewees agreed upon the notion that collaboration should be encouraged and provided suggestions, albeit specific to different situations, on how collaboration can be encouraged.

One interviewee has suggested that even without a formal local space agency “there is still the ability to combine capabilities in Singapore in order to do something good.” The interviewee suggested that perhaps initiatives from the ground up may be even better than those from the top down. Some ingredients suggested to make this possible was 1) shared infrastructure, 2) shared assets, and 3) shared talent. The company itself started off having a jet propulsion arm, but has evolved to have other capabilities. Having understood the difficulties of starting up a space company, the company now desires to support new start-ups be it by acting as an assembly and integration centre, or assisting in the storage of satellites. By having more arrangements such as these and by having a collaborative and symbiotic relationship with other space companies, a bustling space ecosystem can be built from the grassroots.

Companies

To reiterate the importance of emerging companies in the local space ecosystem, an interviewee explained how other entities such as universities are limited in what they can do to grow the ecosystem. If a university renders assistance to such projects, problems may be faced down the road. These include IP and licensing issues which arise because universities have to be accountable when it comes to how resources are being expended. Only companies that have had some success and are in the position to help others have the necessary freedom from such institutional hurdles.

Ancillary

An interviewee suggested that collaboration between companies should be made easier and even encouraged. In particular, one interviewee felt that collaboration between GLCs and smaller companies in particular could be encouraged if GLCs were more transparent about their decision-making process.

### A Grassroots Approach to Research

A change in the current approach to research, especially in regards to funding, was recommended.

Ancillary

Some interviewees claimed that a grassroots approach to supporting research was more necessary, wherein the funding agencies study the current issues and pain points of the scientific community in order to fund relevant and interesting research topics. Another response stated that in order to improve the communication between program managers (at the funding agency) and the scientific community, was to adopt the European or American model of hiring program managers who were formerly researchers within the scientific community itself, instead of (what appears to be) the current standard where National Research Foundation (NRF) and Ministry of Education program managers do not seem to have a research background.

## Should There be a Dedicated Space Agency?

The question of whether Singapore should have a dedicated space agency attracted a myriad of answers. There were reasonable arguments both for and against having a dedicated space agency. Importantly, the government is well aware that it is not uncommon for states to have space agencies and many of our neighbours already have established their own. As is known, the government is currently assessing the need for having such an agency locally and has yet to announce whether they intend to formalise one or not.

### Yes, There Should be a Space Agency

There were several arguments in favour of a space agency, generally centred around the function it would serve as a facilitator and coordinator for the industry.

A common critique voiced by respondents was the lack of a central governing space entity that's equivalent to the USA's NASA, Japan's JAXA or India's ISRO. The respondents felt that such agencies provided a clear direction and roadmap for the nation's space agenda in terms of the scientific, exploratory and technological goals.

Interviewees noticed that efforts relating to the space industry are currently decentralized across various agencies and that there needs to be some consolidation with the setting up of a centralized space agency. Such a proposed space agency should be a place where everyone can go to when they are in doubt and required help navigating regulations. For example, as mentioned above, the application of a frequency licence can be a long and tedious process. A centralized agency could aid in facilitating and streamlining such processes.

Another important function of a space agency would be the brokering and procurement of deals with foreign space agencies and entities. Given that an individual space company in Singapore might not have a large enough influence, it would be beneficial to have a local entity to help broker deals with these foreign entities since it would have more bargaining power as a centralised government institution.

Interviewees raised arguments for the formal creation of a space agency. The key concern was that of Singapore's space strategy. Without a space agency to coordinate our national goals and provide a balance between our research targets and our economic targets, there is a fear that we will remain directionless, while the rest of the world marches forward decisively. As a result, a space agency which could be modelled after the German Aerospace Center (DLR), known for its research capabilities, and the Australian Space Agency would be apt, one respondent said.

Global dynamics seem to be shifting towards the formation of space agencies. In the past decade, at least 13 countries have established space agencies – primarily with a focus on facilitating and enabling commercial ventures to lift-off more easily. Portugal, for example, established Portugal Space, a new agency, in 2019 on the island of Santa Maria<sup>20</sup>. They intend to make it into a key spaceport for Europe's launches. One respondent opined that having a space agency in Singapore might similarly smoothen out operations by helping to coordinate ongoing activities.

<sup>20</sup> During the second World War, the Allies received authorization for the building of two airport bases. The airport is still the largest income provider of the tourism-dependent, laid-back island. This raises the question of how lives around an area, especially one that's geographically small, will be affected by the development of such industries, which can disrupt the peace and quiet of daily life.

### No, Such a Space Agency is Not Required.

The arguments against a formal agency were generally centred around having a low degree of bureaucracy by capitalising on existing agencies which are better suited for specific processes.

While some companies see the utility of a centralised space agency, other companies do not think that such an agency is necessary. One company took the view that such an agency might not make things easier but instead may introduce more regulations and more bureaucracy. Within the context of the space industry, time is of the essence. Technology becomes redundant very fast and the runway for the technology being developed is extremely short. Such legal and administrative hurdles would stultify the development of start-ups. In other words, the absence of a space agency and constant oversight might actually be beneficial for some start-ups.

The reason most interviewees felt that a formal space agency was unnecessary at the current stage was the feeling that Singapore did not need an agency to put in place a regulatory regime. Interviewees opined that Singapore's ecosystem is rather cohesive, even without formal space policies in place. Other bodies like the EDB, OSTIn, MAS, or IMDA would likely be able to set effective legislation themselves. Space agencies often serve the purpose of regulating launches and since Singapore does not do that, respondents felt that an agency was unnecessary.

One interviewee noted, however, that while it was not necessary to have a formal space agency, having a proper space agenda was extremely important. They felt that a space agency was not necessary to set an effective space agenda.

In 2019, the Pentagon (USA) also launched another space agency – the Space Development Agency – under the Department of Defence. However, the decision has been doubted in policy circles worldwide. Critics question whether more bureaucracy really is the solution to the problems of an industry that is developing rapidly.

We also found that the aforementioned example of Portugal Space, one of the world's latest space agencies, was actually established after it was managed for a decade by Portugal's FCT, their funding agency for science and technology. According to Manuel Heitor<sup>21</sup>, the reason an agency was ultimately formed was to address the increasing challenges that needed effective collaboration between private and public sector actors, both locally and internationally. This communication is expected to be particularly important because of the fact that Portugal intends to have an active spaceport.

One respondent helpfully pointed out to the fact that national space agencies often do not make regulations that apply to the space industry themselves. In the UK model, it is the Office of Communications (more commonly known as Ofcom) that does the work for their satellites such as in the areas of frequency management and insurance. In the US, different aspects of the space industry are also managed by different government agencies—the Federal Aviation Administration regulates air launches; the Federal Communications Commission regulates the use of frequency; and several other agencies are involved in national security matters.

Hence, having a space agency might not be a solution to Singapore's problems and the real issue is likely the fact that Singapore does not have a published framework for easy reference.

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<sup>21</sup> Manuel Heitor is the serving Minister for Science, Technology and Higher Education in Portugal. He made these comments in the 'Portugal Space 2030' strategy report.



## COMPETITIVE ECOSYSTEM

Sun Tzu is famous for the saying 知己知彼，百战不殆 (“Know thyself and know thy enemy; a thousand battles a thousand victories”). Competition between companies has often been thought to drive innovation. That was not always the case though. During the post-war period, based on the work of John Galbraith and Joseph Schumpeter, many believed that big firms with tremendous market power, even with a strongly interventionist government, signified a successful economy. However, conventional wisdom has shifted towards a more laissez-faire approach instead and it has proven to be rather successful over the past few decades. Ultimately, in the rivalry between competing stakeholders – be that Starlink vs OneWeb or USSR vs USA – encourages radical, innovative ideas and typically leads to greater accessibility. As Singapore attempts to inculcate and grow a competitive ecosystem, perhaps by looking at other states such as Luxembourg or Taiwan, she must remember that no two countries are fully alike and that no two countries can apply the same solutions and hope to get the same results. While Singapore doesn't consider its competitors as being “enemies”, Sun Tzu's advice should be heeded in our journey forward.

In this section, respondents discussed how every country has their own constraints to work around and how Singapore was no different. They were of the opinion that to address Singapore's competitive disadvantages, understanding them was crucial. Most respondents recognized that every coin has two sides and so Singapore, too, has her own strengths and should leverage them. Furthermore, respondents raised what they believed were desirable attributes in other ecosystems which were worth emulating.

Most responses for this section came from the industry, with more detailed responses being proffered up by the 'Company' group. This was largely expected because the industry is generally more attuned to the competitive dynamics in the marketplace. This also emphasizes the previously-mentioned need for policymakers to communicate openly with the industry.

## The Singapore Brand

While there have been concerted efforts in many sectors to emphasize the Singapore brand, one interviewee stated that “Singapore Inc” would be hard to achieve in the space sector. However, the opinions on the Singapore brand name<sup>22</sup> were generally positive, thanks to the seamless business landscape, the global networks, developed infrastructure, and local support systems. The concerns raised were about the talent pool, among other things, which was described as proficient but fleeting.

## Business Landscape

As mentioned under the ‘Regulations’ section above, Singapore has consistently been ranked among the best business friendly places in the world. Most respondents from the ‘Company’ and ‘Ancillary Services’ groups recognize that and greatly praise the effort led by the government to establish and maintain a conducive business landscape. However, some interviewees did raise the counterpoint that while Singapore is good for business, it has limitations in terms of geographic and market size.

Most companies expressed that the seamlessness of setting up a business was what made them incorporate their companies in Singapore. Singapore’s policies being highly pro-business and its neutrality in global geopolitics have made it favourable for start-ups to tap on and access the international market.

For companies that have established Singapore as a base of operations, the most frequently cited reason was the support received by the government, especially by the local economic agency, the EDB. A respondent from a satellite operator company even averred that Singapore actually did not have a market for its services as Singapore already had a national operator. Nonetheless, the decision to establish a regional headquarter in Singapore to support their Asia market was due to the support of EDB.

This support ranges from setting up of operations, application of licenses, sourcing for talents to participation in tradeshows and networking events. Overall, companies felt that they were well taken care of by EDB in terms of the business aspect of operations.

There are, of course, sub-industry specific reasons which led to companies setting up operations in Singapore. One company, which utilizes blockchain technology, chose to start its business in Singapore because there was a strong and friendly blockchain ecosystem. Singapore was described as being ahead in establishing a blockchain ecosystem and had clear regulatory rules on top of providing guidance, which made the interviewee favour Singapore considerably.

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<sup>22</sup> Technically, the most recent branding that Singapore has adopted has been the ‘Passion Made Possible’ campaign. It is an ongoing, joint effort by the EDB and the Singapore Tourism Board (STB). Given that the EDB’s and the STB’s aims and audiences are rather different, it was considered a surprising move at the time. Singapore is no stranger to branding efforts. Prior to ‘Passion Made Possible’, the EDB championed the ‘Future Ready Singapore’ campaign while the STB adopted the ‘YourSingapore’ branding. The STB previously spent SGD 200 million in ‘Singapore Roars!’ to attract more travellers in the post-SARS period of 2003 and SGD 90 million for its ‘Boost’ (Building On Opportunities to Strengthen Tourism) initiative of 2009. Both those examples were to boost tourism after a crisis. This time, as we overcome COVID-19, one has to wonder how ‘Passion Made Possible’, and by extension the EDB, will be affected by upcoming campaigns.

The interviewees valued the pragmatism and rigorous due diligence performed by the local government prior to implementing policies. They agreed that Singapore's friendships with other nations positions her well on the global stage, and they also raised that Singapore has a unique advantage of being trustworthy when it came to the management of our finances.

Ancillary

In terms of the space ecosystem, they acknowledged that the government recognizes that Singapore does not have a large role in following global trends, given our geographical size and constraints. However, the opinion that Singapore is primed to capitalize on her strength in the service sector to tap on the opportunities within the space industry's downstream service sector was brought up. Furthermore, Singapore was said to be well positioned to become the global financing hub for space, due to our reputation for having a budget surplus and being able to transparently manage money.

Companies

### **Local Infrastructure and Global Networks**

Interviewees agreed that the established infrastructure and highly globalised networks in the company-dense Singapore was one of the appealing reasons to operate locally. These conditions are seen as having allowed other industries to flourish which helped benefit the space industry by providing complementary expertise, a customer base, and avenues for collaboration.

Companies found that Singapore was one of the more developed countries in the region with a developed supply chain. Singapore's strategic location at right at the heart of South East Asia along with the deep waters of the Straits of Malacca has allowed Singapore to be a regional aviation and maritime hub. This trait of Singapore allowed it to be favourable for manufacturing and hardware-centric businesses. Alongside government efforts, one interviewee stated that if a European or United States satellite company wishes to expand into Asia, Singapore is the most likely choice. These often lead to trickle down effects as it provides downstream providers with opportunities and, therefore, business.

For software-centric businesses, particularly in the context where cloud software is utilized, one company praised the server infrastructure in Singapore due to its security and internet connectivity.

As mentioned above, Singapore was also praised for being more open to blockchain innovations. Hence, while other countries have more developed infrastructure in Space, they did not provide the same level of expertise in blockchain as Singapore.

Another company found Singapore's experience and maturity level in the field of satellites, specifically in cube satellites, to be quite high. The interviewee mentioned that Singapore purportedly has one of the highest concentrations of satellite companies in Asia and that our level of commitment to CubeSats and smallsats is high compared to other Asian countries. This makes it easier for companies to source for potential customers and partners, making it a vibrant and collaborative small satellite ecosystem.

Singapore is known to have a high business density with more than 91 businesses per 1000 people<sup>23</sup>. One of the benefits of this characteristic, caused in part by the Singapore brand, is that Singapore is one of the few countries in the world to have a diverse range of companies within a small geographical footprint.

One respondent pointed out that the above characteristic leads to a high concentration of venture capitalists (VC) in Singapore. Now, while these VCs are not purely focused on the space industry, we can assume it leads to a higher number of financing options for local companies.

Another benefit that was highlighted was that having a high density of companies aids the development of networks and collaborations. Having a diverse group of companies within Singapore, many of whom have established regional headquarters locally but have international reach, widens networks and promotes international collaboration. As most efforts in the domain of space provide benefits to Earth, these networks provide opportunities for finding partners for collaboration even when the actual use of the solution may not be in Singapore.

### **Global Talent Pool**

Respondents were generally receptive and had positive sentiments of both the local talents and the access to a greater talent pool. However, several points of tension were raised by the ‘Ancillary’ group regarding a transient workforce and internal competition between industries. Points were also raised about how the talent pool could be better developed.

Respondents generally agree that Singapore is a knowledge-based economy. While most respondents agree that Singapore might not have many graduates in the particular domain of space, they found Singapore to be welcoming to foreign talent. This allowed teams to comprise of talents with various citizenships, which promotes both diversity and knowledge transfer. An interviewee felt that drawing foreign talent to other industries, rather than just the space industry, would be beneficial for space companies in general.

Another interviewee opined that National University of Singapore (NUS) and Nanyang Technological University (NTU) produce good talent and that students are generally open to pursuing start-up routes. Another interview cited how having a well-educated talent pool, which was proficient in working and communicating in English, was a significant pull factor for Singapore. Finally, there was a sense that while human and technology resources in Singapore may be expensive, they are of good quality.

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<sup>23</sup> As of January 2020, there were approximately 5.70 million people in Singapore and 518,395 businesses, according to Singstat and ACRA respectively. Do note that this is not a commonly used nor a meaningful measure by itself. The Cayman Islands, for example, approximately had a business to population density of 2,000 businesses per 1000 people. However, that does not, by itself, imply that the Cayman Islands has a better brand or business environment than Singapore.

Respondents from the ‘Ancillary’ group felt that one of the biggest challenges in Singapore is the lack of local talents. They clarified that this does not signify that there is a lack of talented people, but that most talents are often drawn to the finance and consultancy sectors. Some interviewees believe that the solution is to get talented individuals to work and commit to something as daring as space.

The respondents also felt that Singapore’s access to a global talent pool could be a double-edged sword. They highlighted the unique nature of Singapore where there are many expatriates within a small population. This leads to a transient workforce where talents can leave as quickly as they are attracted to Singapore. Unlike countries where locals normally commit and stay in a sector, Singapore has to train talents locally to develop a workforce, while seeking talent from overseas at the same time. One respondent expressed that in areas like space law, where expertise is needed, Singapore needs to provide an environment for locals to be able to absorb knowledge from foreign experts while also getting the experts overseas to aid in developing the local workforce – one cannot happen without the other.

Singapore has a recorded history of bringing in foreign experts to grow local industries. A well-known case of this was when the late Senior Minister Lee Kuan Yew brought in John Olds<sup>24</sup>, an American banker from J.P. Morgan, in August 1998, to turn the Development Bank of Singapore into a top-tier bank.

It seems to be an open secret that Singapore lacks the requisite talents for specialized fields in space, given how new the nation is to the industry. There are government schemes which sponsor companies to bring in talents to train employees in Singapore, facilitating capability transfer inwards. These efforts have been dampened in recent years by changes to the requirements for work passes and work permits. That being said, the changes in requirements affect every industry equally and predominantly affect companies whose employees consist almost entirely of foreign nationals, with no Singaporean hires. Hence, this is less likely to be a pressing issue for homegrown companies.

In terms of developing talent, one respondent highlighted that Singapore has one of the highest concentrations of STEM talents in the region. As per our findings, two of the local universities, NUS and NTU, have established expertise in satellite technology and this expertise is predominantly found amongst the professors and graduate students.

With respect to the space industry, countries like Singapore, which have a small population, do and will always struggle with internal competition between the various industries that aim to attract talents away from other fields.

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<sup>24</sup> A Wall Street Journal [article](#) from the year 2000 argued that Olds has played a pivotal role in the growth of DBS. However, in a more recent [article](#), Emmanuel Daniel, founder of The Asian Banker, argued that Olds may not have been as pivotal as some would like to believe. Regardless, both articles discussed the intended and actual effects of bringing in foreign talents to nurture or grow local companies – finding that ultimately it has a positive effect, if managed properly and openly.

### Support Group

In the absence of a dedicated space agency, grassroot efforts have emerged and served as support systems for stakeholders in the community. Respondents from both the ‘Company’ and ‘Ancillary’ groups were grateful for the continuous support provided to them by the closely knit community.

Respondents were grateful for the support they received from relevant trade associations and organisations, which helped to foster a more vibrant space ecosystem on top of the government support extended to them. One company reportedly was extremely thankful for the great support provided to them by Singapore Space and Technology Limited (SSTL).

Respondents were also grateful for non-profit organizations such as the Space Generation Advisory Council and Students for the Exploration and Development of Space for taking the lead to assist with student development and for promoting space to the future generation that will eventually emerge to contribute to the local space scene as well.

Interviewees agreed that organizations like SSTL played a critical role in facilitating conversations through events such as the Global Space and Technology Convention and their accelerator programs. They even brokered atypical services like launch services, further facilitating development in the industry. One respondent felt that the support systems which encourage co-development and co-investments within the community were also highly necessary to continue pushing the sector forward.

## **Identifying Strengths from our Disadvantages**

Most respondents acknowledged that, like all countries, Singapore had to grapple with certain inherent limitations. However, the respondents also suggested ways in which Singapore could overcome the limitations.

### **Emerging Status**

Respondents agree that Singapore's space industry is in its nascent stage. However, there are disagreements about whether that is a beneficial label or if it's detrimental. In either case, the need for a space agency, or more specifically, a space agenda, was also raised in a more global context. Its importance was underscored to discuss how it could be beneficial to local stakeholders.

Respondents agreed that Singapore has yet to achieve the status of having an established space industry. Yet, one interviewee claimed that this made Singapore more attractive as a location to incorporate a company as opposed to already established space superpowers such as the USA and China. The interviewee labelled Singapore as an "emerging superpower" and defined it as a country that has a desire to establish presence in space, but is not quite there yet. An interviewee stated that it is the recognition of the importance of the space industry by the government, coupled with a less crowded ecosystem, which makes "emerging superpowers" attractive. This supposedly allows support to be afforded to new players who can be the pioneers in paving a new path in a nascent industry.

While being classified as an emerging space nation has its benefits, respondents in this group have also expressed their thoughts as to why this status could make Singapore a less attractive nation for prospective companies. Being an emerging nation and not having a clear agenda as a result could have further implications, such as companies experiencing difficulties in positioning themselves, leading to vague funding opportunities.

'Ancillary' group respondents had similar sentiments regarding the lack of a formal central governing space entity. The respondents felt that the Singapore government's typical wait-and-see approach could be of disservice to the recent space economy, which has been growing in recent years. By taking the lead early and capturing key markets, they felt that Singapore would be able to avoid competing in a red ocean market.

Some interviewees also felt that clear and specific goals and milestones, such as the amount invested within a specific timeframe or the number of start-ups developed within a segment of the value chain, would allow stakeholders to better position themselves to be a part of the government's master plan. They argued that this would also allow Singapore to retain her talent in the long run and assist with the development of the local workforce.

## Geographical Constraints

Respondents generally understood the constraints brought on by Singapore's geographical location. Some respondents suggested that greater regional collaboration could unlock more value and provide more cost-effective solutions for all parties involved.

Companies recognized that Singapore is a small island state and that it has a small land mass with a relatively small population. As such, companies understand that the local market is unlikely to be big enough to sustain their businesses. For sub-industries, such as launch services and remote sensing, a larger land mass would be critical for operations. However, one interviewee claimed that this constraint allows companies to target for export from inception, which allows them to compete and pit themselves with the best amongst the global market.

An interesting technical viewpoint raised was that Singapore's geographical location does have an advantage, from the perspective of launch service providers, as Singapore is located near the equator. This was said to be beneficial as it allowed companies to take advantage of having access to a wider range of inclinations and, therefore, payload. However, this benefit could only be realized if Singapore manages to overcome her small geographical size.

Interviewees also felt that until Singapore develops her own capabilities in the launch services industry, she would not be able to tap on the benefit of her proximity to the equator and would still have to rely on other nations to launch Singaporean satellites.

One interviewee noted that due to our small geographical size, the cost of land space in Singapore would undeniably be prohibitive. Regardless of the incentives provided by the government, it would not overcome the constrain of the cost, making it difficult to bootstrap start-ups as the burn rate would be high.

Some interviewees raised the point that one way to overcome the cost constraint could be to promote greater collaboration between the ASEAN nations<sup>25</sup>. The interviewees stated that such a collaboration would have to be a mutually beneficial relationship, with some nations offering cheaper land and labour, while others (like Singapore) offered their technological and managerial expertise.

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<sup>25</sup> Inter-ASEAN initiatives are definitely an area that the Singaporean government has contributed to effectively. One such major project is the Master Plan on ASEAN Connectivity 2025, where nations intend to work towards 67 initiatives (including 52 incomplete initiatives from the Master Plan on ASEAN Connectivity 2010) in the areas of Physical Connectivity, Institutional Connectivity, and People-to-People Linkages. Although not directly linked to space, the initiatives do have far-reaching implications on both the communications industry and the economy as a whole. While the goals are ambitious, the results are often harder to achieve than they appear. Only 39 of the 91 initiatives under the 2010 Plan were achieved (as of mid-2016, when the 2025 plan was detailed).

## Culture

The cultural norms of the region were a novel point that was discussed by respondents of all groups. The general consensus was that cultural norms, which rely on engagement, should change alongside the development of the space industry in Singapore.

Companies felt that it was important for there to be visible success cases. They believed that successful entrepreneurs and achievements in the field would motivate and inspire the next generation to dream big and join space companies. Many respondents felt that Singapore's success in the fields of finance and consultancy have led to many talents being diverted towards those industries. They felt that this was only exacerbated by the risk-averse culture of Singapore, whereby many would rather stick to tried and tested paths as oppose to charting a new path in the space industry. However, another interviewee opined that the local student body at least (other segments of society were not mentioned) has generally become more open to pursuing riskier start-up routes.

Some interviewees felt that Singaporeans would be more engaged with space if there were more forums dedicated to audiences who are not already knowledgeable about space. One interviewee believes that one of the reasons why there is not as much engagement around space in countries like Singapore is that those who are not directly involved in space do not care about it much.

One respondent felt that if there were more avenues to present a wider variety of perspectives, dialled down to cater to the masses, people would definitely be inspired and interested in space. They further stated that one way to enhance the general population's appreciation for space is to increase awareness of how dependent everyone is existing space infrastructure and how our standard of living could be improved with greater investment in the domain.

The general understanding was that there could definitely be more engagement opportunities and effort placed into increasing the exposure of people to space, beyond the usual platforms such as fiction and television shows.

One respondent noted how some university-centric competitions, like NASA's Big Idea Challenge enables undergraduate student groups, like SEDS Northeastern University (USA), to be a part of NASA missions by designing robots for deployment in space. They stated that this played a pivotal role in including the next-generation of space professionals into something tangible and real.

## Learning from Others

We surveyed our interviewees to ask what makes a country competitive in the space industry and what could we learn from the efforts of other nations. Several notable points were raised about what made other ecosystems attractive or unattractive.

### Attributes of Foreign Space Ecosystems

Numerous attributes were raised, which respondents found were key to a vibrant space ecosystem. These included having strong support systems, access to greater funding opportunities, costs, and having an open economy. Unsurprisingly, the 'Company' group provided many incisive responses, likely due to the fact that they would have had to consider these questions more deeply before setting up a business anywhere.

Companies had a wide range of comments about what made a country a good (or bad) place when considering the different aspects that they'd have to deal with.

*The comments have been split by region for readability. Since the attributes listed are based on the countries mentioned by the interviewees, the lack of a country under a region doesn't imply that the country doesn't have a good space ecosystem.*

## North America

### United States of America:

- The United States has a highly established start-up and space ecosystem which provides extensive support for new entrants. New companies are able to heed the tried and tested path of successful companies before them.
- However, the lack of a United States citizenship may preclude it as an option as there are tight regulations that deters foreign ownership of companies within the industry.

### Canada:

- Canada provides a strong outer space ecosystem for space start-ups as well. An interviewee highlighted that the American and Canadian systems are largely similar, implying that familiarity with one is often translatable to the other.

## Europe

### United Kingdom:

- One respondent explained how they started a company in Singapore but expanded to the UK. Through this, the company was able to connect with the European Space Agency from the get-go, which provided several grants to the company.
- Several respondents have raised concerns over the harsh regulatory environment in the UK which resulted in some start-ups having to wait for years in order to get regulatory approval to perform certain operations. One company felt that this was extremely dangerous for young businesses since capital would continue to be burnt while waiting.

## Oceania

### Australia & New Zealand

- Australia and New Zealand were the most cited alternative to Singapore as a business location for space companies. Several companies felt that, in the context of satellite operators seeking to cover the Asia Pacific and Oceania region, Australia and New Zealand were great options to set up operations.
- For the satellite sub-industry, it was mentioned that Australia had a focus on small satellites, with initiatives such as an incubator hub for start-ups in Adelaide named Lot Fourteen. The location also houses the Australian Space Agency.
- One interviewee also noted that Australia is a space technology friendly location given their vast land and terrain that can potentially replicate conditions on Mars.

## **Asia**

### **Japan, Korean, Taiwan and Hong Kong**

- A respondent from this group opined that East Asian countries like Taiwan and Korea provide a good ecosystem with a sufficiently large customer base to anchor operations.
- In Japan, it was noted that the domestic demand for space business was sufficient for businesses to survive without having to compete for contracts in the international market.
- The JAXA was also widely praised by respondents to be professional and reputable.
- One of the concerns raised by multiple respondents was the language barrier in these countries, which is often the primary factor that discourages companies from setting up their operations there.
- For satellite operators, Hong Kong was another hub, which respondents felt had similar qualities to Singapore, and was widely selected as the next best alternative they would have chosen had Singapore's government not provided support to them.

### **China:**

- Respondents had great appreciation towards China's dedicated space agency and their efforts to provide easier access to resources. The space community within China, her sound infrastructure for technology companies, and the engineering talents produced by the local universities also received great praise by respondents.
- Respondents were impressed by the progress China has made in developing their satellite market, where satellites produced are capable enough to compete on the international market.
- However, several limitations were raised with regards to the regulatory environment in China. Respondents felt that the regulations were difficult to navigate and it has been averred that the government has more control over space than commercial companies would like. This hurdle would have to be mitigated before respondents would consider operating their business in China.

### **India:**

- Like China, companies also had a great appreciation for the efforts made by the ISRO. Due to its large geographical size and population, it was highlighted that it was easy to find talent and the cheaper resources India provides were said to be very appealing to start-ups.
- Despite these benefits of a dedicated space agency, it was observed that funding was difficult to acquire because most funds were controlled by ISRO. As such the private sector has not yet fully developed.

## **Middle East**

### **United Arab Emirates:**

- Respondents noted that funding in UAE is generous and the country has an openness to foreign companies, making it conducive towards creating a start-up ecosystem.
- Additionally, the country has recently established the United Arab Emirates Space Agency which has made great progress in driving space science and research projects.

Respondents from the ancillary services provided much more general opinions about critical attributes for a successful space ecosystem. They noted that successful space industries had some form of program in most frontier technologies, like quantum computing. They also commended competing Asian economies for making large strides.

#### Ancillary

China, in particular, was cited as being successful due to their commitment to space as a national policy. One respondent raised the point that having space as a national priority and plugging it into the Belt and Road Initiative helped open up financing streams for the development of critical space infrastructure.

Another respondent expressed that the space industry could do more to engage with the media. The respondent observed that many companies do not focus on publicity and media outreach unless they cater to the B2C market. It was highlighted that for deep tech space start-ups, generating interest for the company's technology is extremely important as it would help establish connections outside of their own industry that could be critical to their success.



Photo by mentatdgt

## TALENT

After World War II ended, hundreds of German scientists, engineers, and technicians were employed under the American government, in what came to be known as Operation Paperclip. Their contributions played an important role early on, leading to the “Bumper-WAC” – the first man-made object to enter space. However, hoping to receive skilled labour in a post-war environment was not a reliable way to nurture talent within an industry. Governments realised that they would have to grow their talent internally and so they started initiatives, such as the National Space Grant College and Fellowship Program, to recruit and train citizens for a career in the space industry. Many immigrants became naturalised citizens in order to work in the space industry, which was dominated by the public sector in the past. As the private sector emerged, the need for talent grew to become even more important. As McKinsey put it, a “war for talent” had begun. While the situation now and in post-war America are starkly different, the fundamental equation has not changed – talent is necessary for progress. Nowadays, as it was then, having great talent is crucial to the development of the local space industry. Like America, Singapore too may have to be open to finding, attracting, and developing talent from all sources possible in order to create a sustainable industry.

In this section, respondents were asked their opinions on the issues they faced in terms of hiring and retaining skilled labour, as well as the role of diverse talents in the industry. Most respondents agreed that recruiting was generally difficult, especially due to the nature of the emerging space industry. However, they also shared some measures that they employed to try to overcome such challenges.

Given that the access to and the employment of talent is a pressing concern for most stakeholders in any industry, the responses were generally well distributed amongst the different groups interviewed.

## Recruitment Challenge

The common consensus amongst respondents was that recruitment of talent to the local space industry remains a challenge. Companies and research institutions reported low application rates for internship and job opportunities. Respondents have also stated that the local talent pool is limited and that the industry is characterized by high turnover rates. Some reasons for this – a nascent industry, misconceptions, and competition – were also discussed.

### Nascent Industry

Most respondents agreed on the fact that the local space industry is still in its infancy. That, coupled with some of Singapore's limitations, was cited as being part of the issue with recruitment into the industry.

Companies generally found low demand for space-related talents and poor industry awareness to be the primary reasons for their recruitment woes. Respondents stated that local space companies are small in size and few in number, resulting in limited jobs available in the field. Many companies felt that the limited demand for space-related graduates, coupled with the general lack of industry awareness in Singapore, results in fewer individuals interested in entering the industry. As such, some of the respondents noted that there was a general lack of specific expertise in Singapore's space ecosystem. One company opined that for the supply of space-related jobs to increase, more space-related companies need to be established in Singapore.

Being a nascent industry means that many local space companies are start-ups. Many of them cited difficulty in hiring talented employees due to limited resources. Many respondents stated that they did not have the capacity to expend significant time and effort to engage in prolonged searches for potential hires. As a result, companies claimed that a significant number of potential candidates were only attracted to the industry due to personal interest, which may be based on a superficial understanding of space technology and the industry. Some observed that a portion of prospective hires had misconceptions regarding the focus and capabilities of the local space industry.

Most ‘Ancillary’ respondents agreed that attracting talent into the space industry is challenging, especially given the already small workforce in Singapore and the lack of understanding of space. Respondents stated that industrial awareness was a key issue. A common perception raised was that space was not seen as being relevant. One of the respondents opined that the biggest disservice the aerospace industry did was having sustained a lack of willingness to understand how space technology affects other industries. Respondents agreed that there needs to be better messaging about all the value that space creates for other industries. A number of potential hires were reported to have misconceptions about real life space-tech capabilities. They supposedly assumed that space technology was only relevant in the scope of science fiction-esque applications. As a result, upon realising the reality of the space industry, many lost their interest in the local space scene.

Ancillary

One respondent claimed that the inherent gap between how engaged space enthusiasts are as compared to the disinterested public is a factor that ultimately leads to a lack of interest in the development of the industry. While forums and engagement play a part in trying to bridge the divide, they respondent said that engaging the public remains one of the significant hurdles for the nascent industry.

Some interviewees also claimed that most of the current workforce is unaware of career opportunities that are available in the local space industry. One respondent argued that if mid careerists could be convinced that their skills were transferrable, that their expertise was critical to growing an ecosystem, and that there were numerous opportunities in the sector, they would surely take these opportunities.

SEDS

Singapore’s small population, which results in it having a relatively constrained base of talent, has likely been a key issue for the nascent industry. Consequently, some respondents believe that the number of people who are keen to develop specialized skillsets for careers in the space industry may not be that large, particularly in comparison to other more established industries. That being said, mature markets, like the American space industry, are not immune to talent shortages either. In a 2016 study, Space & Satellite Professionals International found that the workforce was significantly older – 45- to 55-year olds – than the industry desired<sup>26</sup>. That made it difficult to recruit and develop talent, especially in the private industry.

Generally, our respondents agreed that any young industry may require some direction, guidance, and support to grow and that space was no different.

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<sup>26</sup> As per the [findings](#) by Deloitte, the median age range of top-level program managers in the American space industry was in the mid-50s, “which is the highest it’s ever been for the satellite and national security space side in several decades”. Meanwhile, the median age across all engineering fields in the U.S. was between the late 30s and early 40s.

### Common Misconceptions

Respondents across the industry generally believed that there are a number of commonly held misconceptions regarding the local space industry and that these misconceptions hamper efforts to attract talent.

While Singapore lacks specific expertise in aerospace engineering, the space industry looks at disrupting a number of different fields. In the local space industry, some companies work with upstream space technology while others develop products based on downstream space technology. As such, there is a need for companies to hire professionals from different skillsets, not just aerospace engineers. Companies seek engineers specializing in various branches of the engineering discipline, like mechanical, communication, and electrical engineering, where potential applications of space technologies may lie. Some respondents have also opined that possessing a generalized skillset is not an issue, as new hires can be easily trained to specialize in the niche technology of the respective sub-industry the company is developing products in. In fact, a respondent believed that even a “general intellectual background” is sufficient, suggesting that the flexibility may be more important than specific domain expertise when their company hires. Nevertheless, most of the companies interviewed expressed a focus on seeking employees with a background in engineering due to the heavy R&D duties involved.

While engineering skills are coveted, space companies do seek a balance in soft skills as well. Some notable soft skills are the ability to develop and maintain relationships with clients, adaptability, and problem-solving. These skills are valued by companies as many of them engage in international collaborations. However, a few respondents found that local engineering undergraduates may be lacking in terms of international exposure and the skillsets needed for such collaborations. From a broader perspective, companies have high expectations for employees to learn on the job. Being a nascent industry, experience is not necessarily a prerequisite for employers in the local space industry.

Respondents raised the point that there was a misconception about the requirements to be in the space industry, claiming that a common assumption was that a degree in aerospace engineering was the primary way to enter the space industry. However, many respondents argued that that was not true and that the skills that one would learn in any math, engineering, or physics degree would provide them with the relevant skills needed in the space industry. STEM degrees aside, respondents also noted the growing need for people with business and marketing acumen, pointing out that a technical background was not a prerequisite to joining the space industry, simply because the roles that existed in other industries, like accountants or salesmen, would also exist in the space industry. This was also particularly true for the other parts of the value chain, with one respondent saying that once the infrastructure was set up, leveraging the data would depend on multiple downstream industries that would be deeply integrated into the space ecosystem.

Another assumption that was challenged was that prior experience in space-related work was required. One interviewee cited how some students wanted to emigrate to study and gain some experience in the space industry, following which they wished to return to develop further locally. A respondent suggested that the lack of interest to start their journey in Singapore could be due to a lack of excitement regarding developments in local space industry.

Several respondents stated that the issue of interested students being dissuaded from pursuing the industry was an important matter that the government ought to address, perhaps through programs in emerging sectors like space.

### Competing Industries

The common consensus amongst the different groups was that the talent pool in Singapore tends to be drawn to competing industries, to the detriment of the local space industry. While some respondents felt that there were solutions, like raising salaries, they argued it may not be feasible.

Companies believed that attractive salaries and more stable career prospects are driving factors in pulling talent away from the space industry to other sectors, such as finance and tech. One company notes that there is a trend of local, trained engineers choosing to pursue a career in industries, most notably in finance and banking, that are perceived as more lucrative. Companies opined that these jobs may be viewed as more attractive compared to the job scope in space-related companies, where engineers have to toil comparatively long hours in R&D activities before bearing fruitful results.

Companies

Ancillary

SEDS

Respondents recognized the need to pay higher salaries in order to attract and retain good talent. However, some respondents have noted that this would be a challenge for start-ups due to the tighter budgets they operate with.

Based on our understanding, Singapore's small population size and the relatively abundant number of opportunities in other high-tech industries tend to result in fewer people applying for jobs in the local space industry. One respondent said that this was partly due to the successful push by the government, in the past decade or two, to encourage participation in other core industries. Another respondent noted that better alignment for job-seekers and careers in the space industry would be required in order to boost application rates and reduce turnovers.

## Developing Talent

In order to improve the state of talent in our industry, and in turn to improve the industry itself, respondents discussed the different measures they feel have been necessary to employ. These include both employing skilled labour from elsewhere and developing it locally, typically through universities. However, all respondents were also mindful that these solutions to develop talent would have to be dynamic to account for the trends in and around the industry.

### Expat Workforce and Outsourcing

In order to cover the gaps in talent, companies are trending toward hiring foreigners who bring specific skillsets and outsourcing general engineering work to other countries in order to be more cost effective. While the inward transfer of skills to fill up the gaps has been an ongoing government initiative, emerging limitations might change industry dynamics moving forward.

To address the issue of a small local talent pool in Singapore's space ecosystem, companies said they would hire a mix of local and foreign talent. Foreign talents help plug not only the existing labour shortages, but also fill in technological skills gaps within the industry. Given the observed lack of specific expertise in Singapore's space ecosystem, foreign professionals close the gap by providing integral knowledge for the companies' product development. This would also allow for a much-needed technology transfer to the employees, company, and the industry.

Another measure companies took to address the talent issue was outsourcing certain operations. One company reported that they maintain a small team of core, in-house engineers who only engaged in the development of the company's core technology. Other less sophisticated engineering work is outsourced to other firms in the region. Such an arrangement allowed operations to be cost-efficient while making the most out of a small talent pool.

As mentioned by an interviewee earlier in other sections, Singapore was thought to be somewhat unique in the sense that there are a lot of expatriates in the workforce, which results in a small and transient workforce, which ends up affecting how many people can commit and stay in a sector. In order to develop a community which can commit, some respondents felt that there should be opportunities at various levels and that OSTIn should be pushing towards such a target.

As mentioned under the 'Competitive Ecosystem' section, government schemes have been supportive of bringing and training talents in Singapore, especially to fill gaps in the current workforce and create inward capability transfers.

However, as also noted in other sections, the aforementioned efforts could be potentially limited by current quotas on work passes<sup>27</sup>. There are also several salary and non-salary requirements for employment passes and work permits that companies must meet. One respondent observed that some companies might struggle with these requirements, especially if they're foreign companies, operating in Singapore, that have few local hires.

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<sup>27</sup> A persistent conversation that has recently been garnering more attention has been about the intake of foreign talent. In the context of specialized talent, especially where none may be available locally, the question of open immigration policies becomes more pertinent. Policy decisions in this area will definitely be of interest to the space industry because the policies, if not well-designed, could jeopardize the knowledge-transfer and investments (particularly non-monetary) within the space sector.

## Education

Respondents generally viewed the Singaporean education system in a positive light, even though there were no space-specific programs like those offered overseas. ‘Ancillary’ respondents had more keen views on the education system and how it achieves its goals, likely due to the fact those respondents generally deal with students more frequently. That being said, all groups agreed on the fact that experiential learning was valuable in many regards and ought to be encouraged.

The current education system has been perceived by space companies as being adequate. Companies reported that local hires were well-versed in their specialized discipline and possess the ability to tackle various problems based on engineering concepts. They also reported that the hires were skilled in other hard skills paramount in the industry, such as troubleshooting, mechanical skills and project management. Companies observed that local talents were adaptable and could contribute to various fields when required. Respondents gave credit to the Singapore education system for the high standards of local graduates in their employment.

The ‘Ancillary’ interviewees were of the view that local universities played a good role in bringing together talented individuals from around the region. One respondent stated that a university’s role was to train those who are passionate about space so that they could continue within the space ecosystem. Another respondent stated that collaborations between companies and universities have been a great medium for students to find jobs within the industry instead of going into the competitive arena of academia.

One aspect in which Singapore’s universities differ from some other educational systems, like Oxbridge or University of New South Wales, in the sense that the local universities do not offer space-specific courses. One respondent raised the concern that this put Singaporean students at a disadvantage as they had lesser experience and lower calibre in the domain of space. However, the respondent did note that NTU and NUS produce good talent regardless and that student organisations, like SEDS, help push for more student involvement.

Besides the rigour of the education system contributing to the quality of local graduates, companies also lauded the existing space-related programmes in Singapore universities, which allow some professors and students to embark on space projects, such as the development of satellites and satellite systems. This was supposedly seen by the industry as a beneficial initiative for developing a talent pipeline for the space ecosystem in Singapore.

However, a few of the respondents had concerns regarding recruiting and retaining students in space-related graduate research programmes. One such example that was cited was that many of the space-related research projects were short term in length and limited in scope. Hence, it was supposedly difficult to attract talent to take up such projects. A respondent mentioned that if there were concrete projects with longer term timespans or possibly permanent research programmes, they’d be able to expand their team and recruit more individuals. One respondent mentioned that university research groups are keen to help train students in preparation for careers in the space industry and that the aforementioned measures would help boost enrolment and retention in space-related graduate research programmes.

Similarly, with regards to industry, it was pointed out that it was common for people to move around and so what was needed was to ensure that there were ample projects, start-ups or international companies with opportunities in Singapore.

Our respondents were confident that students in universities were trained to quite a high standard in the local educational system. One respondent stated that while new space players, like Luxembourg, offered comprehensive space education programs, there were plenty of space nations that emerged without dedicated space degrees and instead built on their existing manpower. Another respondent agreed and stated that students specialising in space in their course of study may be premature.

Specialization in space would require dedicated educational and training programs. A valid concern, that any government or university must ask itself is whether students would be interested to pursue these niche areas of study. Such programs would ultimately fall within the purview of universities and the fact that a dedicated university degree on space does not exist in the current education system is likely because there is little demand for such a course.

One respondent felt that the demand might rise in the future and that the discussion regarding a dedicated space course or program will keep evolving. Degree programs aside, other initiatives, such as secondments or internships in the local space industry, were touted as being valuable for both students and employers due to the experiential learning. According to a 'Space & Satellite Professionals International' 2016 report, the American space industry was suffering from 'graying' [sic] because only between 25% to 30% of space companies had drawn up plans to engage and attract younger talent through university outreach and internships.



## FINANCING

Since 2009, Space Capital has found that the cumulative amount raised in private investments by space companies totalled nearly USD 26 billion. In comparison, the Apollo program cost the United States USD 205 billion (adjusted for inflation). This simply goes to show both the extreme costs that many pioneering projects command as well as how decreasing prices are enabling companies to achieve great things. None of these achievements would be possible without the financial machines that kept them going. Ever since financiers saw that they could lend their money to promising ventures and get a higher return from it, entrepreneurship has intertwined with financing. Financing is also important for basic research, which helps push the boundaries of human knowledge. As Singapore moves forward, it has to make strategic decisions with regards to how financing is carried out within the country so as to enable a vibrant and innovative ecosystem.

In this section, respondents' discussions centred around the different elements of financing. For any industry, financing is often a key component for growth as it increases accessibility to capital for companies and allows them to innovate and build their businesses. Respondents discussed their views on funding mechanisms, the different considerations that are likely to occur when companies are seeking funding, and whether formidable funding gaps exist in the industry.

While the views raised in this section are fairly well distributed between the different groups of interviewees, the 'Ancillary' group did tend to have more detailed opinions on some matters. This was unsurprising because the ancillary group includes both investors, who are key components of the private funding route that most companies lean towards, and scientists, who are key beneficiaries of government-sponsored research.

## Funding Mechanisms

Most company and ancillary service respondents were aware of the typical funding mechanisms in place – grants for R&D and investments for commercial ventures. The general sentiment lingers around the fact that while funding is hard to come by, the opportunities are accessible. That being said, there were certain improvements suggested within the current ecosystem itself.

### Existing Mechanisms

Most respondents responded positively to the existing mechanisms and appreciated the value it provided. Some respondents even discussed the value of more directed support, be it to certain companies or fields of study, even with current limitations.

The restructuring of OSTIn, in order to capture economic opportunities and foster the growth of a thriving space industry in Singapore, was cited by interviewees as a good sign of more opportunities to come.

Some companies believed that the government has placed a big focus on the space industry as an engine of growth for Singapore, putting in place a funding structure that is favourable for spinning off start-ups. Many companies have mentioned that they received generous and structured support from EDB and that it has been useful for them. As mentioned under the ‘Regulations’ sections, the government’s support has also been reflected in the implementation of several incentives and useful schemes in terms of grants and fund matching (e.g. EDB Government Scheme).

Several funding mechanisms were discussed by the interviewees, with most government funding coming in the form of research grants under the National Research Foundation and the Ministry of Education. Some projects received funding from international sources as well. A noteworthy point that was raised was that not all research which contributed to the space industry was under a space project. Fields of study such as image processing and artificial intelligence had alternative funding opportunities available, while still being applicable to the domain of space.

As mentioned in a previous section, our understanding is that the government is currently working with partner agencies to support companies on EDB’s radar with grants where appropriate. That aside, agencies like Enterprise Singapore do already have several grants and schemes in place to help start-ups. Through their investment arm – SEEDS Capital – they also co-invest in *deep-tech* companies. Other government subsidiaries, like Heliconia Capital Management Pte Ltd, also attempt to catalyse growth capital in Singapore through initiatives like the ‘Co-Investment Programme’. That being said, one has to ultimately be aware that any support that is channelled towards the private sector from public coffers will likely be scrutinized to ensure that the taxpayer’s money is being well spent.

Another point worth noting is that OSTIn is not an official space agency (as of now, it is an office under the EDB), nor is it a procurement agency. For the time being, OSTIn is more of a central coordinating office and hence, may not be able to effectively channel funding in the form of contracts.

## Funding Considerations

In regards to funding considerations, and by extension, ways to adapt to those considerations, several points of conflict were raised between different groups of respondents and, in some cases, even within a single group of respondents. Ultimately, multiple points are raised about the different considerations that may be present in the space financing arena.

### The Singapore Market

In general, most respondents agreed that even though Singapore is a limited market, its strengths enable it to potentially incubate a financially attractive space industry. In general, there was agreement across all parties that Singapore's features definitely posed some limitations, which needed to be resolved. Some respondents even questioned whether using Singapore as a launchpad was a wise move to begin with.

Most companies agree that Singapore is a reputed and established financial centre that has also established itself as an excellent business centre and a hub for the region. Yet, with its relatively smaller size, they believe that Singapore's space ecosystem lacks a critical mass. As a matter of fact, there was one company that stated that starting abroad and then expanding into Singapore was a more strategic move for both growth and seeking investments.

Nevertheless, several of the companies that were interviewed are optimistic that there is potential for a good space ecosystem to be nurtured in Singapore due to Singapore's favourable business environment, which would in turn create a conducive environment for capital inflow.

While the interviewees all acknowledged that Singapore was a small market for almost any industry, one interviewee in particular raised the point that Singapore's features, like its geography, costs, and geopolitical position were limitations that would prevent it from truly developing a space industry for a long time. In such a case, the interviewee shared the opinion that it may be wiser to start the business elsewhere.

Some other interviewees instead suggested that Singapore's marketing should be better designed to highlight her success stories to foreign investors. One interviewee emphasized the fact that while Singapore may not have made strides in asteroid mining, it has made advancements in applying space technologies to downstream sectors and that more awareness should be raised about how that too is within the domain of space-tech.

Singaporean policies have generally been cognizant of the limitations that local start-ups face due to our small domestic market. Agencies like Enterprise Singapore have initiatives, such as Enterprise Development Grant and Market Readiness Assistance grants, aimed at helping companies expand beyond the domestic market.

One respondent noted that international expansion is often a balancing act as doing it too early could result in high costs from setting up a business in another country and the recurring overhead costs. They cited the example of Ofo<sup>28</sup>, a bike-sharing company from China which raised USD 700 million to expand overseas but did not manage to make significant returns on its investment, especially as competition heated up.

<sup>28</sup> Ofo is now mostly defunct overseas. In fact, Singapore's Land Transport Authority suspended Ofo's operating license in 2019 due to its dwindling fleet size and failure to meet regulatory requirements.

## Risk Considerations

We found that different groups agreed that some level of sophistication was needed to properly assess the risk involved in space investments. However, where the groups differed was in their judgment of how that risk is typically assessed and how they accounted for it.

Companies

Some companies claimed out that some investors, unaware of the significantly democratized and accessible nature of the space industry, hold the preconceived notion that an exorbitant budget is required to become successful in the space sector. Moreover, local funds are also often perceived as risk averse as compared to the more well-known space investors in other countries.

Ancillary

Interviewees noted several points. One interviewee stated that investing in these areas required sophistication and a framework to understand the horizons and the proportionate return on investment, citing that software and hardware solutions typically differ greatly in their horizons. Another interviewee pointed out that many VCs pool their resources together to mitigate risk in their investments. An interviewee also stated that a lack of traction in a company's offering implies that the company may be an even riskier investment.

SEDS

In order to mitigate or underestimate the risk involved, most interviewees felt that having strong governmental backing behind the industry would be a strong draw. They highlighted comparisons to how the American government's initiative of undertaking numerous public-private partnerships catalysed private investments.

Other forms of support, like government funding, typically come with their own risk assessment and caveats. The government, for example, needs to be aware of their fiduciary duty to the taxpayer and adjust their risk profile accordingly. That would likely entail that there would be certain constraints on the companies if they were to engage in such contracts. As mentioned earlier, government funding does tend to come with some conditions, like hiring requirements or transparency guidelines.

Companies

There were some companies that felt that certain sub-industries, such as the launch services industry, have been overlooked and that Singapore's incentives in the space sector were largely aimed at companies that usually focus on satellites and launching hardware. Some interviewees brought up how Singapore typically focuses on smart city implementations and software uses that followed satellite launches, while much less attention was given to software used in the satellite manufacturing phase itself.

Ancillary

Respondents had the opinion that certain areas, like software, would definitely attract more interest than hardware, simply due to the risk profile and investment horizons. Yet, one interviewee did note that software solutions could still incur high capital expenditure as customer acquisition costs for software could be significantly high.

All across the world, we found that the common stance held by both governments and industry players at large is that if a company is truly solving a compelling problem and has a technological edge, they will receive the support necessary.

SEDS

However, one respondent raised that the ASEAN region may, reasonably, have a bias for software over infrastructure investments when it comes to space<sup>29</sup>. They felt this was the case because most ASEAN countries prioritize fiscal prudence over glamourous (and typically expensive) projects when it comes to space<sup>30</sup>.

Ancillary

### Research Funding

The different groups of respondents had slightly differing opinions on how and where the money should be allocated.

One interviewee raised the point that one aspect in which governments could be (and had been) potentially helpful was in using public funding to incubate deep tech to higher Technology Readiness Levels, almost to a point where it could be validated.

Moreover, other than working on technology at the forefront of knowledge, some interviewees believed that good research would be more readily funded, with resources being distributed appropriately, if the program managers for government funds were also from research backgrounds.

SEDS

In Singapore, entities like the NRF and the Ministry of Education play leading roles in determining the direction and funding for research. However, other agencies have also stepped up every now and then to provide resources for institutional research. One respondent noted that while the government could generally be expected to support companies and research with grants, there would have to be added bureaucracy to ensure that the taxpayer's money was being spent and managed well. Another respondent also highlighted that if a government body is to fund research, it is reasonable to assume that they would fund the research which showed the most promise in terms of holistic development of society.

<sup>29</sup> We found this to be a global trend, hastened by COVID-19. Space Capital's 2020 Q2 [report](#) found an 85% decline quarter-over-quarter against Q1 in terms of infrastructure investment. On the software side, however, USD 5.3 billion was invested in these companies globally (bulk of it being in the US). The report also found that VC funding overall was up 4% year-over-year for H1 2020 versus H1 2019. It is worth noting that these trends could change post-COVID.

<sup>30</sup> As mentioned in the *Global Overview > Main Players > Governments > Southeast Asia subsection* earlier in the report, this was found to be true. Assuming these nations do keep increasing government spending on space, whether this trend will persist for good is another question. The reason for the uncertainty is that, historically, as a nation gains more experience in space projects, they tend to create their own infrastructure for more bespoke projects – especially in the realm of security.

## Value Proposition

We learnt that there were several key considerations when it came to assessing the overall value proposition of a company: technology, business model, market size, competition, team, cost-effectiveness, and a commercialisation strategy.

The technology underneath the company's offering was raised as being a very important consideration when seeking funding. One interviewee stated that understanding how the technology is collected at the infrastructure level and how it gets distributed to society is crucial as well.

The business model was also raised as an important funding consideration. Key questions that were raised in this regard had to do with whether the company was offering a marketplace, in which case factors like transaction fees and scale were significant. On the other hand, if the company was selling a service or making a widget, the sources of revenue and whether they were recurring were raised as more central questions.

The market size was also an important consideration. One interviewee said that VC firms typically invest in areas such as data usage for terrestrial applications. They noted that, for more radical ideas with smaller markets, like lunar servicing, angel investors have more leeway than VC firms. What is likely to happen, the interviewee claimed, is that the government would eventually be the anchor customer for developments like commercial human lunar transportation<sup>31</sup> and following that, venture funds would channel money towards these markets.

Improving a company's value proposition by finding innovative ways to leverage space was cited as being useful in attracting financing. One interviewee stated that incumbents in relatively mature areas of space, such as small launches, will likely continue to get funding while new entrants in those areas would not as they wouldn't have a unique edge. In contrast, companies that can exploit the existing infrastructure to utilize data in order to create commercial returns would be well positioned for investment.

Another beneficial value proposition cited was to have experienced founders as it was seen as a method to validate the technical risks associated with a start-up.

We understand that having an interim, early commercialisation plan aimed at gaining revenue or a proof of value even before the completion of the fully developed final product was likely to help in building a case for funding as well. One respondent made the observation that successful companies offered value propositions which met a real need for the company's business and that the businesses had to be cost-efficient. Hence, a company could be working towards a larger (more celestial) goal and still bring in funding with a slightly different interim goal. Two such companies – Transcelestia Technologies, a company that uses laser communications, and Addvalue, a company that sold satellite terminals – provided for an unmet market need while working towards a larger goal.

<sup>31</sup> While not for lunar transportation, NASA announced a new contract, in mid-September of 2020, for the 'Purchase of Lunar Regolith and/or Rock Materials from Contractor'. The contract itself contains some interesting points, such as NASA saying that they'd accept delivery on the moon, but the more interesting implications are about how NASA seems to be gearing up to be a customer for high-tech endeavours such as in situ resource utilization. This adds more credence and weight to the continual discussions on asteroid mining and water extraction from celestial bodies.

## Funding Gaps

Generally, there has been a consensus between all respondents that obtaining private funding is largely tough in the space industry. One interviewee noted that the problem of funding is true for most industries but that the space funding scene has it worse. When asked about it, interviewees cited several reasons why they may exist.

### Why They Exist – Investor's Understanding

We learnt that the different groups had different perceptions as to why an investor would not want to invest, based on their understanding of the industry.

Companies believed that, oftentimes, investors still possess a misguided notion that in order to become a successful space company, one requires an exorbitant budget, not realizing that space technology has become increasingly democratized and is more accessible than ever before today.

Other than misguided notions, companies believed that most investors and VCs within our local financing ecosystem are not very familiar with space companies, their product applications and back end processes. This lack of familiarity was stark, with a number of companies mentioning that many a time during pitching, they had to explain basic parts of back-end processes, such as what is a simulator and why it was needed.

One interviewee did acknowledge that it may be true that investors were not as knowledgeable about the underlying technology and systems as someone in the space industry, especially when the technology itself is poised as being a breakthrough or unique. However, the interviewee also pointed out that, regardless, the onus was on the start-ups to successfully explain themselves and their value proposition when pitching rather than expecting the audience to do the work.

The interviewees also reported that hardware companies, which typically have low margins, were probably not appropriate for many venture firms who provided growth capital. In comparison, other growing companies with more opportunity would likely attract more venture funding.

Based on our understanding, the government is likely to be aware of the funding difficulties present, particularly those for early-stage start-ups. In the past, government entities have taken steps to try and reduce such funding gaps (among other gaps) in different industries, such as the major push for biotechnology in the 2000's. We also believe that any such effort to mitigate the effects of the lack of funding will involve multiple agencies. One respondent pointed out that deep tech start-ups may find it difficult to raise Series A and subsequent rounds because the route to commercialization is fairly long and capital intensive, something investors may not be willing to consider.

### Why They Exist – Risk Profile

We found that different groups seemed to generally agree on the notion that local funds are typically more risk averse<sup>32</sup> than their foreign peers.

Companies

Local funds are often perceived as risk averse, perhaps in some nature due to our conservative local culture and mindsets. One company mentioned that it is much easier obtaining a big investment overseas, then expanding back to Singapore, as not many local VCs are comfortable with the amounts that space companies ask for.

Ancillary

Some interviewees also had the perception that the local investors were typically more risk averse than investors in Silicon Valley, where there are VC funds dedicated to space.

Ancillary

### Why They Exist – Milestones

One group discussed a failure to have met certain milestones (which could be a result of being in a small domestic market), would affect a company's attractiveness.

Some factors that were raised as being standard milestones for VCs when looking at providing growth capital were:

- USD 1 million in customer revenue prior to Series A, ideally recurring
- USD 5 million in customer revenue prior to Series B, but typically more
- Significant traction

The interviewee speculated that if these criteria were not met by companies, it was unlikely they would receive funding from venture funds.

Companies

### Why They Exist – Equity

We found one group felt that the equity model that some start-ups commonly agree to in Singapore is flawed.

Companies felt that foreign VCs, such as those based in the US and China, often require less equity and have investors that are more comfortable with investing in the earlier stages, thus providing greater support for early rounds of fundraising. With local companies, companies tend to give up too much equity in early stages, thus making subsequent fundraising rounds more difficult. Companies felt that this may have led to funding gaps due to a lack of compatible companies.

<sup>32</sup> A minor and ultimately unimportant point is that 'risk-averse' is a hard quality to quantify. Some argue that it depends on whether the investor's portfolio has a beta value less than 1, if an investor is diversified enough, are majority of their holdings in blue chips companies, and many more arbitrarily defined standards. Investors who are typically associated with low-risk investments would invest in start-ups, however unlikely, if they felt it was a low-risk venture for some reason. What definition the respondents considered when calling financiers risk averse, even though the amount of money being allocated to space is growing, is unclear.

### Why They Exist – Feasibility of Research Projects

We found that there were particularly high standards required when assessing a research project's feasibility.

A primary concern that was raised happened to be regarding the feasibility of using certain technologies. As mentioned elsewhere, one way start-ups could attract more funding would be through using founders that validated some of the technical risks through their own experience. Another case which was cited had to do with the NRF's scepticism on certain projects. The interviewee stated that due to the poor track record of university-led nanosatellites operating in space, the NRF had its doubts. However, after being reassured that the processes followed would be systematic and that the project was solid, they decided to provide the development grant.

### Why They Exist – Chasing Trends

We learnt that there is a spectrum within the ancillary services about the net benefits of being first in an emerging area of research.

One possible reason, that was raised, for such a gap is the notion that the local space industry may be lagging behind the world, chasing trends rather than being cutting-edge.

That being said, another interviewee pointed out the approach to 'wait-and-see' before allocating significant resources was beneficial, in the grander scheme of things and that it could be seen as a result of more careful and purposeful planning. They argued that the trade-off incurred – that Singapore may not be the first mover in a certain field – was worth the added caution of smart planning.

### Changing Tides

We learnt that companies are generally hopeful about the future of space financing.

More recently, things seem to be taking a positive turn as companies have seen a slowly growing interest in space-based applications, with local investors starting to understand and acknowledge that even though there are high risks at the start of such commercial endeavours, technical success accompanied by economic feasibility is achievable. Despite this, some feel that perhaps more initiative could be done from a governmental standpoint, to lead the way and provide additional confidence to external investors.



*Photo by Rakicevic Nenad*

## TECHNOLOGY CAPABILITIES

Developing our capabilities leads to more opportunities. Many technologies that used to reside purely in the realm of sci-fi are now available to us as everyday items. The creation of these inventions, commercialising them, and ultimately using them to create even better innovations are great boons, contributing to the growth and employment within a country. Over the past 10 years the local space industry has acquired homegrown expertise in the manufacturing of nanosatellites and traditional satellite communication services. Recently, the focus has turned to developing new emerging technologies which have the potential to disrupt the global space industry. To spur these efforts, the government has set up programmes and supported R&D as well as entrepreneurship in the local space industry.

In this section, respondents were asked their views on emerging technologies and the measures implemented to support the development of the local technological capabilities. While generally positive and hopeful, there were some concerns raised about how the capabilities were being sustained and transferred.

All groups had appropriate responses in regards to technology capabilities. The ‘Ancillary’ and ‘SEDS’ groups were marginally more vocal.

## Development of Capabilities

Most respondents were aware of many of the efforts that was being undertaken by Singapore to develop better technological capabilities locally. They also believed that these measures were generally effective in improving Singapore's R&D landscape. However, the opinions regarding how effectively R&D or industry knowledge could transform into real, commercial innovations were more coloured.

## Research and Development

One respondent noted that Singapore's and, to a larger extent, Asia's space industry has substantial potential in the area of R&D, but has been lagging behind the more established Western space nations. Another interviewee felt that if Singapore is to achieve the same quality of space R&D as America, it has to go through the same rite of passage, which will take time and can't be avoided. In order to bridge the gap, the government has supported R&D of technology that has shown commercial potential. Respondents have generally agreed that these efforts have been fairly effective in improving the technological capabilities of the local space industry, but that certain issues still have to be considered before committing to any trade-offs which may end up being detrimental in the long term.

Respondents cited the benefit of collaboration in the R&D process. We have detailed in other sections, particularly in the 'Competitive Ecosystem' section, how all our respondents viewed collaboration as beneficial. They mentioned that industry-academia partnerships are great for many purposes. However, in the context of developing knowledge, some respondents stated how there must still be a place for upstream technology development and more theoretical or esoteric research work. They felt that the integrity of the research community should be maintained and that the goal of scientific research and understanding should not be superseded by discussions regarding commercial viability. One interviewee had the sentiment that the scientific community should not be chasing trends and should instead remain focused on scientific enquiry.

Another interesting issue that was raised had to do with the leakage of knowledge. One interviewee stated that knowledge leaks out because people join the local space industry, figure out the tricks of the trade and essential information, but fail to properly pass on this information to others within the organisation. The interviewee stated that COVID-19 has made this problem particularly difficult.

Based on the evidence thus far, the government has been supportive of R&D efforts as a whole. For space research in particular, there have been some funds allocated for areas like satellite and communications research. Given the diverse nature of research projects in academia, it is worth noting that it will be unlikely that the government (or any entity) can focus all their support on deep technology endeavours alone, as they have to look at other areas, such as applied research and commercialisation endeavours as well.

## **Innovation and Entrepreneurship**

Several local space start-ups are spun off<sup>33</sup> from university research groups, where the underlying technology that was developed with the support of an academic or research institution is commercialised. Most respondents agreed that more improvements could be made in order to create a sustainable pipeline of newly researched technology being commercialised and innovative start-ups being created.

Engaging youth at an early stage was raised as being important to the development of knowledge and connections. In the example given, one interviewee stated how the young founder of a prominent space technology start-up in Singapore likely got their inspiration from attending events about the space industry, where the seed for innovation was planted.

Interviewees also considered the transfer of knowledge in the industry to be beneficial for the space ecosystem. One interviewee stated that the phases of life where entrepreneurship was more feasible was either in one's early 20s, before the responsibilities set in, or in their 50s, when one has saved up sufficiently, gained experience, and lesser familial responsibilities. Hence, the interviewee felt that getting the more experienced folks to come in as mentors to the younger entrepreneurs could help in the transfer of knowledge.

An additional component discovered when discussing the development of tech capabilities was how innovation could be encouraged in regards to having a space agenda, or lack thereof. It was noted that because Singapore lacked a distinct space policy, there was no clear indication of a direction of growth for the industry. While the flaws of such a system have been discussed in other sections, the silver lining was stated to be the freedom that followed. One respondent felt that with a formal dictum on the sectors that the government supports, several entrepreneurs may have been discouraged from following their true passions in the space sector if they were not in line with Singapore's strategic goals. Moreover, as discussed in the 'Competitive Ecosystem' section, the breaking down of barriers definitely helped encourage innovation from younger entrepreneurs. One respondent cited the example of programs under Entrepreneur First and Antler, which has made the risk associated with start-ups much lower and incentivised more people to create innovative start-ups.

As mentioned in a prior section, one respondent felt that the underutilization of IP in Singapore could be because of the risk appetite of the professors in relation to whether they thought it would be worthwhile to commercialize IP they have developed. Truly enough, these individuals have to make important decisions, taking bets on their careers and jobs in order to start these spinoffs. The respondent opined that if such a person is willing to make a jump, the hurdle of IP licensing would not in and of itself hinder such an endeavour. As part of the discussion, the suggestion of focusing on identifying people who are willing to make such jumps and supporting them was raised. That could be considered instead of necessarily looking to make substantive changes to the IP licensing regime. This is not to say that such processes cannot be further streamlined.

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<sup>33</sup> The NUS Industry Liaison Office has been pivotal in getting more than 720 patents granted and more than 110 technology-based companies spun off from NUS. Similarly, NTUitive has helped NTU get more than 1,543 patents and 55 start-ups or spinoffs get started.

## Emerging Technologies

Respondents expressed excitement about the several new emerging space-related technologies being developed in Singapore. Two of the more commonly mentioned sub-industries are highlighted below.

### Satellite Technology

Most respondents see the ongoing advancements in satellite communications as being exciting and cutting-edge, with all groups of interviewees being hopeful for the sub-industry.

Companies generally see satellite communications as an exciting sub-industry that is rapidly evolving. Many of the companies interviewed were developing novel and innovative communications technology for usage on-board spacecraft. On the upstream side of this sub-industry, one company supplies satellite communication terminals for people who are using satellite communication systems for their vessels, vehicles, and installations in remote places. They have expanded their product catalogue and started offering on-demand, low latency connection between satellite communication terminals and LEO satellites.

A company made breakthroughs in its wireless laser communication technology by achieving higher bandwidth at lower costs, essential for its objective of global connectivity. In the sub-industry of laser communications, another respondent foresees that laser communication technology will be used for communication to the moon, which could potentially serve as a platform for communication between celestial bodies.

Communication networks based on quantum computing at the Centre for Quantum Technologies was cited by several interviewees as being cutting-edge. Compared to information transmission via optical fibres, a communication network of quantum systems can be used over longer distances. Ultimately, this technology can be used to build a network of ground stations and orbital satellites that transmit quantum information efficiently across the globe. An interviewee said that space-based telescopes, which accurately receive entangled signals from ground stations, is also in the works. That specific project is an international collaboration between UK and Singapore. The respondent also stated that in about 3 years, after the proposed launch of the satellite with a transmitter, they expect to see the satellite send signals to grounds stations around the world.

We understand that the government would be supportive of development of new methods of satellite communications after the early success of companies in this sub-industry, such as SpeQtral, Transcelestial and AddValue. Ultimately, however, one respondent pointed out that a government is likely to be supportive of any company or institution that is proving to be successful in its own field.

### **Industry 4.0**

The industry has also been hopeful in regards to the advancements taking place wherein space technology is being integrated with other technologies to unlock greater value.

The ongoing fourth industrial revolution has spurred many entrepreneurs to start businesses that merge state of the art digital technology and systems with spacecraft. These companies are creating new applications for space technology with emphasis on efficiency, non-space-related use and connectivity. One respondent discussed the application of space technology in other industries, such as the integration of space data with machine learning analytics. A potential application was cited as being in agriculture. Through satellites, data is collected and can be optimized to analyse factors, such as by monitoring humidity, affecting a farm's yield.

Another company is developing nanosatellites to relay Internet-of-Things (IoT) products. Nanosatellites are suitable as the IoT products do not require high data rate connections and are small in data size.

Another company is also developing an open-source satellite network by integrating block chain with space technology. This allows for international collaboration on technology between satellite companies.

Another technological shift in capabilities has come from the creative use of components and processes from other industries. One respondent cited the trend of how off-the-shelf components and the miniaturization of components exemplified that point - components from other industries, like the automotive industry, are already tested, weathered, and able to be utilized in space technology.



*Photo by Nicolas Lobos*

## LOOKING AHEAD

Space has always been about the future. When one thinks of an ultra-futuristic society, space travel and technologies tend to feature heavily in those visions. This isn't without good reason either. Many of the inventions on one of the most popular space-based TV shows, Star Trek, have been brought to life in ways that would have been unimaginable to the people of the time. Given the leaps we're making in the space industry and given how developments in the space industry tend to seep into other areas of society, one can only imagine what the future holds. Perhaps the Jetsons and Orbit City will no longer be a far-fetched fantasy.

Ultimately, we discussed the opportunities that may arise in the future and how Singapore should align itself to be a valuable part of it. This includes the increasing influence and importance of non-governmental efforts. In fact, one respondent noted that most efforts in the industry now are driven by the people and less so by the government. They added that the new generation of innovators should have their own ideas and should explore those ideas, asking for help where necessary.

While the breadth of opinions was diverse, the majority of the views that were raised in this segment were from the 'Ancillary' and 'SEDS' groups. This was unsurprising because these groups did tend to have a broader view of the space industry and did tend to look at it on a more macroscopic level.

## Where are we headed?

Almost all interviewees felt that the industry is definitely headed in a positive direction, with the general consensus that the ongoing small satellite revolution is an important area of growth. The interviewees also noted how the industry dynamics are shifting towards greater collaboration, downstream development and enabling policies.

### Collaboration Between Parties

Other sections of this report have discussed the opinion within the industry about collaboration. When looking forward, several interviewees raised their thoughts on how collaboration should proceed. With a desire to increase awareness and further develop the space industry, there were a number of salient points brought up by the interviewees that stakeholders can consider investigating to further cultivate the local space industry.

Some companies suggested that the industry should work with student groups to utilize them as an effective conduit to spread awareness about opportunities within the space industry. They felt that the seemingly wide disparity between the number of applicants applying for established corporations as compared to start-ups, despite a relatively similar pay scale, was an uncomfortable dynamic that has been taking shape.

Some companies also advocated for greater collaboration between local universities, as their joint research efforts are often fragmented. They claimed that minimal sharing and collaboration led to duplication and wastage of resources.

As mentioned before, several companies also mentioned that they would prefer it if facilities were centralized, as shared infrastructure, assets, and talent would make the industry more nimble. Additionally, local collaboration should be a key first step prior to broader collaborative efforts with other countries.

Some of our interviewees also pointed out that there seems to be a positive change taking place in the industry where scientists and companies are collaborating more. They argued that this would also lead to greater opportunities being unlocked within the value chain, as was the case in the example cited by an interviewee where they stated how Singtel collaborated with the researchers to implement quantum communications within their optical fibre network.

One respondent personally felt that more collaboration is a promising path. The respondent stated that student groups like SEDS Singapore could be an effective conduit between different stakeholders and could be particularly beneficial in finding insights on a grassroots level and from a different perspective. These findings could ultimately be channelled towards stakeholders, like the government, for policy planning. Other benefits that were raised were greater encouragement of interest and entrepreneurship in the industry.

Another respondent argued that the governments of different countries needed to set the example by collaborating and enabling a greater flow of information and opportunities. In that case, as well, the respondent said that university students could play a lubricating role to create insider channels.

## Satellites

The general consensus between groups was that satellites (especially small satellites), were undeniably an important and growing part of the space industry. However, there was some differences in opinion about how much emphasis should be placed on the development of costly infrastructure. It should be noted that while the ‘Companies’ group did not explicitly comment in this area, even there this industry dynamic was evident by the fact that most space companies in Singapore are in the satellite manufacturing, assembly, integration, and testing subsector.

Several interviewees highlighted the similarities they saw between the current trajectory of the space industry and that of the development of the internet. One interviewee raised the point that there needs to be a move beyond the expensive and high-risk infrastructure projects, like satellites and rockets, towards becoming vertically integrated.

Another interviewee, however, felt that the satellite sub-industry was still an important part of the value chain. They also noted that Singapore already seems to have some presence in the satellite manufacturing, assembly, integration, and testing sub-sector but also pointed out that Singapore’s limitations could prevent it from effectively carrying out manufacturing and testing.

Comparing it to the internet, one interviewee pointed out how the early internet relied on having the infrastructure in-house and moved towards having the infrastructure itself rented out. The interviewee believed that far more opportunities would become accessible if an equivalent model was followed by the space industry.

One respondent highlighted that the most prominent trends that they are seeing take place currently are the emergence of small satellite constellations, the lowering of launch costs over the decades, and the increasing frequency of small launches. Those trends have made space highly accessible for smaller countries. This, coupled with the large proportion of satellite companies in Singapore, leads us to believe that Singapore would likely support the small satellite sub-industry and those related to it, especially as there have been fewer established leaders and they feel that not much attention has been placed in this sub-industry. As mentioned in a previous section, one respondent pointed out that a government is likely to be supportive of any company or institution that is proving to be successful in its own field. The same can be said for an industry as well. While this area shows great promise for Singapore in terms of growth, proper confirmation of government interest in this area can only be determined after Singapore announces her roadmap.

## Downstream Development

As mentioned above, interviewees acknowledged the immense potential within the satellite sub-industry but slightly differed on how exactly one should participate in it. When explored further, it was found that the two groups – ‘Ancillary’ and ‘SEDS’ – were equally aware of the eventual shift that will be necessary from satellites to more downstream applications.

Downstream services which build upon the existing infrastructure are expected to be an area of high growth potential to many interviewees. One interviewee raised how the shift towards such downstream services was even more necessary in times of economic uncertainty, where costly hardware projects may be a hard sell. Innovating in this area would provide entrepreneurs with an entry point.

However, one interviewee cautioned that while downstream research was definitely an area that would become more important, upstream research should not be disregarded and a balance should be achieved. The interviewee believed that upstream development would give rise to downstream development and that ultimately nurturing minds to tackle problems would result in more innovative solutions which will have various direct applications.

One respondent did raise the point that with an increasing number of satellites, the uses of these satellites are unclear, indicating that they could be used for communication, Earth observation, etc. Moreover, as we generated more data, several respondents believed that downstream development to capitalise on that data would be crucial.

Ancillary

SEDS

## Policy

More nuanced policy points have been discussed in other sections. However, when looking forward, the need for policy in such a dynamic industry was raised as an important step for Singapore.

A salient point that was raised pointed to the fact that space policy will likely be a more active area in the coming years, especially in order to facilitate the more complex developments ahead. In addition, one interviewee claimed that Singapore needs to set an agenda, citing that all successful space nations had clear agendas. The interviewee further added that having an agenda will help Singapore align herself to achieve that agenda and help her find her place in the value chain.

A large role of the government is to set policy, after considering the views and constraints on the various stakeholders. It is our understanding that, as a result, policies are currently being researched and considered by the government. The need for effective policies is ever present and is especially so when the industry is moving at an increasing pace.

Ancillary

SEDS

## What's going to happen?

When asked where specifically they felt the most commercial breakthroughs would come from, there were few disagreements between the different groups (likely due to the fact that they weren't asked about the feasibility of different possibilities). The most common area of growth that was cited was in data analysis and usage.

### Data

All groups of interviewees agreed that satellite-generated data and its applications will grow to be increasingly important, citing examples of how they can be used for proper commercial applications.

Companies

As mentioned in other parts of the report, many interviewees noted that there was a significant amount of data being generated by existing infrastructure and that it would unlock new opportunities. One interviewee discussed the application of space technology in other industries, such as the integration of space data with machine learning analytics. A potential application is in agriculture. Through satellites, data is collected and can be optimized to analyse factors, such as by monitoring humidity, affecting a farm's yield.

Ancillary

All respondents acknowledged the importance and opportunity that data interpretation and analysis held. Other ways that were suggested to handle data were to open source them to lower their risk profile and find ways to blend different types of data (such as synthetic-aperture radar and hyperspectral imaging) from private and public sources in real time. Another subsector with massive opportunity, as cited by a few interviewees, is in geospatial intelligence. An example of that – GPS mapping capabilities – allow us to create an augmented reality and see the digital world in a physical sense by overlaying information on top of it. Optical imaging was also quoted as being a high growth industry once the complex sets of geospatial data could be monetized. Other applications of downstream services that were raised were agricultural and maritime monitoring. On top of the new technologies and services that will be created, interviewees also stated that the greater dependence on space infrastructure would likely contribute to engaging more people about space.

SEDS

Most respondents noted there would be a growing need for downstream services, especially as satellites are likely to remain a growing industry. Should the satellite industry become more important for Singapore, the downstream services would also grow in importance. Areas such as image processing and data analysis were cited as examples of areas that may be increasingly valuable with the advent of effective utilization of data, stemming from the large abundance of data that will be generated.

### Communications

Different groups also agreed upon how communications would be a key application of the breakthrough technologies being developed today.

One interviewee foresaw that laser communication technology would be used for communication to the moon, which could then serve as a platform for communication between celestial bodies. Another interviewee argued that quantum communications has been a cutting-edge field and Singapore is at the frontlines of it due to the pioneering work done at the Centre for Quantum Computing. Certain technologies, like quantum key distribution, are also being pursued by local university spinoff companies.

Several respondents also pointed out that space-based quantum communications, which everyone amongst the ancillary companies agreed was a cutting-edge field, was also an area of growth for Singapore. They believed that as the technology matured, more groups would be working on the applications of this technology. It was also brought up that Singapore seemed to be heading in the right direction with regards to communication technologies, like 5G and IoT, with investments in companies like Transcelestial Technologies.

### Skilled Services

Interviewees agreed that the importance of skilled services would grow in tandem with space technology developments.

One more area of future growth for Singapore was stated to be her skilled services sector. Several interviewees raised points on how Singapore could be a hub for space finance, due to her reputation as a good and accountable money manager. One interviewee stated the possibility of bringing in investment experts to pick the right companies while the government acted as a financier. Other than finance, interviewees also stated that Singapore could provide value in the areas of urban planning, food tech, biotech, and general management of resources.

One respondent noted that services which were ancillary to the space industry, like finance and law, would also be extremely important as the space sector itself experienced growth. However, it is likely that the government would rather prioritize supporting the primary industry, as without it, the ancillary industry would be rendered moot. That being said, one respondent pointed out that some decision-makers in foreign (ancillary) companies, like Marsh – an insurance company that covers satellites and space collisions – are based in Singapore.

### Other Exciting Opportunities

Interviewees also pushed forward some other, more exciting avenues of growth for the space industry in general.

The future of launch services was described by several companies to be a mix of providing planetary access and landing services. They noted a possible polarization of the sub-industry between small launch capacity suppliers and those that offer larger launch capacities. Landing and mining technology were seen as a possible extension from rendezvous technology.

Space debris removal was also seen as a sector that was heading towards commercialization, with interviewees stating that it is likely to be a problem that would become worse over time and that currently, there were only few companies developing such services.

Other than more scientific missions to build upon the advancements of today, interviewees said that manufacturing and supplying of rocket and propulsion tools would likely be an area of high growth. They were generally cognizant of the fact that launch services were highly popular around the world but that Singapore lacked a need for it. They also recognized that while areas like space exploration and tourism were also gaining popularity, they were likely not on ‘pragmatic’ Singapore’s radar. Other areas of opportunity that were raised were entertainment where Astro Life Experience and their ‘shooting stars’ were cited as an example. Ubiquitous high-speed internet connectivity was another exciting area. Space-based solar power was also cited as an endeavour that could gain traction in the future.



*Photo by NASA*

## Concluding Thoughts

*The concluding thoughts have primarily been written by Nick Lee Jia Luo. Nick, along with Ramu Vairavan, led the founding of the Singaporean chapter of SEDS, in 2019. Nick writes about what SEDS Singapore had envisioned early on and the hopes we hold on to today.*

The concept of a SEDS chapter in Singapore was conceived back in early 2019 by a group of passionate Singaporean students coming together, hoping that they could be a part of this exciting domain. From the very beginning, they understood that they couldn't do this alone. For progress to be made, they had to identify the gaps, plug themselves in and work alongside with the stakeholders of the local space industry as a collective to address them.

While it is commonly mentioned that humanity reached the moon by competing with each other, we have to remember that the International Space Station, one of the wonders of the world, was created through the collaboration between nations, which included Cold War adversaries – the USA and Russia. It is commonly said that “If one wishes to go fast, go alone. But if one wishes to go far, go together. When we go out into space, we too will go together. And to quote the title of a recently popular Apple TV series, when we go, we go “*for all mankind*”.

While we are very proud of what Singapore has achieved since her independence, it was more comforting to hear the many positive observations our interviewees had about Singapore. This made us realise Singapore's self-efficacy and has sharpened our resolve that Singapore could someday be a part of this future too. Right now, it is only imperative that we continue with the momentum and develop Singapore into a nation that would be able to be a part of this grand vision out in space.

So, what is this grand vision which we so often speak about, and how do we get there? The various sections of the local insights, which we outlined in the report, were areas which we felt we could analyse and work on. By understanding the constraints we have as a nation, the desires and needs of various stakeholders and also Singapore's role in space, this is our collective view of the future which we would like future generations after us to experience and live in.

The dominant theme in our vision of the future is working together. This is an effort which would require active participation from all aspects. From private and public sectors to even grassroots efforts. Over the past few years, it has been comforting to be a part of Singapore's tightly knit NewSpace community. We are eternally thankful to all our mentors for their support and for providing opportunities to the members of our club. We can confidently say that without their assistance and guidance, many of our initiatives would not have been successful. If such modest efforts could have such a profound effect to a new club like ours, just imagine what we could achieve with greater involvement and collaboration between the various stakeholders - be it the industry players, associations, research institutes, government agencies or institutes of higher learning and beyond. Moving forward, we wish for a more cohesive community that looks out for one another as we continue to strive towards making our little red dot visible out there in space.

While we work towards greater synergy within the Singapore ecosystem, the next step we wish to see is the greater integration of ASEAN, thereby bringing about greater prosperity and opportunities to the region. Tapping on our already well-established business and infrastructure landscape, the growth of the region would be one that allows for greater involvement in the

space scene. While doing so, Singapore should continue to work towards establishing adequate guidelines. Not only does this provide a clear direction for the stakeholders in the industry, but it also allows us to continue to be responsible stewards of mankind's future in space, as outlined by our commitment as a member of the United Nations Committee on the Peaceful Uses of Outer Space.

Whilst doing so, we should continue to stick to our principles and maintain our status of neutrality. We should invest in space to protect not only our national interest, but to go above and beyond to identify key areas that both benefit Singapore and allow us to extend our capabilities to help others, similar to how we readily extend our assistance in humanitarian aid and disaster relief operations. Be it climate change, food security, air traffic management, maritime security or any number of other areas, our investments in Space should be focused on improving life here on Earth.

In doing so, we hope that Singapore will continue to be a melting pot for the proliferation and convergence of technological capabilities and talent for years to come. Our research and development in space will lead to trickle-down benefits to our nation and beyond. A vibrant space industry would provide opportunities for our workforce such that even if they do not end up working in the space industry, the expertise and experience they gain from their efforts in the space industry would allow them to benefit whichever areas they eventually venture into. Singapore's decision and continued commitment to be open and to welcome globalization has always allowed us to learn from others. This learning has been what has enabled us to establish and achieve many of our amazing feats which we see in Singapore today. However, moving forward, while we continue to learn from others, we should take the initiative and play a larger role to contribute back to efforts in space. This way, we would be able to extend the benefits and empower others around us, just like how it has allowed us to achieve what we have today.

Our journey towards achieving this grand vision of the future will not be an easy one. Along the journey, we will no doubt be battered by obstacles such as pandemics, economic crisis, social issues, climate change and many more. Yet, we do know that no matter what obstacles we face, our investments in space would have a big role to play in resolving and combating such issues.

Personally, I have been blessed with the opportunity to be inspired by space. This journey has charted a path in life for me. I remember listening to my professors speaking of how their parents called them into the house to witness Neil Armstrong lay the first step on the moon. This inspired a whole generation, who then went on to achieve greater heights. And in the process, inspiring me down this path too. I wish that future generations could have similar inspiring stories that alter their lives, just like how space inspired me and the generations before me. The team hopes that this report would spark the beginning of how we all play a part in creating this grand vision which we all dream about. . But instead of it being a mere dream, we hope that there would be a continued push towards daring mighty things! As we stand on the shoulders of the giants in the generations that have preceded us, we too seek to set the infrastructure for the next generation to build upon, and for them to bring us to greater heights.

For one day, we could either be watching it happen, or look back and know that we were a part of making this happen. Which will we choose?



## Company Profiles

We sincerely thank the following entities for their invaluable insights and support through the duration of this project.

# Satellite Manufacturing

## Photonicity



**HQ:** Singapore

**Number of Employees:** <10

**Contact Name:** Dr Charles Ho (Founder)

**Contact:** <https://www.linkedin.com/in/charles-kf-ho/>

**Firm Website:** [www.photonicity.com](http://www.photonicity.com)

**Solution Type:** Remote Power Solutions

**Company Description:** We are developing a power transfer technology (wireless or wired) that is a power solution for remote vehicles operating in highly challenging environments (long-range or severe pressure or temperature or radiation) for extended periods.

**Highlights:** Our key differentiation is that the tech is based on lasers versus other forms of energy. This solution will unlock unprecedented values for our customers.

**Recent News, Awards and Accolades:** Graduated from Founder Institute HK, Selected for the inaugural Call to Orbit IOD Initiative sponsored by ESA

## Transcelestial



**HQ:** Singapore

**Number of Employees:** 11-50

**Year Founded:** 2016

**Contact Name:** Rohit Jha (CEO)

**Contact:** [jobs@transcelestial.com](mailto:jobs@transcelestial.com)

**Firm Website:** [www.transcelestial.com](http://www.transcelestial.com)

**Solution Type/ Category:** Space Tech / Telecommunications

**Company Description:** Building the future of Internet Distribution

**Notable Customers:** Telecom Infra Project, SK Telecom and various other telecoms

**Highlights:** World's First Company to work on Wireless Laser Communication

**Recent News, Awards and Accolades:** Raised \$9.6M in recent Series A funding round

## GomSpace A/S



**HQ:** Aalborg, Denmark

**Number of Employees:** 51-200

**Year Founded:** 2007

**Contact Name:** Dennis Elgaard (Sales Director)

**Contact:** del@gospace.com, +45 71 741741,

<https://www.linkedin.com/in/denniselgaard/>

**Firm Website:** [www.gospace.com](http://www.gospace.com)

**Solution Type/ Category:** CubeSat products and mission supplier.

**Company Description:** GomSpace is a globally leading manufacturer and supplier of CubeSat & small satellite solutions for customers in the academic, government and commercial markets. Our positions of strength include systems integration, CubeSat platforms, advanced miniaturized radio technology and satellite operations. Our international team is devoted to understanding our customer's requirements and to delivering flawlessly.

**Notable Customers/ Partnerships/ Projects:** ESA, NASA, KARI, JPL, AIRBUS, HawkEye, AISTECH, UnseenLabs

**Highlights:** GomSpace is a one-stop shop for CubeSat mission providing both parts, turnkey projects and mission operations support. The GOMX test missions are unique and gives valuable knowledge about our product and mission control in general.

**Recent News, Awards and Accolades:** GOMX-5 mission with ESA, general involvement in ESA missions.

## SpaceChain Foundation Limited



**HQ:** Singapore

**Number of Employees:** 11-50

**Year Founded:** 2017

**Contact Name:** Zee Zheng (CEO & Co-founder)

**Contact:** <https://www.linkedin.com/in/zee-zheng-2b582041/>

**Firm Website:** [www.spacechain.com](http://www.spacechain.com)

**Solution Type/ Category:** Integration of blockchain and space technologies

**Company Description:** SpaceChain fosters decentralized infrastructure for the New Space Economy. By combining space and blockchain technologies SpaceChain is making the development of space applications easier and making space more accessible.

**Notable Customers/ Partnerships/ Projects:** International Space Station, NASA, GomSpace, Nanoracks, UK Space Agency, Singapore Space and Technology Association, European Space Agency, European Space Agency's Kickstart Program.

**Highlights:** SpaceChain Foundation is facilitating the development of open-source standards for hardware, software, and communication protocols for low earth orbit (LEO) satellites. Utilising these protocols, we would like to empower people to build a multi-vendor, multi-jurisdiction, Decentralised Satellite Infrastructure. This model makes more economic sense and is much more efficient, especially for the smaller satellite companies and startups. Empowered by blockchain technology, we are building a very dynamic environment for space companies around the world to collaborate. SpaceChain Foundation continues to push forward towards its goal of opensource standards for hardware, software, and communication protocols, furthering our mission of building an open and neutral infrastructure for the New Space Economy, together.

**Recent News, Awards and Accolades:** 1) SpaceChain Sends Blockchain Technology to the International Space Station (click [here](#))

2) SpaceChain Foundation Invests in Core Semiconductor to Produce Open Hardware Platform for Direct Satellite-to-Devices Communication (click [here](#))

3) SpaceChain Foundation's Blockchain Hardware Installed on the International Space Station (click [here](#))

## Anchor Orbital



**HQ:** Singapore

**Number of Employees:** <10

**Year Founded:** 2020

**Contact Name:** Ushantha Wanigaratne (Co-Founder and CEO)

**Contact:** +94703922608, ushantha@anchororbital.com,

<https://uk.linkedin.com/in/ushantha-wanigaratne-bb5812118>

**Firm Website:** <https://www.anchororbital.com/>

**Solution Type/ Category:** Propulsion/Debris Mitigation

**Company Description:** Anchor Orbital is developing the Calypso thruster, a propellantless stationkeeping device that will finally enable cost-effective VLEO satellite operations.

**Notable Customers/ Partnerships/ Projects:** The Sail

## Aliena Pte Ltd



ALIENA

**HQ:** Singapore

**Number of Employees:** <10

**Year Founded:** 2018

**Contact Name:** Mark Lim Jian Wei (CEO & Co-founder)

**Contact:** +65 97947323, marklim@aliena.sg

<https://sg.linkedin.com/in/mark-lim-jian-wei-3b460a188>

**Firm Website:** <https://www.aliena.sg/>

**Solution Type/ Category:** Electric Propulsion and Space Systems Service Provider

**Company Description:** Aliena Pte Ltd designs and manufactures highly efficient and cost-effective plasma thrusters for small satellites.

The highly efficient thrusters developed by the company increases the operational lifespan of satellites and allows for sophisticated manoeuvres, which were once limited due to technical constraints, to be performed in space, thereby opening new frontiers in space to be explored.

**Highlights:** First privately owned jet propulsion test facility and nanosatellite propulsion assembly/integration centre in Singapore and the region. Unique electric propulsion systems with fully owned IP. Highly disruptive solutions and systems that aim not to chase performance parameters blindly, but to provide operational advantages to technically inaccessible regimes in space

**Notable Customers/ Partnerships/ Projects:** Momentus, NTU SaRC, NuSpace, Cap Vista, 500 Startups, Paspalis, Darwin Innovation Hub, Project Cyclotron

**Recent News, Awards and Accolades:** Raised S\$1.5m led by Cap Vista, 500 Startups and Paspalis Innovation and Investment Fund (2019)

Demonstration mission for constellation management system with NuSpace (2019)

## Infinite Orbit



**HQ:** Singapore

**Number of Employees:** <10

**Year Founded:** 2017

**Contact Name:** Akshay Gulati (CEO)

**Contact:** <https://www.linkedin.com/in/akshay-gulati-b437812b/>

**Firm Website:** [www.infiniteorbits.io](http://www.infiniteorbits.io)

**Solution Type/ Category:** Guidance Navigation and Control systems for satellites

**Company Description:** Infinite Orbit provides GNC solutions for space rendezvous and docking, active debris removal, debris collision avoidance, space situational awareness and satellite life extension.

**Notable Customers/ Partnerships/ Projects:** Gap filler satellite for Indonesian MSS orbital slot

**Highlights:** State-of-art space rendezvous systems that is orbit and target agnostic

**SpeQtral**



**HQ:** Singapore

**Number of Employees:** 11-50

**Year Founded:** 2017

**Contact Name:** Lum Chune Yang (CEO)

**Contact:** chuneyang@speqtral.space

**Firm Website:** <https://speqtral.space>

**Solution Type/ Category:** Satellite-based Quantum Communications

**Company Description:** SpeQtral is a global quantum technologies company on a mission to transform the world's networks for the quantum revolution. Powered by technologies developed at the Centre for Quantum Technologies in Singapore, SpeQtral provides specialized solutions for quantum security to clients concerned about the security of their communications networks and infrastructure. SpeQtral's core expertise lies in using a space-based quantum platform to establish long distance quantum networks with a global reach.

**Highlights:** Entangled quantum light source in cubesat form factor with space heritage

**Recent News, Awards and Accolades:** CBInsights Game Changing Startups 2020; Winner, Hello Tomorrow Singapore Pitch 2019

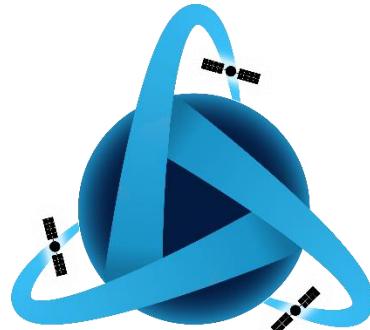
**Additional thanks to:**

**NuSpace**



# Software

## Delta-V Robotics Private Limited



**Delta-V Robotics**

**HQ:** India

**Number of Employees:** <10

**Year Founded:** 2019

**Contact Name:** Naushad Rahman (CEO)

**Contact:** +65 90674186, naushad@deltavrobo.com

**Firm Website:** deltavrobo.com

**Solution Type/ Category:** Software solution

**Company Description:** Delta-V Robotics is a deep tech Space startup. Our product is cloud-based AI Platform named “SAT-PASS” which assist the Space industry during Mission design and Simulations by creating a virtual model of the satellite and its environment. It also assists during the planning and operations of the mission. SAT-PASS will simplify designing, testing, analysis and manufacturing process.

**Notable Customers:** 75 Student Satellite Programme

**Highlights:** First cloud-based AI platform for satellite designing and operation integrated with system engineering management.

**Recent News, Awards and Accolades:** Won APSCC-2019 Pitching competition

## Keysight Technologies Singapore (Sales) Pte. Ltd.



**HQ:** Santa Rosa, CA, USA

**Number of Employees:** 51-200

**Year Founded:** 2014

**Contact Name:** Oh Sang Ho (SAP Marketing Manager)

**Contact:** sang-ho.oh@keysight.com, +65 62157196

**Firm Website:** www.keysight.com

**Solution Type/ Category:** Provision of Test & Measurement equipment and solutions for testing and manufacturing as well as testing, visibility, and security solutions to strengthen applications across physical and virtual networks.

**Company Description:** Keysight Technologies, Inc. is a leading technology company that helps its engineering, enterprise and service provider customers accelerate innovation to connect and secure the world. Keysight's solutions optimize networks and bring electronic products to market faster and at a lower cost with offerings from design simulation, to prototype validation, to manufacturing test, to optimization in networks and cloud environments. Customers span the worldwide communications ecosystem, aerospace and defense, automotive, energy, semiconductor and general electronics end markets.

**Notable Partnerships:** (1) Helping Thailand's national space agency (GISDTA) overcame challenges in its CubeSat launch program by setting up an RF satellite lab, leveraging a FieldFox Handheld Spectrum Analyzer.

(2) Teams with European Space Agency, Airbus, SpaceTech GmbH to Evaluate Radar for Icy Moons Exploration Antenna

**Highlights:** The diversity and breadth of our products, solutions and services plus our presence in over 100+ countries with more than 12000 people, our commitment to innovation and quality and finally our company culture of uncompromising integrity, high performance, speed and social responsibility makes us stand out from the crowd.

**Recent News, Awards and Accolades:** Winner of the 2020 BIG Innovation Awards presented by the Business Intelligence Group for its PathWave Test 2020, Frost Radar Best Practices Award for Growth, Innovation & Leadership (GIL) in the Communications Testing Market, Global TD-LTE Initiative (GTI) Innovative Breakthrough in Mobile Technology Award

# Satellite and Space Services

## Eutelsat



**HQ:** Paris, France

**Number of Employees:** 11-50

**Year Founded:** 2012

**Contact Name:** Charles Disneur (Senior Business Development and Marketing Director)

**Contact:** cdisneur@eutelsat.com

**Firm Website:** <https://www.eutelsatasia.com/home.html>

**Solution Type/ Category:** Satellite operator

**Company Description:** Eutelsat Asia delivers comprehensive coverage and high-bandwidth capability for any client, with any communication need, anywhere in the Asia Pacific. Our commitment is to help broadcasters, video service providers, telecom operators, ISPs and government agencies grow their business in the Asia Pacific region and connect them to the rest of the world. Based in Singapore, Eutelsat Asia embodies Eutelsat long-term commitment to the Asia-Pacific region.

**Highlights:** Eutelsat supports the strong growth of the Asia Pacific region with three satellites optimised for business requirements:

EUTELSAT 70B provides regional and intercontinental connectivity for a wide range of satellite-based applications

EUTELSAT 172B is a new high-capacity satellite for fast-growing applications in Asia Pacific, including in-flight and maritime connectivity, cellular backhaul, corporate networks, video and government services;

EUTELSAT 174A offers a wide range of telecom and mobility services.

With capacity commercialised on 37 satellites delivering reach around the globe, Eutelsat Communications is one of the world's leading satellite operators.

## Addvalue Technologies Ltd



**HQ:** Singapore

**Number of Employees:** 51-200

**Year Founded:** 1996

**Contact Name:** Tan Khai Pang (CTO)

**Contact:** khaipang.tan@addvaluetech.com

**Firm Website:** <https://www.addvaluetech.com>

**Solution Type/ Category:** Terminals, electronics and radio frequency product development, prototyping and final assembly for space, defence and aviation industries.

**Company Description:** Addvalue is a leading satellite-based communication solutions company that provides state-of-the-art communication terminals for use in space, in the air, at sea and on the ground. The company also offers extensive engineering and integration services to its customers including leading organizations in commercial, defence and space industries.

Addvalue's expertise extends far beyond where the world's terrestrial networks end.

Whatever the market or application, the company's wide range of satellite-based products and services is sure to offer the right technology to drive enhanced connectivity.

**Notable Partnerships:** Various satcom projects: Inmarsat, Viasat, Yahsat/Thuraya; Various aerospace projects: Avionica, Capella Space, leading companies in LEO satellite industry: Special connectivity solution projects: National and regional governmental agencies, resellers and integrated service providers in fishing industry and IoT markets.

**Highlights:** Resilience, Agility

**Recent News, Awards and Accolades:** Inter-Satellite Data Relay System (IDRS)

**Planet Inc**

**HQ:** San Francisco, California

**Number of Employees:** 51-200

**Year Founded:** 2010

**Contact Name:** Vincent Kessler (Sales Director)

**Contact:** [vincent.kessler@planet.com](mailto:vincent.kessler@planet.com)

**Firm Website:** [www.planet.com](http://www.planet.com)

**Solution Type/ Category:** Earth Observation

**Company Description:** Planet is the leading provider of global, near-daily satellite imagery data and insights. Planet is driven by a mission to image all of Earth's landmass every day, and make global change visible, accessible and actionable. Founded in 2010 by three NASA scientists, Planet designs, builds, and operates the largest earth observation fleet of satellites, and provides the online software, tools and analytics needed to deliver data to users. To learn more visit [www.planet.com](http://www.planet.com) and follow us on Twitter at @planetlabs.

# Launch Services

## Equatorial Space Systems



**HQ:** Singapore

**Number of Employees:** <10

**Year Founded:** 2017 (as Equatorial Space Industries), 2020 (as Equatorial Space Systems)

**Contact Name:** Mr Simon Gwozdz (Founder & CEO)

**Contact:** +65 96254519, simon@equatorialspace.com

<https://www.linkedin.com/in/simongwozdz/>

**Firm Website:** <https://www.equatorialspace.com/>

**Solution Type/ Category:** Launch Service Provider

**Company Description:** Equatorial Space Systems is a Singapore-based startup that is developing a dedicated launch vehicle to address the booming small satellite launch market.

Using its innovative hybrid propulsion and proprietary solid fuel composition, its space launch vehicle will be capable of responsive deployment, orbital and scheduling flexibility - while providing improved degree of safety compared to existing systems.

**Notable Customers/ Partnerships/ Projects:** Nanoracks, Commercial Space Technologies Ltd, Open Cosmos, GomSpace, Southern Launch Australia, Responsive Access, Steelhead Composites, Swagelok, Precious Payload, EXOLaunch, ANSYS

**Recent News, Awards and Accolades:** Grand Prize (MBRSC Innovation Challenge 2018)

Level 4 (SpaceFund Reality Rating 2020)

# Ground Operations

**Amplus Communication Pte Ltd**



**HQ:** Singapore

**Number of Employees:** 51-200

**Year Founded:** 1999

**Contact Name:** Eric Ong (Sales/Marketing)

**Contact:** +65 64836089 ext 824

**Firm Website:** [www.amplus.biz](http://www.amplus.biz)

**Solution Type/ Category:** VSAT transceiver

**Company Description:** Design and manufacture of satcom transceivers

**Notable Customers/ Partnerships/ Projects:** Customers from 47 countries around the world

# Multi-function

## HOPE Technik Pte Ltd



**HQ:** Singapore

**Number of Employees:** 51-200

**Year Founded:** 2006

**Contact Name:** Ms Joni Chen (Marketing Lead)

**Contact:** 6877 0193, sales@hopetechnik.com

<https://www.linkedin.com/company/hope-technik/>

**Firm Website:** [www.hopetechnik.com](http://www.hopetechnik.com)

**Solution Type/ Category:** Delivering high performance engineering solutions

**Company Description:** HOPE Technik, a Singapore-proud engineering company, has been evolving the industry landscape with its technological innovations since 2006. Together with a strong team of dedicated engineers and technical personnel, HOPE Technik is committed to deliver innovative products and solutions, translating concepts into reality.

**Highlights:** Recent News, Awards and Accolades: Contactless self-check temperature kiosks to be rolled out at 70 bus interchanges and MRT stations

## IN.GENIUS Pte Ltd



**HQ:** Singapore

**Number of Employees:** <10

**Year Founded:** 2009

**Contact Name:** Lim Seng Marvyn (Founder and CEO)

**Contact:** +65 98314888, ingenius.gospace@gmail.com

**Firm Website:**

**Solution Type/ Category:** Stratospheric Testing Services / Special Projects

**Company Description:** Space-related design/development; prototyping; engineering solutioning

**Notable Customers/ Partnerships/ Projects:** SSII space-based satellites - presented 2015 UN ITU Space Resources Symposium; 2015 lab rat flight tests, Hyderabad; 2016 two flight tests 31km;7hr, Alice Springs; 2019 1st manned flight test Cannon Ball.

**Highlights:** Attempt to send a 1st Singaporean to cross the Armstrong Line @ 20km into Space using stratospheric balloon and CNA Documentary (Click [here](#) and [here](#))

**Recent News, Awards and Accolades:** 6 years of stratospheric capability, coupled with past 15 years of complex space-related projects experience such as the Hypersonic SpacePlane Demonstrator, Space-Based Solar Energy; Supernova Neutrino Detection, and Space-based Internet (invited by United Nation ITU Space Resources Symposium 1stOct2015 speech)... etc

## Media

**The Business Times**

# THE BUSINESS TIMES

**HQ:** Singapore

**Year Founded:** 1976

**Number of Employees:** 51-200

**Contact Name:** Ms Claudia Chong (Journalist)

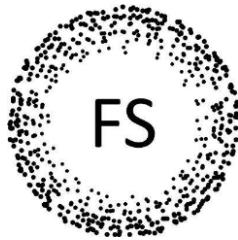
**Contact:** chongkmc@sph.com.sg

**Firm Website:** [www.businesstimes.com.sg](http://www.businesstimes.com.sg)

**Solution Type/ Category:** Media

**Company Description:** The Business Times, a member of the Singapore Press Holdings group, is a leading financial daily based in Singapore. BT brings its readers daily corporate, financial, economic and political news, analysis and commentary on print and digital platforms. It provides readers with in-depth coverage of Singapore and Asian business and economic developments, as well as global trends that impact Singapore companies. BT's lifestyle journalists bring busy executives the latest in recreation, entertainment, the arts, design, food and shopping.

## Filling Space



**HQ:** New Zealand

**Number of Employees:** <10

**Year Founded:** 2018

**Contact Name:** Mr Nicholas Borroz (Founder)

**Contact:** nick@filling-space.com

**Firm Website:** <https://filling-space.com/>

**Solution Type/ Category:** Media

**Company Description:** We publish weekly interviews with space experts.

**Highlights:** Our goal is to provide a variety of perspectives on how to engage with space. To the end, we interview space experts with varied backgrounds. Besides interviewing scientists and engineers, which would be typical of a website dedicated to space, we have also interviewed people with various profiles, including philosophers, historians, authors, journalists, artists, and social activists.

# Venture Capital

**Christopher Gomez**



**HQ:** New York

**Number of Employees:** 11-50

**Year Founded:** 2007

**Contact Name:** Christopher Gomez (Analyst/ Fund Advisor)

**Contact:** +65 96501654, christopher.gomez@leoniehillcapital.com

**Firm Website:** [www.leoniehillcapital.com](http://www.leoniehillcapital.com)

**Solution Type/ Category:** Private Equity Fund

**Company Description:** Leonie Hill Capital is an exempt fund manager under paragraph 5(1) of the Second Schedule to the Securities and Futures (Licensing and Conduct of Business) Regulations of Singapore.

**Notable Customers/ Partnerships/ Projects:** SpaceX, Amazon, AirAsia, Maxis, Baidu, Tencent, Alibaba.

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Additional thanks to:

Space Capital



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# Research Institutes

## Satellite Research Centre

*School of Electrical & Electronic Engineering - Nanyang Technological University*



**HQ:** Singapore

**Number of Employees:** 11-50

**Year Founded:** 1981

**Contact Name:** LIM Wee Seng (Executive Director)

**Contact:** +65 67906289, LimWS@ntu.edu.sg, <https://www.linkedin.com/in/limweeseng/>

**Firm Website:** <http://www.eee.ntu.edu.sg/research/SaRC/Pages/Home.aspx>

**Solution Type/ Category:** Space and Satellite Research & Development, Design Services, Consultancy, and Training

**Company Description:** Satellite Research Centre (SaRC) prides itself as an innovative centre that provides an exciting and dynamic research environment for aspiring satellite and space enthusiasts. Within the centre, we have a well-mixed team of researchers and engineers who bring with them different expertise and experience, working towards a common goal of achieving excellence and innovation in space technology. Externally, collaboration with local and international organisation has created much synergy and excellent output. These collaborations provide great opportunities and exposures to our faculty, researchers, engineers, postgraduate and undergraduate students.

**Notable Customers/ Partnerships/ Projects:** ISRO, CNES, Caltech, LASP/CU, IIST, Kyutech

**Highlights:** Birth place of Singpaore Satellites – Merlion payload (1999), 1st locally design microsat XSAT (2011), VELOX PII (2013), VELOX I, PIII(2014), VELOX-II (2015), VELOX-CI (2015), AOBA VELOX-III(2016), SPATIUM(2018), AOBA VELOX-IV(2019)

**Recent News, Awards and Accolades:** President's Technology Award, PTA (TEAM) 2016, Nanyang Awards - Teamwork 2014, Defence Technology Prize Team R&D Award 2011

Additional thanks to:

**National University of Singapore**

*Centre for Quantum Technologies*



# Associations and Consultancies

## Space Generation Advisory Council



**HQ:** Vienna, Austria

**Year Founded:** 1999

**Number of Employees:** <10

**Contact Name:** Faith Tng (National Point of Contact, Singapore)

**Contact:** [faith.tng@spacegeneration.org](mailto:faith.tng@spacegeneration.org)

**Firm Website:** <https://spacegeneration.org/>

**Scope of Work:** SGAC works diligently to raise awareness among the next generation of space professionals on a global scale working together with the United Nations Office for Outer Space Affairs (UNOOSA) in promoting UN workshops and activities, and in supporting SGAC members to attend UNOOSA workshops, events and High Level Fora. By hosting international, regional, local and thematic events, as well as attending various events globally, SGAC provides its members with opportunities to expand their knowledge of international space policy issues as well as space topics of a scientific or technical nature, think creatively about the future direction of humanity's use of space, and engage with current leaders from space agencies, industry and academia.

**Company Description:** The Space Generation Advisory Council in Support of the United Nations Programme on Space Applications is a global non-governmental, non-profit (US 501(c)3) organisation and network which aims to represent university students and young space professionals ages 18-35 to the United Nations, space agencies, industry, and academia. Headquartered in Vienna, Austria, the SGAC network of members, volunteers and alumni has grown to more than 15 000 members representing more than 150 countries.

SGAC was conceived at UNISPACE III in 1999, whereby states resolved, as part of the Vienna Declaration, "To create a council to support the United Nations Committee on the Peaceful Uses of Outer Space, through raising awareness and exchange of fresh ideas by youth. The vision is to employ the creativity and vigour of youth in advancing humanity through the peaceful uses of space". SGAC holds Permanent Observer status at the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) and regularly takes part in the annual meeting, as well as its Legal and Scientific and Technical Subcommittees. SGAC holds consultative status at the United Nations Economic and Social Council (UN ECOSOC), contributing to discussions on the role of space in achieving the UN Sustainable Development Goals.

Additional thanks to:

**Singapore Space and Technology Limited**



**Astropreneurs HUB**



# Acknowledgments

Additional thanks, for their guidance or insights, to:

**The Office for Space Technology and Industry, Singapore**

**SEDS USA**

**SEDS India**

**SEDS Earth**

**Nanyang Technological University**

**Earth Observatory of Singapore**

**Smart Small Satellite Systems Thales**

**Mr David Ho**

**Mrs Jacqueline Chia**

**Mr Neel V. Patel**

## Appendix: Methodology

As mentioned under the ‘Our Approach’ section, the team had to carry out numerous forms of data collection, compiling, and review. We used the information we found to facilitate and formulate the stakeholder interviews, in the context of global industry dynamics.

In the same section, it was stated that we have purposefully chosen not to include all the background research that was done for both the sake of brevity and because the primary goal of the report is not to serve as a primer. There are several existing market reports, such as those by Bryce or Frost & Sullivan, which are effective primers for anyone looking to get a detailed understanding of the space industry.

The primary purpose of the report is to collect, collate, and organise the multitude of viewpoints that stakeholders have about Singapore’s space ecosystem, such that their views are valuable to the readers who are considering how they can be involved in and contribute to the ecosystem.

### Global Overview

For the first phase of research, the team was split into sub-teams in order to read existing literature regarding the state of the space industry globally for the purpose of gaining a deeper understanding of the industry. Based on the in-depth information derived from the report, the team did further literature reviews in order to help us situate our work in relation to existing knowledge. Lastly, the team thoroughly discussed and extracted information regarding sub-industries and trends of relevance to Singapore. The purpose of doing so was to narrow our scope prior to contacting and interviewing members of the industry.

In total, the team cumulatively read over 20 unique published documents, which included:

- Industry Reports, such as Frost & Sullivan’s ‘The Future of Space, 2030 and Beyond’ and Bryce’s ‘Start-up Space’
- Government Publications, such as The European Investment Bank’s ‘The Future of the European Space Sector’
- Company-specific Reports, such as Virgin Galactic’s ‘Fourth Quarter and Full Year 2019 Financial Results’
- Journal Articles, such as Harvard Business School’s ‘SpaceX, Economies of Scale, and a Revolution in Space Access’
- Other Publications, such as Space Capital’s ‘U.S. Government Support of The Entrepreneurial Space Age’

All of the above, along with the remaining materials which were not mentioned above, were excellent resources and we highly recommend them to any parties interested in gaining deep and specific knowledge about any one of the multitude of domains within the space ecosystem.

As mentioned, based on the above, we derived the sub-industries within the global space ecosystem. Thereafter, we chose to only focus on sub-industries which were relevant to Singapore. The primary way we determined relevance to Singapore was by assessing if there were any companies operating in Singapore which were under the previously determined sub-industries. If there were no active companies under a certain sub-industry or if there were companies under a certain sub-industry but none responded to requests for interviews, we

removed the sub-industry from consideration for the report. For example, one such sub-industry which features on global lists but not in our *Insights Report* is the ‘Space Tourism’ sub-industry.

## ‘Company’ Group Interviews

In the next phase of the report, having narrowed down our scope to areas of relevance to Singapore, we collated the list of local companies in the space sector and positioned them under the sub-industry in which they were best suited.

To find as exhaustive a list of companies as possible, we employed several methods, including using online databases (such as nanosats.eu and Crunchbase), academic and research publications, and personal connections within the industry. While we reached out to a number of companies, ultimately, we managed to interview 18 companies from 6 different sub-industries.

The sub-industries of interest were: ‘Satellite Manufacturing, Assembly, Integration, and Testing’, ‘Ground Operations’, ‘Satellite and Space Services’, ‘Software’, ‘Launch Services’, and ‘Multi-Function’ (typically for larger companies which didn’t fall under any one primary category).

In order to contact the firms with interview requests, we followed a framework. First, we used traditional methods, such as emails and personal introductions, to connect to the company’s decision makers. If that failed or if it was not an option, we sent a follow-up email. If that failed, we would try to connect with a decision-maker on LinkedIn, clearly stating the context of our outreach. Lastly, we would attempt to reach them via listed contact numbers (company phone numbers) or the general-purpose email, typically found in the company’s ‘Contact Us’ page. After receiving a positive reply, we would provide some context, where required, and set up a time and date for the interview. All interviews in this stage were conducted via teleconferencing.

The interview process was fairly standard across most interviewees, with slight variations depending on the answers given by the interviewees. A standard questionnaire was designed beforehand, but liberty was given to the interviewer to adapt the questions based on the context of the company and their responses. When possible, there were at least 2 interviewers present so as to capture the points raised more accurately.

We asked a set of questions on 6 particular topics: Regulations, Competitiveness, Government Support, Talent, Financing, and Capabilities. While some of the questions asked were designed to fit the context of the company responding, the fundamental question we were seeking answers to was “What are your opinions on [topic] in the context of Singapore?” Based on the answers to those questions, we would ask further clarifying questions if needed. There was also a final forward-looking question asked, where it had not been answered already, about what opportunities do they see in the coming years.

## ‘Ancillary Services’ Group Interviews

In the next phase of the report, we zoomed out a bit to see what were the ancillary services that were critical to developing a space ecosystem. We practiced a certain amount of discretion in determining which ancillary services were to be included. This was because of the varying

magnitudes of relevance of different ancillary services to the growth of the space ecosystem. For example, an accounting firm is fairly important for space companies, as it is for most companies. Similarly, an investor is also fairly important. However, one would not consider accounting companies to be have a vested interest in the space ecosystem, likely because there are no space-specific accounting firms. However, there are space-specific venture funds, which implies that those investors are more invested in the growth of the space ecosystem. While this argument can be challenged, we decided to use the aforementioned ideology, our best judgement, and guidance from the industry itself to determine the ancillary services of interest.

To find as exhaustive a list of companies as possible, we employed similar methods to those described in the previous sub-section of ‘Company Interviews’. We reached out to a number of ancillary companies, but ultimately, we interviewed 9 companies from 4 sub-industries.

The sub-industries of interest were: ‘Associations and Consultancies’, ‘Academia’, ‘Investors’, and ‘Media’. Media was added towards the end our research after a few interviewees raised the importance of their role. While we were also in discussions with national research agencies, due to the sensitivity of any information they might provide (and given that we intended to keep our report publicly accessible), there was a mutual agreement to not conduct any interviews for this report.

In order to contact the firms with interview requests, we followed a similar framework to that described in the previous sub-section of ‘Company Group Interviews’.

The interview process was also largely similar to that described in the previous sub-section of ‘Company Group Interviews’.

We asked a similar set of questions on the same 6 topics that were previously described in the sub-section of ‘Company Interviews’. However, as we had already learned some preliminary details from our interviews with the companies, we placed more emphasis on certain topics to get more detailed views. There was also a final forward-looking question asked, where it had not been answered already, about what opportunities do they see in the coming years.

## ‘SEDS’ Interview

Unlike what the name may imply, this phase of interviews was not centred around SEDS members or different SEDS chapters (although that was a small part of it). In this phase, our interviews were less structured and more conversational. The purpose of these conversations was to get a better understanding of certain issues, which may or may not have been discussed in the report. Typically, these conversations by themselves would not qualify as interviews and so they have been bundled together under this section.

The reason that this section has been included is to add some external perspectives to some of the matters discussed.

The content and findings for this section came from various sources:

- Primary Research
  - Conversations with members of foreign SEDS chapters
  - Conversations via email or text conversations with space industry professionals from foreign countries, without a known stake in Singapore.

- Conversations with Singaporean professionals (from diverse industries) who are not a part of the space sector.
- Conversations with government officials, both from OSTIn and other agencies. While all statements have been anonymised, it should still be noted that the views expressed by the respondents were their own views and not representative of the government's stance on any matter).
- Secondary Research
  - Background research done by the team, which was not included in the 'Global Overview' section.
  - Supplementary research done as a follow up to the aforementioned conversations.

This phase was primarily carried out after the interviews with the ancillary services group. The conversations, as mentioned, were largely unstructured but generally covered 1 or more of the 6 aforementioned topics, along with the aforementioned forward-looking question. The individual questions themselves, as well as any follow-up clarifications, were typically more nuanced than in the other phases.

## **Post-Interview Review and Insight Generation**

After each phase of interviews, a small sub-team was assigned to comb over all the interviews in a certain phase ('Companies', 'Ancillary Services', or 'SEDS') and review the content within to see if there were any incomplete or unclear pieces of information. If there were any spotted, a clarification email would be sent to the interviewee in order to rectify the issue.

Assuming all the information was correct and updated, the sub-team would then take on the task of iterating through all the comments made on the different topics of discussion in order to find insights about the industry.

For a comment to qualify as an insight, it had to provide us with information that helped describe the larger theme (eg. Regulations, Financing etc) under which the point was made, either through observations, experiences, data, causes, consequences or proclamations. It is reasonable to consider that defining an insight was a subjective activity. In order to reduce the subjectivity, we employed a more thorough framework. In addition to the point above on the criteria for qualifying insights, the sub-team would follow that up with reiterating through the interviews to see whether the connections between points strengthened. Typically, upon a second viewing, the insights generated in the first round, which could be somewhat isolated or unsupported, were strengthened with supporting evidence from other comments. If there were any insights which remained isolated points, didn't add to the larger theme, or were weakened significantly during the second round of reviewing, they were left out of the report. Moreover, in order to have similar standards for the insight generation, the sub-teams were kept to a maximum of 3 (and a minimum of 1, where possible).

Finally, after insights were generated and collated for all three phases, the team worked to combine them together. This was done, over other formats of presentation, to add value to the reader. By employing this method, we were able to show each group of stakeholders' views on certain issues. In doing so, we were better able to show the user potential points of conflict and agreement. On top of that, for specific issues which only garnered responses from one group of

stakeholders, it can be used to determine which matters may be a non-issue for one group but troublesome for another.

## Anonymity

Throughout the insights generated, we have tried to anonymise the responses of our interviewees so as to still convey the central point of their argument, without implicating them. What should be noted is that most of the insights are a sum of similar comments raised by different interviewees to similar questions. Hence, an insight on academic research (for instance) does not necessarily imply that it has come from an academic. While some interviewees would likely prefer to be named, as they have provided extremely valuable insights, the standard we set for this report is to respect the privacy of all who took time out of their busy schedules to help us in our efforts.

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*Photo by Tiff Ng*