The SSP 2017 Program of the International Space University was held at the Cork Institute of Technology in Cork, Ireland.

The front cover artwork is an original concept of the ARESS team.

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Acknowledgements

The ARESS team wishes to thank the faculty and staff of SSP 2017 for all their guidance and assistance, with special thanks to:

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ISU and the ARESS team wish to express their sincere appreciation to Cork Institute of Technology, Blackrock Castle Observatory, Cork County Council and Science Foundation Ireland for their sponsorship of this project.

We would like to thank our team project visiting lecturers for their valuable insight and advice:

- Ian Downey - UK Integrated Applications Program / ESA
- Anthony Denniss - Airbus
- Jayar La Fontaine - Idea Couture
- Professor David Southwood - Imperial College London / UK Space Agency
- John Vesey - Satellite Applications Catapult
- Professor Nick Veck - Satellite Applications Catapult
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<td>Yanbin Xu</td>
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Achoimre

I mblianta tosaigh ré an spáis, bhí bheim faoi leith ar thaiscéalaíocht uailmhianach, ar iomaíocht idir na náisiúin óllchumhachtach agus ar infeisteacht ollmhór ó na rialtais éagsúla. Is dócha gur thug an mheid sin le tuiscint do náisiúin eile nár choir dóibh siúd an spás a bheith mór sprioc dá gcuid gniomhaíochtaí náisiúnta. Tá tionscal an spáis sa lá atá inniu ann éagsúil ar fad, áfach. Tá deiseanna ann do go leor náisiúin an spás a chur i bhfeidhm i saol na tíre, gníomh a spreagann feabhas sochaí agus fás sa gheilleagar, chomh maith leis na glúnta atá atá le teacht a ghríosú, agus an slándáil náisiúnta a chur chun cinn. Chomh maith le sin, spreagann sé nuálaloicht tras-thionscail agus ardaíonn sé meas agus féinmheas ar an t祇. Cé go bhfuil cuma air go bhfuil an spás deacair agus costasach le fáil isteach ann, is í fírinne an scéil go bhfuil an tionscal oscailte do chách. Léiríonn an tuairisc seo an tslí do náisiúin éagsúla le cumas spáis a chothú. Pléimid tarraingt agus buntáistí an spás do náisiúin, ag glacadh leis go mbíonn cúiseanna difriúla ag brath ar chultúr agus meon na ndaoine. Tugaimid aghaidh ar chomhthoirí a ghabhann leis an gcinneadh an tionscal spáis a sheachaint. In a dhiaidh sin, dírímid isteach ar na priomhánáisiúin sa tionscal spáis, ar mhargáí poiblí agus príobháideacha, agus ar na treochtaí is deireanaí le tóir fhealsionann an tionscal a nachtrad. Ansin, léirímid ar dtuaiscint agus agus ã n-anaílís do thrí chinn déag de na náisiúin atá cumasach sa spás. Úsáidimid eiseamláirí ón grúpa sin le plean oibre don tionscal spáis, a bhraitheann ar fhianaise, a mholaíth. Cuireann ARESS san áireamh prionsaibh ghinearálta a theaghlann do gach náisiúin, chomh maith le modh don náisiúin féin céimeanna roinnt aithint ag brath ar luidreachtai, ar chomhthéacs geopolaitiúil agus ar a gcúiseanna féin. Beidh an tuairisc ARESS in a hasmhainn luachmhar i gcomhhair náisiúin atá ag iarraidh forbairt a dhéanamh sa tionscal spáis.

Abstract

The early years of the space age, marked by ambitious exploration, competition between international superpowers, and massive government investment, may have led many nations to believe that space should not be a part of their national activities. The space industry of today, however, is vastly different. There are opportunities for many nations to implement space into their national fabric, thereby driving societal improvement and economic growth, inspiring future generations, advancing national security, sparking cross-industry innovation, and elevating national prestige. Though space may be perceived as a sector which is difficult and costly to enter, the reality is that space is open to all nations. Our project provides a general roadmap for nations to build space sector capacity. We discuss why various nations would want to pursue involvement in space, noting that different cultures can have vastly different rationales. We also address the opportunity losses of not developing a space sector. Next, we discuss the dominant space powers, public and private markets, and recent trends to provide a clear picture of the global space landscape. We then present our analysis of thirteen established space nations, using examples from these case studies to build an evidence-based roadmap for space sector capacity building. ARESS includes general principles which are universally applicable, yet also provides a method for nations to identify specific steps based on existing strengths, geopolitical context, and rationales. The ARESS report will be an asset for nations wishing to engage in space sector development.
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Faculty Preface

The global space industry is growing faster than ever, and private investment has become dominant in the marketplace. Satellites help us to find our way and to communicate globally. They observe our world and help to improve our understanding and management of planet Earth and its natural resources. They support increasing spatial and temporal resolutions, and the data they generate is used to inform new commercial opportunities in almost all domains, including the environment; climate change mitigation and adaptation; energy (electricity generation and infrastructure); transportation (aviation, road, rail, and waterborne); telecommunication; security and defense; border control; civil protection; migration; marine and maritime activities; agriculture; education; health and human performance, among others.

Never has there been more opportunity for new countries to benefit from the changing face of the space industry. Each emerging space state has strengths that it can harness to great advantage: the space industry requires companies of all sizes, across all disciplines, and the support of local and national governments. This yields a complex matrix of interactions that needs to be understood to realize the diverse and extensive commercial opportunities available.

The challenge set to the ARESS team was to analyze and understand how states such as Israel, India, and Luxembourg have developed space capabilities, and to apply the learning to emerging states, with a focus on Ireland, Hungary, Vietnam, Peru, Oman, and the Philippines. ARESS team members have engaged in face-to-face discussions with leading experts from space agencies including NASA and ESA, with large aerospace companies such as Airbus, and medium-sized technology companies such as the Satellite Applications Catapult. Non-profit associations and networks have also been essential to capture the cultural and societal relevance of the sector. Our visiting experts provided independent and insightful advice based on their experience within the industry. They brought contemporary thinking on how the global space industry is evolving and where new opportunities are arising. Such intensive expertise has rarely been applied to the topic of emerging space states.

The result of these efforts is a report that establishes an evidence-based framework for emerging states to use when formulating or expanding their national space strategies. This report forms a unique resource that will be relevant for years to come. It covers the major topics that a country needs to consider before expanding into new space opportunities.

We welcome this report and applaud the work of all those who contributed to it, especially the 28 ISU participants from 15 countries who comprised the ARESS team. We commend the report to policy makers, industry, the public, and all those interested in capturing the economic and societal benefits of space.

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This report, A Roadmap for Emerging Space States (ARESS), was produced by students at the International Space University Space Studies Program 2017 (ISU SSP17), held from June 26 to August 25 in Cork, Ireland. The students of this team project are grateful to the ISU faculty and staff for their mentorship and guidance over the last nine weeks. We would especially like to thank our Co-Chairs, Ed Chester and Robert Hill, our Teaching Associate, Andrew Butler, as well as Niall Smith and the Cork Institute of Technology community.

The purpose of ARESS is to provide guidance for nations which currently do not have extensive involvement in the space sector, yet have potential to both benefit from space activity and contribute to the international space community. We come from 15 different countries, several of which are considered to be emerging space nations. In our report, we made a special effort to directly address the nations represented on our team whenever possible: Austria, China, India, Israel, Norway, and the U.K. are analyzed as case studies of established space nations, and Hungary, Ireland, Oman, Peru, and the Philippines are included as examples to which the roadmap is applied. Following SSP17, several of us will present this report to various government officials and other stakeholders including at the 2017 International Astronautical Congress (IAC), with the goal of directly contributing to space sector development in our own nations. For our team, ARESS is much more than just a project; ARESS represents future opportunities to work in the field we love in the countries we call home.

Though this report focuses on the most tangible aspects of space, we also acknowledge the personal fascination and excitement about space which inspires all of us. In every nation and era, people have looked out to space and wondered about their place in the universe. Here in Ireland, the monuments at Newgrange indicate that Neolithic people were watching the night sky many thousands of years ago. It is our hope that the ARESS report will help emerging space nations achieve their goals of socioeconomic development, national security, and economic growth. At a deeper level, it will provide opportunities for people all over the world to follow their dreams by helping to make space the province of all nations.

ARESS TEAM
SSP17 — Cork Institute of Technology, Ireland

Plan illustration of the alignment of the Newgrange burial mound with the sun during solstice

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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>SH-SSP</td>
<td>Southern Hemisphere Space Studies Program</td>
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<tr>
<td>SINDAE</td>
<td>National System for the Development of Space</td>
</tr>
<tr>
<td>SIVAM</td>
<td>Sistema de Vigilância da Amazônia</td>
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<tr>
<td>SKA</td>
<td>Square Kilometer Array</td>
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<tr>
<td>SMEs</td>
<td>Small and Medium Sized Enterprises</td>
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<tr>
<td>SOSA</td>
<td>Slovak Organisation for Space Activities</td>
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<td>SSP</td>
<td>Space Studies Program</td>
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<tr>
<td>STEAM</td>
<td>Science, Technology, Engineering, Arts, and Mathematics</td>
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<td>STEM</td>
<td>Science, Technology, Engineering, and Mathematics</td>
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<tr>
<td>STI</td>
<td>Space Technology Institute</td>
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<tr>
<td>U.A.E.</td>
<td>United Arab Emirates</td>
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<td>U.K.</td>
<td>United Kingdom of Great Britain and Northern Ireland</td>
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<td>U.N.</td>
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<td>UCD</td>
<td>University College Dublin</td>
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<tr>
<td>UNCUPOUS</td>
<td>United Nations Committee on the Peaceful Uses of Outer Space</td>
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<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organisation</td>
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<td>UNICEF</td>
<td>United Nations Children's Fund</td>
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<td>UNOOSA</td>
<td>United Nations Office for Outer Space Affairs</td>
</tr>
<tr>
<td>VAST</td>
<td>Vietnam Academy of Science and Technology</td>
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<tr>
<td>VLS</td>
<td>Veículo Lançador de Satélites</td>
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<td>VNSC</td>
<td>Vietnam National Satellite Center</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation</td>
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<td>WTO</td>
<td>World Trade Organisation</td>
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How to Use This Document

This document is intended for any individual or organization involved in national space sector capacity building. Though many of the recommendations discussed are directed at government officials and staff, they can be equally useful to non-governmental organizations, businesses looking to enter the space market in an emerging space state, and private individuals advocating for increased government investment in space. It is suggested that the document be read sequentially, especially chapters 4, 5, and 6, as these all build on one another.

Chapter 2 presents the various rationales for why a state should want to be involved in space activities. Chapter 2.6 presents an important discussion about the opportunities lost if a country fails to engage in the space sector. Rather than justifying why a country should invest in space, we argue that countries should instead justify why they are not investing in space.

Chapter 3 provides an overview of the global space sector landscape, including traditionally recognized space states, governments, commercial markets, and recent trends. This chapter is particularly important for readers who are not familiar with the space sector.

Chapters 4, 5, and 6 represent the development, presentation, and application of our roadmap, respectively. In chapter 4, we discuss our methods to select and analyze 13 different countries which are established space states. Case studies of these countries are provided in the appendix. In chapter 5, we extract general recommendations from the specific examples in the case studies, resulting in an evidence-based roadmap for space sector capacity building. One key aspect of the roadmap presented in chapter 5 is that it is general enough to be widely applicable, yet guides users to specific recommendations for their countries. In chapter 6, we illustrate this process by applying the general roadmap to six emerging space countries: Hungary, Ireland, Oman, Peru, the Philippines, and Vietnam. This chapter is particularly important because it exemplifies how to apply the recommendations in the roadmap to an individual nation.

Scope

The scope of this document is to provide an evidence-based roadmap for emerging space states. We did not consider the time required to achieve a specific space objective as a factor in this analysis as operational time lines depend on many factors that are not easily anticipated. However, the recommendations are flexible to suit the needs of individual countries.
1. Introduction

1.1. Mission Statement

Our mission statement is:

“To provide practical recommendations to emerging space states that enhance and inspire social and economic growth.”

1.2. Project Justification

When an increasing number of states become involved in peaceful space activities, the entire world benefits. Foremost, there are tremendous benefits for the specific countries directly involved. Satellite-enabled services such as telecommunication, navigation, and Earth observation provide an infrastructure which accelerates socioeconomic development. Studies have shown that national space activities produce an average economic return of over three times the initial investment (Cohendet, 1997). Space involvement also has tremendous potential to inspire younger generations and significantly advances national prestige. Additionally, there are benefits for current traditionally recognized space states when new actors enter the industry. Investment helps to grow the global space sector. International collaboration associated with peaceful space activities results in advanced global knowledge, experience, and space technology. Ultimately, as more states develop space programs, all of humankind will experience the benefits.

The road to space has historically faced technical challenges, substantial risks, and significant budgets unlocked by strong political motivation. Furthermore, the public often associates the space industry exclusively with exploration and research, failing to recognize the applications of space technology in everyday life, ranging from car navigation to weather forecasting, or worldwide television broadcasting. These factors, combined with the breadth of fields within the industry make it difficult for new actors to identify opportunities or challenges. This document will aim to increase their space capabilities, maximize the socioeconomic benefits of space sector investment, highlight factors that can hinder progress, and successfully increase engagement with the global space sector.

Deganit Paikowsky – Israel
Author of the "The Power of the Space Club"

“Space is a benchmark for powers. Therefore, powerful countries are expected to develop space programs and ambitious projects. Countries that wish to become powers go for space in order to achieve such a powerful status. Non powers may develop more moderate capabilities for different reasons depending on their needs. Today it is much more economic than it [used to be].”
1.3. **Project Objectives**

**Main Objective**

The main objective of this report is to provide a document that will guide emerging space states to grow and improve their space sector capacity by exploiting various opportunities available, considering their industrial capabilities and geopolitical context.

**Specific Objectives**

To achieve this mission, the ARESS team pursued the following objectives:

- To investigate how established space states developed their strong space presence.
- To understand the geographic context of the space economy.
- To develop a model of space engagement for governments and decision-makers.
- To develop a strategy to promote interaction between the space and non-space sectors.
- To propose recommendations that assist the development of emerging space states.

1.4. **Definitions**

The following terms are defined according to their use in this report:

- **Established space state:**
  An established space state is a state that is a leader, or significant actor, in an area of the space sector.

- **Emerging space state:**
  Emerging space states are states that are taking steps to be more involved in the space sector.

- **New Space:**
  NewSpace refers to the commercial space sector, with its actors being mainly private companies.

- **Socioeconomic:**
  Socioeconomic relates to the interaction of social and economic factors (Merriam-Webster, 2017).

- **Traditionally-recognized space states:**
  Traditionally-recognized space states include the U.S., Russia, Europe, Japan, and China.

- **Outer space:**
  Outer space refers to all places outside of the Earth's atmosphere (Merriam-Webster, 2017).
2. Rationales for Space Activities

Each state has challenges specific to its culture and geography. In this chapter, we show how investments in space sector development can provide elegant solutions to these challenges. The space sector can be seen as the new intercontinental railroad in that after an upfront investment, states can use their space capabilities to address domestic problems more efficiently and cost-effectively (Paikowsky, 2017). With proper planning, emerging space states can leverage space technology as a problem-solving tool. We explore three interrelated factors that might motivate a nation to develop a space presence: economic development, capability, and cultural inspiration. We consider the space sector in upstream, downstream, and space-enabled activities. The upstream activities involve launch services, satellite manufacturing, and payload development. The downstream activities include telecommunications, geomatics, navigation, timing, and many other applications. Space-enabled activities encompass both upstream and downstream activities (OECD, 2004).

2.1. Economic Rationales

There are well documented national economic benefits from the space sector (Wood and Weigel, 2012a). Building space capability can enlarge the economic influence of a state (OECD, 2012). Deganit Paikowsky, author of The Power of the Space Club, states that "technological progress is clearly linked to national prosperity" (Paikowsky, 2017). The historical rate of return for space activities is around threefold (Cohen, 1997). It is important to note that economic returns are not immediate and generally happen over time across different parts of the economy. Since the 1970s, industry has used space applications to create new business solutions. Agricultural, maritime, and consumer technologies are just a few of the areas using space applications. The specific market size and categorical monetary amounts are discussed in more detail in the next chapter.

2.2. Cooperation and Partnerships

International partnerships and collaborations that advance common goals among countries are part of the fabric of many space programs and activities. International cooperation creates relationships and produces diplomatic value beyond space activities. One excellent example is the extremely successful International Space Station (ISS) partnership that resulted from the 1998 signing of an intergovernmental agreement between 15 states. Over the years, the ISS has helped overcome political and economic strains between these states (ISECG, 2013). International cooperation can also promote a healthy national economic portfolio. Examples of how different countries supported an international space sector include: policies to co-develop capabilities, training a workforce in another country, inviting a partnering state’s workforce to train the host state’s citizens, and collaborating with space agencies on specific missions.

Cooperation can also take place across the public and private sector. The space sector generates public-private and corporate partnership opportunities, which can lead to an increased share of the global market and contribute to national economic growth (Northon, 2017). The rise of these new opportunities has led to the NewSpace sector.
A state’s policy approach is highly dependent on its goals and capabilities (Wood and Weigel, 2012a). Policy-induced activities help determine if the country will develop an indigenous space program, outsource space services, or pursue a hybrid insource/outsource approach.

2.3. Technological Rationales

Technological independence is a primary goal of many countries and can be achieved through increased space capability. It can be achieved “through the adoption, imitation, learning, and improvement of foreign technologies” (Lele, 2012).

An effective national space policy will leverage existing expertise while promoting the development of new capabilities. Emerging space states can benefit from accelerated development of workforce skills that are required to support space capabilities. Investments in scientific research create an understanding of technologies and environments that leads to new knowledge, as proven by Bush (1945). Space activities require knowledge in many disciplines, including science. In many cases, space system development results in useful applications for society and individual consumers. Overcoming natural disasters, epidemics, or agricultural problems are just a few of the areas to have benefited from space technology (Irwin, 2017).

Over time, the workforce and skills derived from the space sector provide a greater opportunity for new technology development, more efficient commercial operations, and advancement of a state’s status (Paikowsky, 2017). Solutions developed for space can lead to solutions for terrestrial market sectors and spin-offs from space activities (Brisson and Rootes, 2001; NASA, 2017; Feuerbacher and Messerschmid, 2011). Involvement in the space sector allows a state to further diversify its workforce and broaden the disciplines in which it is engaged.

2.4. Cultural Rationales

All rationales for space are culturally-dependent. “Culture refers to the way we live, the things we believe, the language we speak, the artefacts we fashion and use” (Dator, 2012). Dreaming about space has inspired people to get involved in the arts, such as writing science fiction books, painting, and creating movies (ISECG, 2013).

Promoting a national space agenda can funnel the natural human desire to explore

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Dr. Niall Smith, Ireland Head of Research at Cork Institute of Technology (CIT) and Head of Blackrock Castle Observatory; SSP17 Local Organizer Lead

“Our outreach now has evolved, or is evolving, to [...] not just be inspired by the universe but to [...] understand how to do things with satellites to use that to our benefit on the planet itself. And that's a bit of change in the thinking of the people in Ireland. So outreach is very important to help to influence that. If the public has no interest, then it is very hard to have businesses have an interest [...]. So that matrix I think works best if it works together. In other words, really if I was to summarize it: it's building a culture of understanding that space is important. And if you are to build a culture in your country, then as many people as possible in that country need to buy into that. And the first step on that is bringing them awareness; and that's what outreach does.”
into a socially acceptable and economically advantageous endeavor. Scientific-based cultural rationale forms the base for education, research efforts, and industries (Dator, 2012). The space sector has many interdisciplinary components that can symbolically show how advanced a state is in comparison to its neighbors.

### 2.5. Educational Rationales

There is an ever-present concern in the modern world as to how to encourage young people to study and pursue careers in science, technology, engineering, arts, and mathematics (STEAM) that are necessary for socioeconomic advancement. As W.H. Siegfried (2003) noted, “investment in the Apollo Moon exploration program in the 1960’s correlates with the level of technical education later attained by students.”

The following image illustrates how the number of PhDs in math, science, and engineering awarded in the U.S. increased throughout NASA’s Apollo Program (ISECG, 2013):

![Figure 2.1 PhDs awarded in the U.S. in technical fields during the Apollo program](image)

Outreach can encourage a steady flow of STEM students and help build public support for space investments. Keeping the public informed and inspired is important for any state to generate support for its efforts. An emerging space state can look to the United Nations Office for Outer Space Affairs (UNOOSA) for examples of outreach activities.
2.6. Opportunity Loss

All states have problems and challenges to be solved. Connecting these problems to solutions that use the space sector as a tool will greatly benefit the state. Conversely, failure to engage in the space sector results in a loss of opportunity. For example:

- A country may meet its need for space capability by depending on foreign space markets. However, foreign services may not account for specific national considerations and may provide less timely service than native capability.

- A non-space state risks losing the opportunity to profit from a growing space economy.

- A non-space state has a reduced ability to forecast or quickly recover from environmental and natural disasters.

- Space capabilities create a foundation for adjacent technology markets to develop. Failure to invest in space may also impede growth of these other markets, reducing the country’s international competitiveness.

- Emigration of highly trained or qualified people from a state degrades its ability to compete internationally in technological fields.

Any number of services today require space-related platforms or systems. Countries without space sector capability to provide these services depend on external resources to provide them. Dependent countries have little control over changes in policy of their providers, with consequences that can include potential economic losses. For example, the European Union (E.U.) is investing in its own satellite navigation system (Galileo), despite the fact that the U.S. gives the E.U. free access to its own global navigation system (Navstar Global Positioning System, commonly called GPS). One important reason for this is that “6-7% of Europe’s GDP in 2009, or EUR800 Billion, relies on satellite navigation signals” (European Commission, 2013). Should the U.S. decide to change its free-access policy, the economic impact, not counting the loss of services or security, would be significant.

Countries that entirely depend on external services for their space capability may incur a trade deficit in high value-added services typical to space activities.

Even the most technologically advanced countries today consider their access to space a matter of national pride. Investing in a domestic space program can increase both national and international prestige for the country (Sheehan, 2013).

Other potential losses that are not typically considered are those related to damage or destruction of environmental heritage.

Funmilayo Erinfolami – Nigeria
Scientific officer at ARCSSTEE,
SSP17 Staff, Dipteran

“To all the space aspiring, or emerging nations, I would just like to say that in all the policies, all the plans they have in integrating space […] it is important to go from the human angle, and what are the benefits. How will it make life better for the men on the streets? How will it make the standard of living way better for them? […] Space is for all humankind. Space is for humanity. Space is for better life. That’s it.”
Earth observation applications are among the foremost services that space activities provide. Observation activities help with monitoring land use, deforestation, fire risk, and disaster recovery. Earth observation also supports identification and conservation of historical sites, as seen in the Open Initiative on the Use of Space Technologies to Support the World Heritage Convention signed by ESA and the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2003 (Negula et al., 2015).

The erosion of human capital can present a large challenge for any state. The space industry depends upon highly trained and qualified people. Many of these individuals consider emigrating to countries where they can pursue careers in advanced fields of technology and science. Space sector activities can provide opportunities that inspire these people to stay in their own country. Conversely, foreign engineers and scientists can be attracted to an emerging space state in which these opportunities are available.

These examples are not comprehensive, but are meant to illustrate the reality that failing to become a space actor results in opportunity loss.
3. Space Sector Landscape

3.1. Overview of Established Space Actors

This report reviews some traditionally recognized space states to determine the roots of their success. The achievements of nations such as the U.S., Russia, China, and Japan, are largely due to strong political backing and adequate national funding in the early stages of developing their space strategy. Alternatively, as an international agency with 22 member states, ESA has gained its success by establishing regional cooperation and governance in the space sector.

In 1958, the U.S. founded the National Aeronautics and Space Administration (NASA). NASA is an independent agency of the U.S. federal government and is responsible for its civilian space program as well as aeronautics and aerospace research (NASA, 2017). Its space missions include space science, Earth observation, human spaceflight, and technology development. The agency’s International Partnerships Office works in close coordination with the Office of International and Interagency Relations to support relationships and collaborative activities with global partners. For example, NASA is a key partner of the ISS. Additionally, NASA partnered with ESA and the Canadian Space Agency (CSA) on the James Webb Space Telescope. Through collaborations with industry, NASA facilitates technology transfer to new markets such as space tourism and renewable energy (NASA, 2017). Currently, the agency engages with representatives from 24 nations, including space agencies, universities, research institutes, and technology companies (Schalkwyk, 2015).

Russia’s space program is run by the state space corporation Roscosmos. This program is a national priority for the Russian government which encourages public-private industry interactions (Roscosmos, 2017). Roscosmos ensures Russia’s space program is implemented in accordance with domestic and international regulations. The corporation coordinates the development, manufacture, and supply of space equipment. Additionally, it is responsible for international space cooperation and for leveraging space activities to support Russian social and economic development. Major space activities include space science, human spaceflight, navigation (e.g., GLONASS), Earth observation, human spaceflight, launch vehicles, launch services, and space tourism. Roscosmos partners with a number of countries and space agencies. For example, Roscosmos and ESA worked in collaboration on the ExoMars mission (ESA, 2017b). Russia is also a partner of the ISS program and currently provides the only means of transporting crew to the station. Recently, Russia has established technological partnerships with emerging space states such as South Korea, Kazakhstan, and Brazil (Roscosmos, 2017).

Under the State Administration for Science, Technology, and Industry for National Defense, the China National Space Administration (CNSA) is responsible for defining national space policies, directing the civilian space program, and managing the development of national space science, technology, and industry. China Aerospace Science and Industry Corporation (CASIC) is responsible for the defense industry. The China Aerospace Science and Technology Corporation (CASC) is responsible for the civilian and commercial space industry. Both CASIC and CASC are prime contractors for the Chinese space program. Major space
projects in China include: a space station; a Global Navigation Satellite System called Beidou, to be completed by 2020; and exploration missions (Aliberti, 2015).

In 2003, the Japanese Aerospace Exploration Agency (JAXA) formed following the merger of three aerospace organizations: The Institute of Space and Astronautical Science, the National Aerospace Laboratory of Japan, and the National Space Development Agency of Japan. JAXA’s main mission is to lead Japan’s space development. Currently, JAXA’s major space activities include: maintaining the Experiment Module aboard the ISS, improving navigation capability, and operating a domestic satellite system called the Quasi-Zenith Satellite System. This satellite system will progress into a four-satellite constellation by 2018, and a seven-satellite system by 2023 (Cabinet Office, Government Of Japan, n.d.).

ESA’s research programs cover a broad spectrum of space activities that use the expertise of all its member states. The agency’s main missions are directed at human spaceflight, the space environment, Earth observation, communication, navigation, and exploration of the solar system and deep space. ESA develops satellite-based technologies and services to encourage European private sector engagement. As one example of the agency’s major space activities, ESA contributed the Columbus Laboratory to ISS. Additionally, ESA is working on Galileo, a Global Navigation Satellite System (GNSS) that will be fully operational by 2020 (ESA, 2017b).

3.2. Overview of Current Global Space Activity

The Space Foundation’s Space Report (2017) estimates that the global space sector was worth US$329.3 billion in 2016, increasing by US$6.3 billion from 2015. Commercial revenue accounted for 75% of global activities in space in 2016. The government sector spent a total of US$76.4 billion, with the U.S. having the largest space budget at US$44.4 billion (Space Foundation, 2017).

Figure 3.1 illustrates spending on commercial and governmental space activity. Within the commercial sector, revenues from space products and services include satellite communication, broadcasting, and Earth observation. Commercial infrastructure and support services (i.e. upstream products and services) include ground stations and equipment, satellite manufacturing, the (commercial) launch industry, insurance, commercial suborbital human spaceflight, and - the largest component - GNSS ground equipment worth US$89.9 billion (Space Foundation, 2017).
The Space Report (2017) also reviews the number of people employed within the space sector. The U.S. had the largest space workforce, with more than 220,000 people employed in the space industry in 2015. Europe had 38,000, India 17,000, and Japan 9,000 space sector employees.

3.3. Emergence of Small and Medium Enterprises in the Space Industry

The importance of small and medium enterprises (SMEs) is recognized worldwide because of their contributions to meeting socioeconomic objectives, such as employment growth, output, promotion of exports, and encouraging entrepreneurship (Keskin et al., 2010). Many countries and space agencies support SMEs through distinct programs and policies. In addition to SMEs, the space industry also distinguishes between large enterprises and micro-enterprises, to offer them the best support to develop within the space sector (European Commission, 2017).

The European Commission prioritized support for SMEs to stimulate economic growth, job creation, and economic and social cohesion (Keskin et al., 2010). For instance, the European Union’s Horizon 2020 program dedicates 20% of its budget to SMEs (European Commission, 2017b). The program supports space research to “ensure that space will remain accessible to Europe and safe to operate in the long run” (HORIZON 2020 Space Advisory Group, 2014). It aims to “engage small and medium enterprises in space research and development, especially those not traditionally involved in it,” (European Commission, 2017). Horizon 2020 also creates special projects such as the Earth Observation Big Data Shift, to support companies.
that use Copernicus satellite data (European Commission, 2017). SMEs have become an essential part of the space industry and its future.

ESA has a dedicated website for industry, making data and business opportunities more accessible. It also supports companies and SMEs through Business Incubation Centres (ESA, 2017b). ESA supports the space industry by engaging companies from Europe in ESA projects and by creating partnerships with the private sector (ESA, 2017b).

In China, the major players in the space sector are Chinese state-owned companies: CASC and CASIC (Medeiros et al., 2005). China intends to relax state control of enterprises to encourage innovation and promote competition in the aerospace and defense industry (Aliberti, 2015). CASC engages in both upstream and downstream space technologies and deals with research, design, manufacture, and launch of space systems, and with space applications (CASC, 2017). Some private companies, such as the Xinwei group, participate in small space projects and satellite communications (Xinwei Group, 2017).

NASA is committed to providing all small businesses with opportunities to participate in both NASA prime contracts and subcontracts. The responsible body is the Office of Small Business Programs. Its main objective is to help small businesses pursue contracts (NASA, 2017).

JAXA contributes to economic growth by creating business opportunities involving its space activities, proposing systems for technology transfer, and publishing up-to-date information on developments in aerospace technology (JAXA, 2017).

Russia’s space activities are enhanced through the Skolkovo Foundation, a non-profit organization established by the Russian government. The organization is a catalyst for diversifying the Russian economy. Its goals are to create an entrepreneurial and innovative ecosystem, instigate a start-up culture, and encourage venture capitalism, with particular focus on growing space technologies (Skolkovo, 2017).

3.4. Support for Companies Entering the Space Industry

The private space sector is growing rapidly. From 2000 to 2016, more than 80 companies have been established that were supported by venture capitalists and angel networks, eight of which have been sold at a total value of US$2.2 billion. Among them, these firms have raised more than US$13.3 billion in investment, with two-thirds of that being raised within the last five years (Christensen, Armstrong and Perrino, 2016). Governments and organizations are trying to support both the upstream and downstream private space sectors to take advantage of space-related economic growth. A growing number of governments around the world are supporting global space activities. For example: the Australian government invested US$40 million in the Australian Space Research Program (Department of Industry, Innovation and Science, 2015) and the Israel Space Agency (ISA) supports the corporate development of technologies, components, and systems as part of its agenda (ISA, 2017). An increasing number of private initiatives are being formulated to support new space companies.
3.5. Recent Trends in the Space Sector

Primarily for economic reasons, countries like the U.S. and Russia have dominated advancements in satellite technology. The emergence of small satellites has begun to create opportunities for other countries to participate in space endeavors. Small satellites are low-cost and have a short development time, making them attractive to emerging space states. Depending on a country’s individual situation, it can use small satellite technology for applications such as urban planning, disaster management, and food security (Wood, 2008). Small satellite technology also presents a platform for training students, engineers, and scientists in satellite development and operations. Knowledge can then be transferred to local entities such as universities, local research centers, or local industries to ensure sustainability in a national space program.

In 2016, 51% of the satellites launched into space were nanosatellites and microsatellites, an indicator that small satellites are developing rapidly. A significant portion of these were from established space states such as the U.S. and China, which launched a total of 106 and 36 small satellites respectively in 2016. Nevertheless, emerging space states have also launched their own small satellites (Space Foundation, 2017).

With high-tech computers, increased access to small satellites, and cheaper launch costs, a remote sensing system can be an ideal starting point for a country wanting to enter the space sector. Remote sensing data applications are the foundations of a fast-growing industry that focuses on applications including agriculture, land monitoring, and resource management. Earth observation and remote sensing observe and acquire information about objects without physically contacting them. It is common to have remote sensing systems onboard satellites, or even airplanes and drones. Common applications of these technologies include Earth science and land surveying. Companies can deploy their own satellites or buy data from Earth observation satellite operators. It is common to deploy remote sensing satellites in low Earth orbit (LEO), making it possible to obtain global imagery with fast revisit times. Current trends in Earth observation technology include improved spatial resolution as well as multispectral and hyperspectral imagery.

3.6. Forecast of the Future Space Market

Market expansion

The space industry is expanding rapidly in three ways: size, number of countries involved, and market types. Figure 3.2 shows the overall trends in the global space industry within the last decade. As can be seen, global spending in space has been increasing at an approximate rate of 4% per year since 2005. It is expected that this growth will continue (Space Foundation, 2017).
Geographical expansion

Every year, new countries get involved in the space industry. Figure 3.3 illustrates the increase of countries in possession of a satellite between 1966 (left) and 2016 (right).

Figure 3.4 is a forecast of future satellite launches (launch mass >50kg). This forecast does not account for possible mega constellations, such as OneWeb, which is designed to incorporate 2,600 satellites to provide worldwide internet coverage. This figure demonstrates that the number of satellites to be launched in 2015-2024 is expected to increase compared to the number launched in 2005-2014.
The future space market will bring diverse opportunities for both public and private space actors. We identified examples of future space innovations and applications including small payload launchers, space tourism, space mining, Earth observation, on-orbit servicing, and telemedicine.

### 3.7. Small Payload Launchers

The small satellite market has seen impressive growth as a result of the miniaturization of satellite components. Historically, small satellites were launched as secondary payload aboard larger payloads, however, the rise of the CubeSat market has created demand for the development of launchers dedicated to smaller payloads (Palerm Serra, Barrera Ars and Salas Solanillas, 2013). As a result, several companies are currently developing their own launch vehicles. A new area that threatens to take over small payload launchers is referred to as HAPS, high altitude pseudo-satellites. These pseudo-satellites blend the benefits of both conventional satellites and remotely piloted or autonomous aerial vehicles (Airbus, 2017).

### 3.8. Space Tourism

Space could be the next extreme tourism experience. Blue Origin, Virgin Galactic, Space Adventures, and World View Enterprises are private companies competing to be the first to send tourists on short suborbital flights. Passengers will experience launch with a balloon or a rocket and a few minutes of microgravity. Virgin Galactic and Blue Origin aim to launch their first passengers in 2018 (Foust, 2017).

### 3.9. Space Mining

Asteroids contain precious metals and minerals such as iron, nickel, cobalt, and methane, meaning asteroid mining has the potential to become a trillion-dollar industry. In addition to mining precious metals, water extraction could facilitate space exploration. Two companies that are currently developing missions are Deep Space Industries and Planetary Resources (ASTRA Team, 2010).
3.10. Earth Observation Future Applications

Most Earth observation missions use optical or radar instruments to gather information. These instruments use a range of wavelengths to reveal different features of the same area and may be appropriate for different environmental conditions. Mastering the use of several narrow wavebands with hyperspectral sensors opens the door to new applications, such as, food safety and agriculture monitoring. Similarly, the use of new wavelengths for Synthetic Aperture Radar is creating new applications. For example, the ESA Earth Explorer mission Biomass will “see through” vegetation from space (Quegan et al., 2012), allowing future soil moisture, geology, and forestry applications.

3.11. On-Orbit Servicing

Mastering formation flying techniques is of paramount importance for active debris removal (ADR) (Pirat et al., 2017). Successful ADR missions involve precise rendezvous and docking maneuvers. The growing number of space debris objects in LEO and geostationary orbit (GEO) is a serious hazard to the use of space. Many agencies are leading programs to study different methods of capturing on-orbit debris, such as ESA’s Clean Space initiative (Wormnes et al., 2013). Rendezvous and docking technology also allows space users to perform robotic on-orbit servicing, which would help mitigate component failure or provide refueling services to increase the satellite lifetime or even prevent mission loss (Ellery, Kreisel and Sommer, 2008).

3.12. Telemedicine

According to the World Health Organization (2010), telemedicine is the remote diagnosis and treatment of patients via telecommunications technology. Telemedicine includes various applications, such as telediagnostics, telementoring, and telesurgery (Bonnefoy and Gionet-Landry, 2014). In particular, satellite communication facilitates the transmission and reception of medical data.

3.13. Challenges and Barriers to Entry

It is not always easy to enter into the space market. According to the Organisation for Economic Co-operation and Development (OECD, 2004) there are certain obstacles that have to be considered. These problems include the restriction of market access, procurement policies, and export controls. The World Trade Organisation (WTO) Agreement on Basic Telecommunications is designed to facilitate trade in telecommunication services. Many countries have not signed this agreement, making it difficult for foreign investors to make investments in countries with market restrictions in this sector. Export control refers to the protection of sensitive technology by prohibiting its transfer to another country. Although it serves a purpose, export control can also have negative impacts on the space industry by impeding cross-border business. An example of such an export regulation is the U.S. International Traffic in Arms Regulation (ITAR). ITAR regulates the export and import of defense-related articles and services. Public procurement policies can be unreliable because of changeable political landscapes. Furthermore, these policies do not take into account commercially available products and services.
Public international space law is unsuitable for the commercial space sector. International treaties are aimed at states, but states must attempt to transform treaty-mandated international obligations into national laws that cover private space activities and confer responsibility to the commercial space sector. Ambiguity in national space law regulations can lead to legal uncertainty for private actors. Space policy can obstruct the commercial space sector when policy makers prioritize national security, or other objectives, over commercial development (OECD, 2004).

Technical barriers to engaging in space activities include obtaining radio spectrum allocation, which is managed by the International Telecommunication Union (ITU). Demand for radio frequencies has risen with the development of new technologies such as the rising number of small satellites. However, the number of allocations remains limited and must therefore be taken into consideration when planning a space mission (OECD, 2004).

The cost of transport to space can be a significant commercial obstacle for commerce. For example, it costs about US$20,000 per kilogram to launch a satellite (Coopersmith, 2011). Reducing launch costs would improve access for space commerce. All these factors are important considerations for entrepreneurs looking to enter the space sector.
4. Case Studies

To develop an evidence-based roadmap for capacity building in emerging space states, the ARESS team first analyzed 13 established space states. Drawing from the experience of these countries in space sector capacity building, we extracted 21 general recommendations for emerging space states. First, we discuss each recommendation individually. At the end of this chapter, we organize the recommendations into a roadmap that can be applied to any nation engaged in space sector capacity building.

There are many nations with space programs to consider, but analyzing every such country is beyond the scope of this project. To select the 13 established space states that form the basis of our recommendations, we created an initial list of potential countries. This list contained both traditionally recognized and recently established space states. To select the final countries to be studied, we used the unweighted Space Participation Metric developed by Wood and Weigel (2012a), shown in Figure 4.1. This metric uses space activity to define the extent to which a nation can be considered as an established space actor. One advantage of this method is that it encompasses a broad scope of space activity. Other proposed models consider technological achievements to determine space sector status (Wood and Weigel, 2012b; Leloglu and Kocaoglan, 2008). These methods attempt to impose a “one-size-fits-all” metric that only recognizes tangible, build-and-launch projects. We acknowledge that there are many aspects of the space industry aside from building hardware, such as data processing, law, business, insurance, and ground station operations. Therefore, we avoided metrics that only consider activity involving satellite hardware.

To implement the Space Participation Metric method, we created a scoring system in which countries received one point for each positive reply to the metric items, listed in Figure 4.1. With this score, we categorized the countries into five groups, describing the level of each country’s involvement across the array of space activities: low, medium-low, medium, medium-high, and high. To ensure a diverse sample, we selected countries in every category except low, as at least a medium-low ranking should be achieved to be considered an established space state. We selected any nations from the initial list that were represented on the ARESS team (Austria, China, India, Israel, Norway and the U.K.), as our team members have a personal interest and special insights into their home countries. Finally, we ensured geographic diversity by including at least one country from each continent (except Antarctica). The following are the established space nations we ultimately selected and studied: Australia, Austria, Brazil, Canada, China, India, Israel, Luxembourg, Nigeria, Norway, U.A.E., U.K., and South Africa.
<table>
<thead>
<tr>
<th>Level</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Low</td>
<td>- UNCOPUOS Members</td>
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<tr>
<td></td>
<td>- Group on Earth Observation Members</td>
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<tr>
<td></td>
<td>- Host an International Astronautical Congress</td>
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<td></td>
<td>- Signed the Outer Space Treaty</td>
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<td></td>
<td>- Members of:</td>
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<td></td>
<td>- International Mobile Satellite Organization</td>
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<td></td>
<td>- International Telecommunications Satellite Organization</td>
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<td></td>
<td>- International Telecommunications Union</td>
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<td></td>
<td>- International Astronautical Federation</td>
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<td>- International Astronomical Union</td>
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<td></td>
<td>- National Space Program</td>
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<td></td>
<td>- Space Institutes or Organizations</td>
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<tr>
<td></td>
<td>- Participate in U.N. Program on Space Applications</td>
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<tr>
<td></td>
<td>- Report to UNOOSA on National Space Research Activities</td>
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<tr>
<td>(3) Medium</td>
<td>- Domestic Communication Satellite system</td>
</tr>
<tr>
<td></td>
<td>- International Communication Satellite Earth Stations</td>
</tr>
<tr>
<td></td>
<td>- Earth Observation Facilities and Equipment</td>
</tr>
<tr>
<td>(4) Medium-High</td>
<td>- Launch Facilities</td>
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<tr>
<td></td>
<td>- Launch Vehicle(s)</td>
</tr>
<tr>
<td></td>
<td>- Appear on UN Launch Registry</td>
</tr>
<tr>
<td>(5) High</td>
<td>- Participate in International Space Station or National Human Launch Capability</td>
</tr>
</tbody>
</table>

Figure 4.1 Table to determine the level of space activity within a nation

It is worth noting that we did not include either the U.S. or Russia in our list of established space nations for two major reasons; 1) both the U.S. and Russia have been established space players since the late 1950s. As a result, their initial space sector development was non-contemporary, at a time when space achievements were closely associated with geopolitical and ideological contest; and 2) the U.S. and Russia are traditionally considered leaders of the global space industry. Considering their high status and advanced development in the space sector, it is difficult to compare them to emerging space nations.
We then analyzed our 13 established space states with the following four questions:

1. Rationales – why is the country pursuing space activity?
2. Industry landscape and geographic context – what unique strengths has the country leveraged?
3. National policy and strategy – what are the country’s official objectives and methods?
4. Overall model of space sector – what model has the nation employed?

Though there are several methods that could be used to further analyze the case study countries, such as risk-benefit analysis or strengths, weaknesses, opportunities, and threats (SWOT) analysis, such work is beyond the scope of this project. The ARESS mission is to provide recommendations for emerging, not established space states. Therefore, we study the established space states only to the extent necessary to understand fundamental best practices of space sector development. Finally, we focus on the strategies and practices in use when these countries were in the emerging phase, as this is most relevant to emerging space states today.

In chapter 5, we present the general recommendations extracted from these case studies, discuss them, and organize them into a comprehensive roadmap. Please see the appendix for the case studies.
5. The Roadmap: Our Recommendations

In this section, we introduce our recommendations for emerging space states and discuss examples of these recommendations. We formulated 21 recommendations by analyzing various established space states. We group the recommendations into four main categories: (1) policy and law, (2) international cooperation, (3) education (specialized and public), and (4) economics. In some cases, there is overlap among these categories. In chapter 6, we discuss how to apply these general recommendations to specific countries.

5.1. Policy and Law Recommendations

- Identify clear rationales for space activity and ensure that these drive space strategy.
- Ensure projects are within the scope of budget, resources, and technical experience.
- Ensure that the internal stability of a nation is sufficient for space sector capacity building.
- Commit to public transparency regarding government space spending.
- Consider various space sector architectures and implement the one that is most appropriate.
- Develop a clear government policy and legislative framework to guide space activity.
- Demonstrate commitment to achieve policy goals with stable funding.
- Ratify or accede to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention.

5.1.1 Identify Clear Rationales for Space Activity and Ensure That These Drive the Space Strategy

It is clear from the case studies that the most successful established space states have clearly defined rationales for their space activities. These rationales are largely related to culture, economic well-being, political standing, and geographic location. Rationales are the driving forces that push and motivate a nation to invest in the space sector. Essentially, a rationale answers the question of ‘why?’ A nation will commonly have several rationales for space activity.
The first major step for an emerging space state is to identify and clearly define the specific rationales that will drive its space strategy and activity. To achieve a successful space activity a country must ensure their space policies and strategies are aligned with their rationales. Common rationales include (Logsdon, 2017):

- providing benefits to society;
- facilitating socioeconomic development;
- increasing national prestige;
- gaining scientific knowledge;
- enhancing national security;
- fostering technical innovation; and
- inspiring younger generations.

In many developing countries, safety, security, disaster management, and socioeconomic development are the most powerful drivers for space activity. Malaysia and Vietnam, for example, started their space activity to address security issues (Ismail and Ahmad, 2017). Similar rationales drive emerging space states today. For example, one of the Filipino rationales is to develop space technology to aid disaster management following typhoons.

In other countries, such as the U.A.E., national prestige and economic growth are primary rationales for space activity. The U.A.E. aims to increase its national prestige by becoming the first Arab country to reach Mars (UAE Space Agency, 2017). Additionally, the U.A.E. considers that investment in space is a means to diversify their economy, which has historically been centered on the oil industry. Finally, the U.A.E. states that the happiness of its citizens is a rationale for government space activity (Space Policy and Regulations Directory, 2016).

Australia is an example of a country which for many years lacked well-defined rationales for space. As an active player in the early space race during the 1960s, Australia had the foundation to grow into a leading space nation. Though the government identified its rationales for space activity, it did not capture them in official policy at that time. As a result, the nation’s space capabilities stagnated and declined. Following a 2008 Senate Report entitled “Lost in Space?”, which described Australia as being non-active in space compared to the rest of the global space sector (Australian Senate Standing Committees on Economics, 2008; Asia Pacific Aerospace Consultants, 2016), the government realized this shortcoming and in 2011 published a space strategy followed by its space policy in 2013 (Australian Senate Standing Committees on Economics, 2008; Department of Industry, Innovation and Science, 2013).

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**Dr. Danielle Wood – US Applied Sciences Manager at NASA Goddard Space Flight Center**

“In each country, there are often different motivations for why they pursue investment in space, but really it’s not about space per se, it’s about the kind of goals and visions they have for the next generation in their country.”

“In space, there is often a key role for governments as a number of space services and space investments are generally public services. Governments [have] to make sure that these services are provided successfully to the population. When I think about the future of humans and space I am interested in the future of Earth. I think that our future on Earth hopefully will be informed and improved by our activity and work in space.”

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Therefore, in this roadmap, we emphasize the importance of rationales which must be clearly defined to successfully drive national strategy for venturing into the space sector.

### 5.1.2 Ensure Projects Are Within the Scope of Budget, National Resources, and Technical Experience

Space activities are generally perceived as large, costly, long-term projects. However, there are many projects that require considerably less time, expense, and technical expertise. Pursuing ambitious projects beyond the scope of government support can decrease public confidence in national space activities, especially when the program objectives are not met (Mitchell, 2013). The Brazilian VLS-1 launch vehicle program is an example of an overly ambitious space program. The final report on the tragic 2003 VLS-1 explosion highlighted a number of organizational and management shortcomings (Federal, Da Aeronautica and Comando da aeronautica departamento de pesquisas e desenvolvimento, 2004). The project employees were consistently underpaid and overworked because of an imbalance between the resources required and those provided to the project. Low salaries, stemming from budget cuts, caused experienced personnel to leave the project without adequate replacements. Many of the technical manuals in use had not been translated into Portuguese, indicating a failure in configuration management and overall communication. In summary, the Brazilian Space Agency had committed to develop the launch vehicle, but did not follow through by providing the resources necessary for success. It is advisable for emerging space nations to focus on smaller scale projects in which they can safely succeed, thereby establishing an initial track record of success and garnering positive public opinion.

### 5.1.3 Assess whether the Internal Stability of a Nation is at the Level Required for Space Sector Capacity Building

Space activities are often carried out on timescales longer than election cycles. Even among advanced space nations, space-related budgets are known to fluctuate with changing administrations. For this reason, a certain level of political stability is required to successfully advance in building space sector capabilities.

As an example, the first South African satellite project, GreenSat, was cancelled in 1994 after a major government transition following the country’s first democratic elections (Wood and Weigel, 2011). Though this was a positive government transition for democracy, it illustrates how a changing government structure can adversely affect space projects.

To implement this recommendation, emerging space nations should: 1) consider their geopolitical stability and focus on projects that can be accomplished within a period of stability, and/or 2) focus on achieving legislative support, (e.g. cross-party backing), that can survive governmental transitions.

### 5.1.4 Commit to Public Transparency Regarding Government Space Spending

We noted from our case studies that public transparency regarding space spending allows for better accountability and industrial growth, largely because it garners public support. There are several ways to achieve space spending transparency, such as disclosing financial budgets, audits, and reports; participating in international arms control regimes; and conducting public awareness and outreach campaigns.
For nearly a decade, the Brazilian government rejected export control regimes. This led to the U.S. issuing sanctions against Brazil. In 1987, the U.S. began to prohibit the export of dual-use technology to Brazil. The Brazilian VLS accident is an example of poor transparency. Many questioned the transparency of the federal investigation, and the public did not trust the investigation findings. Brazil’s reputation as a space power was tarnished, which discouraged investment in its aerospace industry (Mitchell, 2013).

Public awareness is closely related to transparency. Outreach programs help to inform a nation’s citizens of how their tax money is being spent and what benefits they are receiving in return. This helps to establish a clear dialog between the government and the public regarding space sector spending. Poor public transparency can lead to public distrust, which has a negative effect on space sector investment. Therefore, public transparency regarding space spending is crucial for the success of every emerging space state.

5.1.5 Consider the Various Space Sector Architectures and Implement the One that is Most Appropriate

How to organize a national space administration and sector is one of the earliest challenges a potential space state faces. Every government must decide what type of structure to use, especially when an emerging space state does not have a well-organized space industry. There are two main types of structures - centralized and decentralized - although these can be blended to create hybrid structures.

Luxembourg is a good example of a decentralized model as it has different governmental organizations for each sector of its space industry. For example, one office addresses space mining and another office handles participation in international organizations. This model can be cost efficient compared to the centralized one, but it could be difficult to maintain coordination and cooperation among these entities (Space Resources, 2017).

Nigeria, on the other hand, implemented a centralized model. Nigeria has a national space agency that is responsible for coordinating the entire national space sector. The supervising entity, the National Space Council, is chaired by Nigeria’s president. Nigeria chose the centralized model so it could manage the sector directly. In general, the centralized model is more efficient than the decentralized model because information can more easily reach the intended recipient. However, centralization is also less flexible and is prone to higher costs (Nigeria Legal Information Institute, 2010). Nevertheless, Nigeria’s example, as well as many other established space state (e.g., Austria, Canada, and India), demonstrate the advantages of establishing a single national space agency or office to oversee and coordinate all national space activity.
**5.1.6 Develop a Clear Government Policy and Legislative Framework to Guide Space Activity**

To successfully develop a space industry, a country must fully establish a clear government policy and legislative framework to facilitate space activity. The importance of this recommendation is clear from the history of the Australian space sector. Although Australia was an active space player in the early 1960s, and did enact space legislation in 1998 as noted earlier, it did not define an official space policy until 2013.

In contrast, Canada, U.A.E., and Norway provide examples where the government was aware of the importance of establishing a clear policy and legislation to regulate space activity in the country (Canadian Space Agency, 2017; Space Policy and Regulations Directory, 2016; Norwegian Ministry of Trade and Industry, 2013).

**5.1.7 Demonstrate Commitment to Achieve Policy Goals through Stable Funding**

Brazil’s national space program historically suffered from a fluctuating budget, which often caused significant time delays (Garvin, 2014). This unstable funding of the space sector is related to periods of economic hardship, when the government controls and restricts the nation’s budget and prioritizes the sectors that most require investment, where the space sector usually does not qualify. In addition to time delays, Brazil’s budgetary fluctuation has caused problems with international collaboration and capability development. Brazil’s example demonstrates the importance of stable funding to establish and maintain a national space program.

**5.1.8 Ratify or accede to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention**

There are five major UN treaties related to activities in outer space: The Outer Space Treaty, the Rescue Agreement, the Liability Convention, the Registration Convention, and the Moon Agreement. Among the established space states previously discussed, only Australia and Austria are parties to all five of these treaties. Among the case studies, Brazil, Canada, China, India, Nigeria, Norway, South Africa, and the U.K. are parties to all the treaties except the Moon Agreement. Israel and the U.A.E. are parties to three of these treaties and Luxembourg is party to two. Each of the established space countries from our case studies is party to the Outer Space Treaty.

By ratifying or acceding to U.N. space treaties, an emerging space state demonstrates that it understands the global space landscape, a political commitment to advancing in space, and a sense of responsibility for how it will conduct space activities. This will assist in establishing cooperative programs with more established states. The treaties also include language that requires governments to establish a national legislative framework for space activities, thereby providing legal certainty to private enterprises (OECD, 2004).

The first four treaties refer to outer space (including celestial bodies) as the “province of all mankind”. The Moon Agreement however goes much further and states that “the Moon [and other celestial bodies as per its Article 1] and its natural resources are the common heritage of mankind”. The phrase “common heritage” is a stronger legal term implying that benefits derived from resources on the Moon and other celestial bodies should be equitably shared with all states, as outlined in Article 11 of the Moon Agreement. This principle is known to
discourage private investment in states party to this particular treaty. Therefore, it may not be advantageous for emerging space states to ratify or accede to this treaty (Nelson, 2010). Apart from the Moon Agreement, emerging space states should ratify or accede to the other four treaties, especially the Outer Space Treaty.

5.2. **International Cooperation Recommendations**

- Participate in international space-related events.
- Become a member of international space-related organizations.
- Cooperate with established space nations to benefit from their experience.
- Pursue involvement in hosting and organizing key space sector events.

5.2.1 **Participate in International Space-Related Events**

We strongly advise emerging space states wishing to develop their reputation within the global space community to attend international conferences (e.g., International Astronautical Congress), space-related networking events (e.g., research interest groups), and workshops (e.g., UNOOSA and ESA workshops). These events can provide a nation’s first contact with the space sector and demonstrate a nation’s intentions to engage in space activities.

Regular participation in conferences allows countries to stay informed on the latest trends and technologies, extend their network, and develop good knowledge on space sector landscape and evolution.

As a first step, countries can fund scholarships to sponsor a person or a group of individuals to attend an event. When ready to make a further commitment, countries can send a delegation to officially represent them and potentially initiate new partnerships.

5.2.2 **Become a Member of International Space-Related Organizations**

There are many international organizations that represent various aspects of the space industry, including UNCOOPUOS, the ITU, the Group on Earth Observations, and the International Astronautical Federation (IAF). Participation in such organizations can offer emerging states an opportunity to improve and strengthen their economy, as well as to form international relationships. The main benefits from this recommendation are the added access to a wide range of skills and talents; the support of more established space states; and the improvement of a nation’s reputation within the space sector.

A well-known example of national participation in international organizations is Austria’s involvement with UNCOOPUOS. Austria was an early space actor in terms of technology, industry, and exploration activities. In an effort to further improve their early space sector, Austria chaired UNCOOPUOS from 1957 to 1996. In 1993, UNOOSA moved their permanent residence to Vienna, Austria (Austrian Research Promotion Agency, 2017). The nation’s past and present work with UNCOOPUOS has allowed Austria to maintain an important role in space law and policy, establishing a leadership role in the global space sector.
5.2.3 Cooperate with Established Space Nations to Benefit from their Experience

Emerging space states are differentiated from established space states in terms of both experience and capability. Cooperation between emerging and established space states, such as a technology transfer program, can facilitate growth of an emerging space nation’s capability.

In the capability building phase, emerging space states develop their local expertise through training and personnel transfers from established space states under cooperation agreements. After several generations of such cooperative programs, emerging space states establish autonomy. This technology localization process is now adopted by most of the emerging space states. We discuss several examples below.

Nigeria is a prominent space actor in Africa. Its strategic partnerships with established space states have been key to the success of its space program. Nigeria used partnerships with China and the U.K. to train people in satellite manufacture and operations. The National Space Research and Development Agency of Nigeria initially procured its first Earth observation satellite from a U.K. company, with a resolution of 32 meters. It then ordered a more advanced spacecraft, while developing a third mission, Nigeriasat-X, which was built by Nigerian scientists at the U.K. company’s facilities (NASRDA, 2017).

5.2.4 Pursue Involvement in Hosting and Organizing Key Space Sector Events

Hosting a major space sector event puts the organizing country in the spotlight of the international space community. International conferences are an ideal showcase for local actors and a springboard for networking.

Hosting an international space education program such as the ISU SSP is also an effective way to boost local space activities and raise public awareness, especially via public lectures. As an example, Australia has been hosting the ISU Southern Hemisphere Space Studies Program (SH-SSP) since 2011. Ireland, which is aiming to increase its involvement in space, hosted the 30th SSP during summer 2017.

Active involvement in the organization of key space sector events sends a strong message that a host country is committed to playing a role in the international space community.

5.3. Education Recommendations

- Organize and support public events to raise space awareness.
- Ensure development of the workforce required to achieve space sector goals.
- Promote high-level awareness by leveraging national pride and considering the public as end users.
5.3.1 Organize and Support Public Events to Raise Space Awareness

Investing in public awareness programs can have a decisive impact on space sector dynamics. The importance of organizing, or at least financing, public events such as open days, forums, or workshops should never be underestimated.

Increasing public awareness is closely related to:

- inspiring the younger generation and potential future workforce;
- educating the public on socioeconomic benefits of space technologies;
- increasing media coverage of space activities; and
- justify funding of future projects.

The public, in particular the younger generation, are often interested in participating in space-related events. This is especially true when ‘hot topics’ are discussed, such as the internet of things, big data, and virtual reality. Example programs include the annual International UN World Space Week (4th-10th October), national level science and technology weeks, and regional events, such as the Cork Summer of Space conducted in Ireland in 2017.

Organization of public events can either be done directly by governmental actors (i.e., open days of national space agencies), or indirectly by sponsoring external actors such as non-governmental organizations (NGOs) or networks (e.g., the Space Generation Advisory Council).

5.3.2 Ensure Development of the Workforce Required to Achieve Space Sector Goals

There is a close relationship between space activity and education – at primary, secondary, and tertiary levels. We considered the role of education systems and programs, including a review of science and discovery centers as they play a vital role in inspiring children. The space sector has been shown to attract young people to STEM fields. A 2009 Nature survey among almost 800 researchers showed that 50% of the scientists whose articles were published by this journal in the previous three years had been inspired to pursue science by the Apollo missions. Additionally, more than 80% of those surveyed felt that the life sciences, physical sciences, engineering, and human physiology all benefited from human spaceflight. Almost 90% of respondents declared that spaceflight continues to inspire younger generations to study science (Monastersky, 2009). In his paper, “Space Colonization-Benefits for the World”, W.H. Siegfried notes that “investment in the Apollo Moon exploration program in the 1960’s correlates with the level of technical education later attained by students.” (ISECG, 2013).

Michaela Musilova – Slovakia
Chair of the Slovak Organisation for Space Activities

“Too many young people emigrate abroad every year in pursuit of better opportunities and it is a real shame. By developing the space sector in Slovakia we can create many new jobs, opportunities for students to get involved in exciting Research and Development in the space sector and ultimately we can help boost our country’s economy.”
Science and discovery centers (e.g. Blackrock Castle Observatory, Cork) play an important role in providing an inspirational infrastructure, expertise, and enthusiastic staff with an ethos to perform societal good. Science and discovery centers inspire primary school children to develop an interest and awareness of STEM through inquiry-based activities that encourage independent thinking. They also inspire teachers, providing them understanding of new technologies, and new teaching methods via continuous professional development programs (Ecsite UK, 2006).

The International Science Center Impact Study, the largest study of its kind, found significant evidence that science and discovery centers provide memorable learning experiences which can have a lasting impact on attitudes and behavior, for both youth and adults, correlated with increased: knowledge and understanding; interest and curiosity; engagement with and interest in science as a school subject; engagement with science and technology-related activities out-of-school (Falk et al., 2014).

The highly technical nature of the space sector requires a community of experts and skilled technicians within the country to execute the work. This, in turn, drives the need for tertiary education opportunities in space-related fields within a country. Several examples exist in which a shortage of opportunity and support for students, researchers, and professionals has hindered the space capability of a nation. The 2008 Australian Senate report on space activity questioned whether secondary education in Australia adequately prepares students for tertiary education in space-related fields (Australian Senate Standing Committees on Economics, 2008). Further, many graduates from space-related programs in Australia have left the country because of the lack of relevant funding and relevant opportunities there.

Countries engaged in space sector capacity building should carefully consider their workforce capability and development of resources in space-related fields. There are numerous methods to maintain and improve the space workforce. Initially, a country with few tertiary programs in relevant fields can arrange exchange programs to send students to foreign universities. The next step would be to implement relevant engineering and science modules within a degree at a national university, which could eventually be expanded to an entire degree program or department. Other potential steps include providing fellowships for students and supporting professionals to attend conferences. Nations should also consider forming an academic body and linked industrial advisory group to ensure appropriate space-related education and training opportunities.

Space activities inspire many young people to pursue technical degrees. Consequently, advanced education is a cornerstone of space sector capacity, ensuring stable growth of a highly skilled workforce.

5.3.3 Promote High-Level Awareness by Leveraging National Pride and Considering the General Public as End-Users

National prestige is a powerful rationale for legitimizing the funding of space activities. For example, the U.A.E. is developing its first probe, Al Amal (“Hope”), a Mars orbiter designed to analyze the Martian atmosphere. This is an ambitious and interesting choice for a first major mission, because space science missions do not usually produce economic returns. As was clearly stated by the U.A.E. Head of State, His Highness Sheikh Mohammed Bin Rashid Al
Maktoum, “[t]his mission is not about reaching Mars, it’s beyond that ... It’s about taking the whole Arab region and making the Arabs active in generating knowledge,” (RT News, 2017). Clearly, a main rationale for the U.A.E. space activities is national pride. It has even become a mission rationale for the Al Amal probe to enter Martian orbit in time for the 50th U.A.E. National Day. The interest of the general public was also a turning point in the development of the first Slovak satellite, skCUBE, developed by the Slovak Organization for Space Activities (SOSA) and launched in 2017. The project received critical funding after being showcased around the country and being featured on national news (Musilova, 2017).

It appears crucial for governmental entities to ensure a high level of public awareness, which can be achieved by treating the entire general community as end users and stakeholders. In 2016, ESA took a step in that direction by organizing the first citizens’ debate on space for Europe. Around 2,000 citizens, representing the demographics of all member states, debated the use of space in Europe as well as the role of ESA (Missions Publiques, 2016). The organization of the debate was an initiative resulting from the new agency strategy best described as Space 4.0 (innovating, informing, interacting, and inspiring) (ESA, 2017a). As mentioned by ESA Director General Jan Wörner, “the Citizens’ Debate is part of the implementation of my Space 4.0 concept, whereby ESA increasingly interacts with all and integrates space more seamlessly into European society”.

After this first debate a dual dialogue seems to have been successfully engaged as 75% of the participants had the impression that their inputs would be taken into consideration. 88% of the participants indicated they had a strong trust in ESA. On the other side, the agency now has a clearer idea of the expectations of European citizens with respect to space activities (Missions Publiques, 2016). This experience demonstrates that raising awareness is not only an educational mission; it also enriches the sector with innovative ideas and supports further funding of space activities.

Michaela Musilova – Slovakia
Chair of the Slovak Organisation for Space Activities
— How did you overcome the challenges of developing the first Slovakian satellite, skCUBE?

“Key components of this were: 1) many years of doing outreach, explaining why the space sector is important for Slovakia to everyone from children to public officials, presenting our work at scientific/technical fairs, and working with the media and 2) building good relations with all many different groups of people in Slovakia, from academia, industry to the government.”
5.4. **Economy Recommendations**

- Identify current trends and needs in the global space industry and consider contributing in those areas.
- Identify existing strengths and leverage them to develop the space sector.
- Focus on excellence in specific technologies, rather than participating in the full spectrum of space activities.
- When entering a new technological area, focus on measurable, incremental progress.
- Establish domestic cross-sectoral cooperation.
- Facilitate development of the private space community.

5.4.1 **Identify Current Trends and Needs in the Global Space Industry and Consider Contributing in those Areas**

Identifying current trends and needs in the global space sector offers tremendous opportunities for emerging space states to enter the market and develop expertise in niche areas. There are multiple areas of new opportunity in space including mining, tourism, and exploitation of debris. A government can decide how to best approach these areas to achieve national space policy objectives. For instance, a country can choose to run the space sector through a governmental body, or they may choose to promote corporate activity within the private sector by establishing a supportive financial and legal environment.

Luxembourg is one example of how a nation can identify its strengths and use these in the space sector as a pioneer within a new market. Luxembourg leaders realized that, as a country which has a well-developed financial sector, they could become a major player within the NewSpace sector. The government created national legislation supporting venture capital firms and private equity investments that fund start-ups and other innovative companies in space-based industry (Space Resources, 2017; Innovation Public, 2016). In addition, Luxembourg became the second nation and the first in Europe to develop national legislation regarding space mining. Luxembourg has used its supportive financial environment to encourage its involvement in this emerging area of the space sector, by providing the most permissive national legal regime for space mining to date.

**Robert Hill - United Kingdom Director of the Northern Ireland Space Office, ARESS Project Co-chair**

“Space is changing. If you go back 10 to 20 years ago, the idea of getting a small company to be involved in space would be very difficult because of the processes, the regulations, and policies within space. Now we are moving into a commercial phase.”

“I see space as an enabler. It is another tool; it is an asset that we have to help society, to grow the economy.”
5.4.2 Identify Existing Strengths and Leverage them to Develop the Space Sector

A nation should identify and use its existing strengths to venture into a new sector. The main benefit of this approach is that the foundations - infrastructure, knowledge, expertise, and skills - are already established within the emerging space state, which saves money and reduces the level of risk involved. A nation may also choose to enhance existing infrastructure to meet the requirements of the space sector.

For example, Australia recognized that its location is highly desirable for ground stations. With this in mind, the Satellite Utilisation Policy (Department of Industry, Innovation and Science, 2013) outlines a plan to contribute existing and developing ground infrastructure to international projects. In return for their cooperation, Australia shares satellite operations with other countries.

Luxembourg is a small and well-developed nation with a strong finance sector. As a result, the Luxembourg government has several initiatives in place to support innovation, venture capitalists and equity investment in the space sector.

Further examples of nations identifying and leveraging existing strengths can be found in the case studies section of the appendix.

5.4.3 Focus on Excellence in Specific Technologies, Rather Than Participating in the Full Spectrum of Space Activities

Various examples of nations with established space sectors indicate that capacity building is more successful when the nation focuses on developing excellence in specific technological areas, rather than a wide scope of areas.

For example, one of the five core principles in Canada’s space policy is to achieve excellence in specific technologies, namely satellite communication, remote sensing, and robotics (Canadian Space Agency, 2014). In particular, Canada’s focus on space robotics resulted in the development of Canadarm, a highly successful robotic arm for the Space Shuttle, followed by Canadarm2 for the ISS. This policy has been successful because of Canada’s efficient focus on an area of national technological excellence. As a result, Canada is considered to be an established space nation, yet invests only 0.026% of its GDP in space activities. Many nations with similar visibility invest more than twice as much (OECD, 2014).

The early years of the Indian Space Research Organisation (ISRO) provide a similar example. ISRO’s initial policy was focused on remote sensing and communications technologies that would help drive socioeconomic development, rather than attempting ambitious and costly space exploration projects. As India developed into a well-established space state, it adapted this policy to include many different sectors of the space industry, including commercial launches and scientific exploration. However, it is important to consider that early successes were achieved in specific, niche technologies (Paracha, 2013).

One final example is found in Brazil’s space activities during the 1990s. A national space policy released in 1996 described three focus areas: (1) access to space; (2) satellites for various applications to benefit Brazilian society; and (3) launching centers for these systems located in national territory. Though this policy attempts to define specific areas of focus, the
defined areas are extremely broad. Throughout the 1990s, Brazil developed an Amazon Rainforest Surveillance System (SIVAM), using both space and ground sensors. Though this program was considered a success and was within the scope of the second focus area, it required large investments that siphoned funds away from Brazil’s launch vehicle development (Garvin, 2014). The slow progress and setbacks that hindered the Brazilian space program can be attributed, in part, to the lack of well-defined areas of focus in its early space policy.

5.4.4 When Entering a New Technology Area, Focus on Measurable Incremental Progress

As a new actor within a given sector, an emerging space state should focus on reasonable, implementable, short-term targets, which still have measurable impact. This technique effectively addresses the learning and development hurdles associated with venturing into a new area. The main advantage of incremental progress is that it ensures that a nation is not overly ambitious and can consistently meet its objectives to establish a successful track record. Nevertheless, these short-term targets should be clearly defined with a documented end goal.

A good example of incremental progress comes from India. The initial space policy defined by ISRO was heavily based on space applications, in particular remote sensing and communication applications. This choice was seen as cost efficient as well as socially and economically beneficial for India. Over the last decade, however, this policy has been revised to focus more on high-tech goals for military use and prestige. This change was initiated in 2007 by ISRO leader Madhavan Nair, who felt that India had developed substantially since the inception of ISRO in 1969 and had achieved its purpose within the space applications sector. As a result, India revisited its policy to identify its next steps, focusing on areas such as commercial launches, space exploration missions to the Moon and Mars, robotics, and human space flight (Paracha, 2013). The success of this method has established India as an established space state.

Another example comes from the recent success of the Slovak Organisation for Space Activities (SOSA). Prior to developing the nation’s first cube satellite, the association members conducted 18 stratospheric balloon launches to obtain technical experience with hardware (Musilova, 2017). Building on the success of these balloon missions, the first Slovak satellite was launched in 2017.

Toby Clarke - United Kingdom EURISY Secretary General

“Nations that want to develop space capabilities often focus on the upstream part. It is more exciting to build satellites and rockets. Nevertheless, it is also important to have a focus on the downstream part because that is where you can really show your citizens that by investing in space, it can bring you benefits and then they won't mind paying their taxes to support these activities.”
5.4.5 Establish Domestic Cross-Sectoral Cooperation

To support national growth, a government should ensure, establish, and promote cooperative relationships between its space sector and other sectors within the country. A government should create and maintain bridges between the sectors, rather than isolate them. A general example of this type of cooperation is many space-based services support non-space-based sectors, such as agriculture, maritime, disaster management, and crisis response.

Austria offers a good example of how a country can effectively implement this recommendation. Following a study conducted by its Federal Ministry for Transport, Innovation and Technology (Federal Ministry of Transport, Innovation and Technology, 2014), Austria identified a wealth of both space-based and non-space-based high-tech industries. In response to this finding, the Austrian government invested heavily in developing an infrastructure for this sector. The main benefit of this investment was the unique opportunity for growth and stability (ABA – Invest in Austria, 2017), a benefit that was shared by space-based, as well as non-space-based, high-tech industries. As a result, a strong relationship exists between the space sector and the high-tech sector in Austria.

5.4.6 Facilitate Development of the Private Space Community

Government policy is an important factor which can help facilitate growth of the private market. Policies such as tax-free scenarios, investment trend instructions, and low interest loans attract private funds. As private companies grow, the government should create policies wherever possible to open opportunities in the international market.

Canada is another example of how a government space agency can leverage the capabilities of the private market. Canada’s Space Policy Framework (2014) outlines the principle goals of the Canadian space sector. The first goal is commercialization, focusing on private industry where feasible, and supporting business models tailored to space operations. These actions are guided by the principles of: (1) keeping Canadian interests first; (2) positioning the private sector at the forefront of space activities; (3) progressing through partnerships; (4) excellence in key capabilities; and (5) inspiring Canadians.

5.5 Summary of Evidence-Based Recommendations

To summarize, the intent of this chapter is to extract the key steps taken by established space states that have facilitated the development of a successful space sector. Our recommendations are based on our case studies presented in chapter 4.

Using a graphical scheme, we identify key recommendations that emerging states can use to develop their space sectors. This graphical representation helps to explain how a country can build on their rationales and existing strengths to exploit key space technology opportunities and achieve a national goal.

For an emerging space state to venture into the space sector, it must follow several crucial steps. The first step is to identify a rationale that explains clearly why the country wants to venture into space. The second is to identify the country’s strengths and weaknesses that affect the evolution of their space sector. Figure 5.2 organizes our recommendations by category and the level of governmental effort required to realize them.
Figure 5.1 Research requirements for emerging space nations
<table>
<thead>
<tr>
<th>Level of Effort</th>
<th>Policy &amp; Law</th>
<th>International Cooperation</th>
<th>Education</th>
<th>Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.1. Identify specific rationales for space activity and ensure that these drive the space strategy. 1.2. Ensure projects are within the scope of budget, resources, and technical experience. 1.3 Ensure that the internal stability of a nation is sufficient for space sector capacity building 1.4. Commit to public transparency regarding government space spending.</td>
<td>2.1 Participate in international space-related events (e.g., IAC) 2.2 Become a member of international space-related organizations (e.g., UNCONPUSOS, ITU)</td>
<td>3.1 Organize and support public events to raise space awareness</td>
<td>4.1 Identify current trends and needs in the global space industry and consider contributing in those areas 4.2 Identify existing strengths and leverage them to develop the space sector 4.3 Focus on excellence in specific technologies, rather than participating in the full spectrum of space activities</td>
</tr>
<tr>
<td>Medium</td>
<td>1.5. Consider the various space sector architectures and implement the one that is most appropriate 1.6. Develop a clear government policy and legislative framework to guide space activity</td>
<td>2.3 Cooperate with established space nations to benefit from their experience</td>
<td>3.2 Ensure development of the workforce required to achieve space sector goals</td>
<td>4.4 When entering a new technological area, focus on measurable, incremental progress 4.5 Establish domestic cross-sectoral cooperation</td>
</tr>
<tr>
<td>High</td>
<td>1.7. Demonstrate commitment to achieve policy goals with stable funding 1.8 Ratify or accede to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention</td>
<td>2.4 Pursue involvement in hosting and organizing key space sector events</td>
<td>3.3 Promote high-level awareness by leveraging national pride and considering the public as end users</td>
<td>4.6 Facilitate development of the private space community</td>
</tr>
</tbody>
</table>

Figure 5.2 Organization of recommendations by category and level of governmental effort
5.5.1 Challenges and Limitations

Every country must select a subset of recommendations based on its rationales, strengths, weaknesses, and opportunities in the space sector. Due to time constraints, the recommendations we explore in this report were extracted from a limited number of country case studies. We selected these countries because of their successes and challenges in pursuing space activities, which are clearly linked to specific governmental policies and actions. There are many scenarios that we did not include in this analysis.

We did not consider the time required to achieve a specific space objective as a factor in this analysis. Operational timelines depend on many factors that are not easily generalized.

In this chapter, we have conducted objective research on the case studies, considering both positive and negative lessons learned. Often, lessons learned from negative examples are the clearest, so we have discussed a number of these examples at length. Lessons learned from all examples provide a balanced view of all the countries studied.
6. Application of Recommendations

In this section, we will apply the general recommendations we introduced in chapter 5 to six emerging space states. The purpose of this exercise is twofold: to demonstrate the practical application of the general roadmap to a specific nation, and to derive a set of specific recommendations for each of the selected states. The overall set of recommendations is all-inclusive. To make these useful, a state needs to identify the particular subset that is most relevant to its rationales and strengths. The added value of the ARESS project is in the national membership of the team. Five of the six nations - Hungary, Ireland, Oman, Peru, and the Philippines - are represented in the ARESS team. We selected these nations to take advantage of team member insights, to capture interesting stages in space sector development, and encompass a wide geographic dispersion. The only emerging space state not represented in our project team is Vietnam. We selected this as the sixth emerging space state based on input from expert lecturers.

We made a qualitative analysis of each emerging space state in line with the general recommendations of chapter 5. Because of the broad scope of this work, it was not possible to delve into the specific recommendations in thorough detail. There is significant potential for future work to expand on this topic. For the purposes of this document, we provide a range of concise recommendations for each nation.

We hope that interested parties from the respective nations will see value in this exercise and be inspired to further develop the recommendations according to their rationales and strategic goals.

6.1. Hungary

6.1.1 Rationales

Hungary’s space activity started in 1967 as a result of its association with the Soviet Union. In 1991, Hungary cooperated with NASA on several projects, such as the design and implementation work of the Materials Science Research Facility, and development of one complex ISS device, Pille-MKS. In the 1990s, Hungary initiated cooperation with ESA and later established the Hungarian Space Office (HSO) as the main coordinator of the Hungarian space sector. After several years of cooperation, Hungary became a member state of ESA in 2015 (Hungarian Space Office, 2016).

Hungary’s main goal is to be active in the space sector, to develop the country’s strong infrastructure, and to promote Hungarian participation in international cooperation projects. As a new member of ESA, the most significant goal for Hungary is to be involved in the majority of ESA’s research and engineering projects. To successfully reach this goal, the Hungarian government has to increase public support for government funding of space initiatives, especially in the private sector (Hungarian Space Office, 2016).
6.1.2 National Strengths and Weaknesses

Hungary has international relationships with Western European nations, the U.S., and Russia, and existing industry presence in the space sector. It has established industries that focus on upstream products and services such as material science, structural engineering, electronics development, manufacturing, and infrastructure, each of which can contribute to space sector growth. Hungary’s downstream industries carry out land surveying and mapping; database building and maintenance; quality control and process monitoring; supplying short and long-range weather forecasting; and atmospheric, environmental, and climate monitoring (Hungarian Investment Promotion Agency, 2016).

Hungary’s academic institutes and universities provide high level training in engineering, material science, information technology, and natural sciences, as well as providing engineering consultancy (Hungarian Investment Promotion Agency, 2016). Hungary has one of the highest rates of patents filed, is ranked 3rd globally in high-tech and medium high-tech industrial output, 12th in highest research foreign direct investment inflow, and is also ranked 12th in research talent in business enterprise (e.g., professionals who are engaged in the creation of new knowledge) (WIPO, 2016).

Hungary’s academic and industrial success is built on government funding (Kállay, 2014). The space activities budget, in 2017, is 2421 million Forints (almost US$10 million) (Act XC of 2016 on the 2017 Budget of Hungary, 2016). Yet, Hungary lacks extensive domestic resources, such as energy and raw materials that are essential for industrial development. To develop Hungary’s private sector, the Hungarian government should increase support, especially financially, to intensify local competition. (Hungarian Investment Promotion Agency, 2016; WIPO, 2016).

According to Dr. Fruzsina Tari, Head of HSO, even though the Hungarian space sector is successful, there is a clear lack of public awareness of the space industry (Áron, 2017). For example, its most recent public national space policy is from 2006, the latest news on the HSO website is dated 2012, and most parts of the website are not available in English.

6.1.3 Opportunities

According to the facts mentioned above, Hungary has significant potential in areas of manufacturing, design, material science development, and electronics. In Hungary, upstream investment in space includes more remote-sensing and communication satellites. Hungary’s downstream industry need more investment from the government, which includes applications in communications, broadcasting, and ground stations for data handling and analyzing.

Education can also be an excellent opportunity to improve the Hungarian space sector through increased funding and facilitating participation of Hungarian students in international space thematic education programs. Hungary may progress by building its space sector capacity with fiscal consolidation, structural reforms, international cooperation, and supportive legislation that will bring considerable social benefits and dividends to its economy. These improvements serve the purpose of becoming a stably funded active member of ESA.
6.1.4 Recommendations

First, Hungary should raise public awareness of the importance of the space sector to support the government funding of the sector. Hungary could be a suitable place to organize key space events such as the IAC, and it should financially support non-government activities, for example the Space Generation Advisory Council, as well as other entities or public events, such as citizen debates. It is a positive step that Hungary organizes several World Space Week events like the International Symposium on Computer Science and Intelligent Controls in October 2017. There are several different possibilities available to advertise the Hungarian space industry - for instance, simple advertisements on TV, in newspapers, or via social media.

Recommendation One: Hungary should conduct a public outreach program in line with space sector development, concentrating on information and knowledge sharing.

Education is a highly important and well-developed field in Hungary, especially in the area of STEAM. There are several high-level universities and institutes of education within the country; for example, the Eötvös Lisuoránd University and the Budapest University of Technology and Economics (Hungarian Space Office, 2016). Hungary should consider funding educational training abroad; for example, providing scholarships to students to participate in an ISU program, or space education programs in foreign universities. ESA’s European Space Education Resources Office can also be a partner of the Hungarian government, which gives scholarships to Hungarian students to study abroad.

Recommendation Two: Hungary should promote internationally based education programs and support Hungarian students and professionals via funding or incentives.

The third recommendation is to encourage participants of the private economy - including start-ups, companies, and banks, venture capitalists and angel investors - to have an active part in Hungary’s commercial space industry. Hungary should boost its own private sector in the space industry by making supportive legislation for start-ups, incubators, venture capital firms, and private equity firms. It is also crucial for the space sector to have stable government funding that is predictable and long-range. Hungary should consider investing more money in its space industry because of its profitability and other economic advantages. Also, it can be an excellent example for other sectors in Hungary to improve themselves and get more funding from the government.

Recommendation Three: Hungary should incentivize the private sector through legislation and fostering a competitive market via public investment.

István Sárhegyi – Hungary Sárhegyi & Partners Law Firm and ARESS team member

“The most important thing for Hungary now is to improve the public awareness of our space industry because it is really well developed, it is a successful industry but the general public is not well informed.”
In conclusion, Hungary has a well-developed space industry with active public and private participation. It has several opportunities to become one of the most developed space sectors in East-Central Europe, and to become the most active new member of ESA.

6.2. Ireland

6.2.1 Rationales

Ireland has been a member state of ESA since 1975. The primary focus of its membership has been to promote the development of Ireland’s contribution to the global space sector with the aim of developing Irish businesses and ensuring economic and societal benefits (Technopolis Group, 2015). There have been many collaborations and technology transfers since then. Additionally, “the number of third-level research institutes engaging with space through ESA has grown substantially, as has their areas of expertise” (Enterprise Ireland, 2013).

Having increased its commitment to ESA to €90 million over the period 2016-2020, Ireland has signified its intent to continue its development of research and industry in line with its current strengths (Irish Department of Jobs, Enterprise and Innovation, 2016).

6.2.2 National Strengths and Weakness

Ireland was ranked the seventh most innovative country in the world in 2016 (WIPO, 2016), having climbed into the top 20 in 2010. The nation’s economy is set to become the “fastest growing economy in the euro zone” (Burke-Kennedy, 2017). Since the global economic slowdown in 2007, Ireland has become focused on sustainable growth and employment. Through recognizing its strengths, Ireland has undertaken initiatives that target growth in several areas of society, research and development, and innovation. The Horizon 2020 initiative, for example, lists science, industry, and society as its target areas for development (Horizon 2020, 2017). Organizations, such as Technology Ireland, Enterprise Ireland, and Science Foundation Ireland, collaborate in the interest of technology, enterprise, and research (Interdepartmental Committee on Science, Technology and Innovation, 2015). The strategic interest in research over the short to medium term lies in facilitating big thinking and maintaining a system of international collaborations (Irish Department of Education and Skills, 2015).

Ireland has over 30 companies that self-identify as contributing to the space market (Enterprise Ireland, 2017). Ireland’s contributions to the space sector have primarily been based in the areas of electronics, software and propulsion (Enterprise Ireland, 2013), but also in precision engineering, optoelectronics, and advanced materials. These efforts are supported by a strong national technology industry. In addition to its current space industry, Ireland has strong space-adjacent industries, including pharmaceutical, biomedical, and data analytics sectors.

On the other hand, there are certain weaknesses that could be addressed. Ireland has not established a national space agency. A national space agency enables industries and government to have a cohesive and collaborative implementation of space sector development. A space agency could advise the government and coordinate and administrate strategic goals. Currently, “Irish companies don’t have access to national space development...
or procurement programmes”. That is why ESA’s support is essential (Technopolis Group, 2015).

Ireland is not a member of UN COPUOS, nor has it enacted a national space law. These oversights may hinder Ireland’s space sector development in the medium to long term future by impeding or diminishing valuable international cooperation or technology transfer programs - also affecting commercial space start-ups that could potentially be of economic benefit to Ireland.

**6.2.3 Opportunities**

Ireland’s primary contributions to the space sector have been based in the areas of electronics, software, and propulsion (Irish Department of Education and Skills, 2015), supported by the strong technology industry in the country.

Through private businesses, academia, and ESA collaborations, Ireland is involved in a wide range of research and space application development; yet Ireland is not fully exploiting all the opportunities at its disposal.

Ireland is “one of the leading locations for the pharmaceutical industry in the world” (McGee Pharma International, 2016). With nine of the top 10 largest pharmaceutical companies globally world distributed throughout the country and more than 25,000 employees working in the pharmaceutical industry, this field is a significant source of social and economic benefit. Similarly, the biomedical sector in Ireland is significant, with 160 companies employing a workforce of 24,000 (CIT, 2017). However, there are many attractive opportunities for pharmaceutical and biomedical research and applications in the unique microgravity environment of LEO. Valuable biomedical research on the ISS has included stem cells, antibiotic resistance, and protein crystallization (SpacePharma, 2017). Interest in long duration spaceflight has spurred a renewed focus on pharmacological development for human spaceflight participants. The problems of human exposure to space radiation and the degradation of space-borne drugs have not yet been solved (Lakshmi, 2016). This is potentially a significant opportunity for Ireland to become a pioneer in space pharmacology.

With increasingly large volumes and complexity of data (‘big data’) coming from space-based systems, the fields of data analytics and machine learning are becoming very relevant. Extracting meaningful information from a wide array of sensors, science instruments, or satellites is key to maximizing the use of space technologies. Ireland has invested heavily in data analytics, with the Insight Centre for Data Analytics being the “largest single investment in a research program in the history of the State” (Insight Centre for Data Analytics, 2016). Similarly, the Centre for Applied Data Analytics (CeADAR) is an Enterprise Ireland and Irish Development Authority (IDA) backed technology center whose primary outputs are “industry prototypes and demonstrators along with state of the art reviews of data analytics technology,” (Centre for Applied Data Analytics Research, 2017). There is a growing market for downstream data analytics-related applications such as Earth Observation, open source data, and scientific research (Engineers Ireland, 2017).
6.2.4 Recommendations

Ireland should establish a national space agency or similar body. This organization would be responsible for the development of a comprehensive national policy to address the development of the Irish space sector. The Space Foundation recommends that emerging space states “should take note of other nations’ existing national legislation on space activities” and coordinate with U.N. efforts (Space Foundation, 2014). A significant role for this organization would be to identify existing space market gaps abroad, recommend strategic space research and industry based partnerships, and enhance space-related technology transfer mechanisms in both directions. Further, a space agency should advise the government on space research, education, outreach, and industry development and investment. A primary goal of the organization would be measurable social and economic growth from space activities, and it should identify specific performance measures in each sector against which to measure and report progress.

Recommendation One: Establish a national space agency to develop a space policy for Ireland and coordinate the Irish space sector in line with strategic goals.

Ireland should expand its international standing by participating in international space collaborations and organizations. Ireland is not a member of UNCOPUOS. Therefore, Ireland should participate in UNCOPUOS, which grew to 84 members in 2016 to became one of the largest committees in the U.N. Joining UNCOPUOS would give Ireland a platform from which to seek better opportunities for the domestic space-related industry and achieve international recognition.

Ireland should cooperate with established space states. The Irish space-related sector can benefit from the industries of these states, facilitating organic industrial capability building. There have been successful examples in technology transfer processes between Nigeria, China, and the U.K.; India, the Soviet Union, and the U.S.; and the Philippines and Japan. In Ireland, the space industry has already developed around various fields so cooperation is more likely to focus on research and development collaboration rather than technology sharing; however, Irish policy may incentivize future programs or businesses to prioritize technology transfer as a useful development tool.

Laura Keogh – Ireland Space Lawyer and Barrister-at-Law

—How would being a member of UNCOPUOS better enable Ireland to grow in the space sector?

“It would show that “Ireland is indeed a space nation and that we do have a point of view on things. It would enable us to be part of the discussion when new laws and directions for the international space sector are being decided. Furthermore, it is a platform for advertising Ireland as a place to do space business; one only needs to look at Luxembourg to see the advantage of that.”

—What does space mean to you?

“It means international cooperation, transcending national boundaries, and working toward a common goal of a better universe where communication, cooperation, exploration, research and peace is seen as paramount.”
Hosting a major international conference on space would be a good opportunity for Ireland to show its capability to the world. Israel, Mexico, and other emerging nations successfully hosted an IAC to encourage national awareness and promote industry collaborations. In 2014, Ireland launched a bid to host the IAC in 2017 (National Space Center, 2014). The bid was not successful, but as the Irish space sector continues to grow, Ireland should make another application to host IAC. The successful bid and hosting by CIT of SSP17 provides an excellent platform and knowledge base to similarly host future international space conferences and events.

Recommendation Two: Join UNCOPUOS and participate further in international partnerships and organizations related to space.

An important component of education at a fundamental level is STEM education. Ireland’s national space policy should encourage space-oriented STEM education, recognizing its significance over time. Organizations such as the European Science Education Research Association (ESERA), ESERO, and Ireland’s Centre for the Advancement of STEM Teaching and Learning (CASTeL) can continue promoting the space sector. There is further potential for coordination with national outreach events or campaigns. Examples include the BT Young Scientist and Technology Exhibition (BT Young Scientist & Technology Exhibition, 2017) or National Space Week (CIT Blackrock Castle Observatory, 2017).

Ireland should increase its investment in space policy and space technology management disciplines at university level. The Master’s degree in Space Science and Technology offered by the University College Dublin (UCD) (University College Dublin, 2017a) is a good example of education that targets the cross-disciplinary approach that has “great potential in terms of both cultural advancement and economic development opportunities” (STEM Education Review Group, 2016), but this is the only such course in the country. Further to this, students from UCD and Queen’s University Belfast are working with the ESA Education Office Fly Your Satellite! 2017 program to put Ireland’s first satellite, EIRSAT-1, into orbit (University College Dublin, 2017b). This is an excellent program to promote education and satellite technologies, but the institutes themselves fund it, which is a limitation on the national scale. Aerospace engineering courses, including satellite engineering, should be prioritized. The university IT Carlow offers a Bachelor’s in Aerospace Engineering (IT Carlow, 2017) and the University of Limerick offers a Bachelor’s in Aeronautical Engineering but these are the only two universities in Ireland to do so (Qualifax, 2017). The educational opportunities do not match the Irish space sector’s growing need for educating professionals.

Recommendation Three: Increase investment in space-related STEM education and incentivize space science and engineering programs.

Ireland’s space industry has developed significantly over the past decade. The Irish Space Industry Group (ISIG), formed in 2015, represents and promotes “the collective interests of companies operating in the space sector in Ireland at [the] national and international level,” (Irish Space Industry Group, 2015). The objectives of ISIG correspond to our recommendations and rationales. The group highlights the need for an “Irish Space Office” with the “power to decide” and develop the space sector as “a significant contributor to the Irish economy,” (Hollidge, 2015). As a potentially powerful contributor to an Irish space policy,
we recommend that ISIG adopt a more formalized structure and reporting mechanism. It is in the interest of Ireland to hear what ISIG has to say, as it is in the interest of ISIG to have a synchronized voice.

The primary modes of Irish space industry development are through the private sector and ESA supported ventures. This is successful to a point; however, Ireland misses greater opportunities by not focusing its space research, development, and business into strategically valuable sectors or technologies according to an Irish policy. By introducing a policy-based approach, Ireland can drive the creation of corporate clusters around thematic areas most relevant to the sector. For example, the European Commission’s Horizon 2020 Space program has implemented a similar approach with dedicated electric propulsion and space robotics research clusters, also placing emphasis on Earth observation big data exploitation (European Commission, 2017a). Public Private Partnerships (PPP) are another tool that could benefit from a clearly defined space policy to support economic growth. Such partnerships should concentrate interests on research clusters. Access to the NewSpace market is dependent on the implementation of policies that open avenues for venture capital investment and business angels (SpaceTecPartners, 2016).

By adding these dimensions to Ireland’s space industry development, Ireland can benefit from social and economic growth. A growing space sector will boost national pride and Ireland’s international profile.

Recommendation Four: Encourage strategically focused private industry to engage in space-related activities that promote Irish technologies, economic growth, and societal benefits.

6.3. Oman

6.3.1 Rationales

Oman is an arid country in the southeastern quarter of the Arabian Peninsula. It has the lowest rate of oil and gas production in the region, and production is declining as wells dry up. Oman faces environmental problems like desertification and a scarcity of groundwater. The deteriorating security situation in Yemen has brought the southern border into a state of unrest, as Oman is now faced with illegal immigration and smuggling of weapons and drugs. These issues compel the country to look to Earth observation satellites for solutions (U.S. Energy Information Administration, 2009).

Oman depends on ground communications - terrestrial microwave links and fiber optics - for broadband services, but when in 2007 a cyclone hit Oman’s main ground communications, many regions were cut off as there was lack of backup communication systems. Disaster management is also a major concern, as cyclones are frequently generated in the Arabian Sea that borders Oman on two sides. Therefore, another rationale for space activity is to improve natural disaster forecasting and recovery abilities. Many ministers and private sector leaders...
demand a national communications satellite to improve national security and provide independent reliable communications (Al-Rawas, 2009).

### 6.3.2 National Strengths and Weaknesses

Oman has an ideal environment for many upstream applications, such as solar array testing, balloon launching, and rocketry. Oman is strategically located along a major oil transitway that has strengthened its economy. It is also politically stable and enjoys good foreign relations. However, GDP growth is estimated to be slowing down, as the economy depends primarily on oil and gas. Oman is trying to diversify its economy by developing shipping ports and building a technical industry base (World Bank, 2017). Oman does not have any background in space technology or industries, and lacks an existing space professional community, although many technical institutes have been recently established.

Oman realizes the importance of education for capability building in many sectors, including space science. Each year the country has 18,600 university graduates of which 36% are engineers (Ministry of Higher Education, 2017). Sultan Qaboos University has signed an agreement in cooperation and experience exchange with international universities and institutes (Sultan Qaboos University, 2017).

The Ministry of Communications is one of the key governmental entities for space awareness. It has conducted workshops in satellite communication and applications in coordination with Airbus 2016 (Ministry of Transport and Communications, 2017).

Oman has used its access to the Indian Ocean by forming a tax-free zone with all facilities in Duqm, a coastal city in the middle of Oman. This attracted foreign investment, including advanced technology and nanotechnology industries (Special Economic Zone Authority, 2017).

There are currently few space companies in Oman. Omantel telecommunications is one of the local companies that provides telecommunication and broadband services; it provides downstream space application services for customers by hiring capacity from foreign satellite operators, such as Thuraya (Omantel, 2017).

The Global Space and Technology Company is a new space company opened in 2017. It is an initiative of a young entrepreneur who provides space science education through space programs and training (Al Shuaibi, 2017).

### 6.3.3 Opportunities

The space market opens new business opportunities in space-related applications such as telemedicine and tele-education. Many economic and social benefits can be achieved through the space sector such as creating jobs and improving education. Although opportunities exist for Oman in the upstream sector, the absence of previous space technology capabilities and the high cost risks of such endeavors present significant challenges. On the other hand, many opportunities exist in the downstream sector that would be easier to pursue and would help Oman achieve its national objectives.
Taking the oil and gas industry for example, remote sensing data can be used to identify important geological features, satellite communication links enable efficient data transfer, and space-based imagery is useful for monitoring wells in remote locations (Shell International Exploration and Production B.V, 2014). Space activities share many characteristics with oil drilling. For instance, both activities involve remote operations, extreme environments, and handling large amounts of data. Looking further into the future, opportunities exist for Oman to transfer technology from its oil and gas sector into the space industry.

Oman can also utilize various downstream space-related applications because of its strategic location. For instance, satellite data can be used to track vessels; monitor maritime spills, pollution, and illegal waste dumping; and provide intelligence on both natural and artificial threats. Similar data is also used to monitor border security, so there are opportunities for the nation’s Ministry of Defence and other government entities to invest in space to achieve national security goals. Oman can take advantage of ground weather stations by using them to support a national weather satellite instead of relying on foreign images.

The Omani government seeks to establish a sustainable digital communication infrastructure that is secure and reliable during unexpected disasters. While a strong ground telecommunications system covers most areas, some areas and villages remain without connectivity because of their difficult terrain. With satellite infrastructure, these areas can stay connected using a direct connection through a communication satellite.

6.3.4 Recommendations

Oman has several stakeholders in the private market and government who would like to develop space capabilities, but there is no single agency in place to coordinate efforts among these groups. It would be beneficial for Oman to establish a government agency or office that would focus on establishing coordination between stakeholders and developing space capacity in accordance with Oman’s rationales. The focus of this office should be on downstream applications for socioeconomic benefits and technology development.

Recommendation One: Build space applications capability by establishing a national space office.

Oman should focus on space science research at universities and colleges by introducing space-related engineering subjects and science departments, as well as increasing collaboration with international educational institutes. Oman can leverage these collaborations to gain the experience and expertise to manufacture small satellites. Educational opportunities can serve dual purposes by enhancing public awareness of the importance and benefits of space technology. Government incubation and promotion of youth and private projects in space science and satellites, events, conferences, and training programs, will prepare a workforce for long-term space activity engagement.
Recommendation Two: Develop the level of education for STEM in space-related topics with more international partnerships and public outreach.

Today, Omani ministries purchase or lease access to communication satellites to meet domestic needs. By coordinating these requirements, government ministries could establish the resources and expertise to develop domestic communication satellite capability. Taking this step would free Oman from foreign obligations and provide increased control over communication assets.

Recommendation Three: Achieve national goals by developing communication satellites to reduce dependence on other countries and achieve independence in telecommunication systems.

As a country newly seeking access to the space sector, Oman’s government is the main funding authority and this may strain the national budget. This could be overcome by allowing the private sector to participate in the national space program. It begins by establishing a government space agency to innovate with global space agencies and sign space law treaties. The space agency should enjoy financial, administrative, and technical independence to achieve transferring and settling space science and industrial technology to establish its own technical capabilities for building and launching satellites in the future. Attracting international corporate investments by encouraging the private sector to cooperate with external space companies can be achieved through the development of legislation, laws, and the creation of new free-trade or industrial zones for international investments (e.g., Duqm special economic zone). Telecom companies should also be allowed to take a lead role in the private sector in handling downstream space applications. The overall involvement of the private sector can have a positive effect on the job market in the country.

Recommendation Four: Establish a national space policy providing the private sector opportunities to grow in Oman.

Oman joined UNCOPUOS in 2015, but has not yet enacted national legislation to govern space activities. Oman has not ratified any of the U.N. treaties on outer space. To demonstrate commitment to responsible space activities and open the door for more international collaborations, Oman should become party to the first four of these treaties.

Recommendation Five: Ratify or accede to the Outer Space Treaty, the Rescue Agreement, the Liability Convention, and the Registration Convention.

6.4. Peru

6.4.1 Rationales

The national rationales of Peru have been clearly stated in the law that established the Peruvian National Commission for Aerospace Research and Development (CONIDA), and defined its major tasks (Government of Peru, 1974). These are summarized and translated by Romero (Romero, n.d.), and consist of the promotion of development and peaceful research in the space field, including theoretical and practical studies in collaboration with national and
foreign entities. It also supports national and educational space projects, encouraging technology exchange, and the training of national specialists.

6.4.2 National Strengths and Weaknesses

Peru’s macroeconomic indicators stand out among the seven largest countries in Latin America, with Peru holding the highest growth and lowest inflation rates between 1990 and 2011 (Cuba, 2013). Peru’s major industries are mining and agriculture. It is one of the world’s largest producer of metals and holds reserves of oil and natural gas. Its tourism market has also expanded rapidly. (World Bank Group, 2017). Peru’s low inflation and a large pool of profitable investment projects in the early 2000s makes it very attractive to foreign and domestic investors. These opportunities, made available by the lack of private investment during the global financial crisis years, are ending as Peru’s recovery period is comes to a close, and investors will be looking for areas of higher profitability (World Bank Group, 2017).

Despite its healthy economy, Peru is still a middle-income country with relatively low international competitiveness. Institutions have not improved the quality of services during this growth period. Such lack of infrastructure could affect the country in the mid-term, even though it is, presently, considered one of the region’s macroeconomic stars (Cuba, 2013).

Another aspect to consider is that the key economic sectors—mining, agriculture and, to a degree, tourism—depend on natural resources, which are subject to fluctuating commodity prices and may threaten socioeconomic stability (OEC, 2015).

In the field of education, Peru has been investing in recent years to promote education in science and engineering; however, according to the U.N. International Children’s Emergency Fund (UNICEF), there is still poor academic performance in basic education. This is also reflected in rankings, and the percentage of young students who complete primary and secondary education is still low, although it has improved in the last decade from 67.7% to 74.5% (UNICEF, 2011). The Peruvian government has shown interest in the development of STEM and has initiated programs to support education and research, which are regulated by the National Council of Science and Technology. Since their inception, these programs have allowed for the educational and technology transfer, benefiting many professionals. In the last three years, six Peruvian students have been awarded scholarships to study at space-related Masters programs in France.

6.4.3 Opportunities

The development process for the rocketry industry in Peru is a great opportunity for Peru to become a country with the capability of sending other countries’ payloads to space, thanks to the special location of the Punta Lobos launching site, Peru can obtain national prestige in this sector (Martin Canales Romero, 2012).

Roberto Ubidia Incio – Peru Biologist, ARESS team member

“The first step [for Peru] is outreach. We want people to know what the country can achieve with the space sciences, mainly space applications, and I have been told that the thing they need to know is that this is going to create jobs, one of the most important things in Latin America.”
Finally, national and international entities have identified the desert Pampas de La Joya in Arequipa, as a Martian analog site with potential for developing space science and technology in Peru (Valvidia-Silva, 2012; Valdivia-Silva, 2011).

Peru is already on its way to producing capable professionals in the space sector, but it still lacks infrastructure and both national and international support for these professionals to effectively participate in space science and promote technology projects in Peruvian institutions.

Being a country with the capability to send equipment to space opens the door for the private sector to get more involved in the commercial space sector. Peru is currently sponsoring private initiatives through programs like StartUP Peru, which may be the entry point for private companies that want to work in this sector, and to collaborate closely with CONIDA and other institutions in relation to space (Start Up Perú, 2017).

### 6.4.4 Recommendations

Though Peru has an official policy (Government of Peru, 1974), which was released in 1974 to establish the national space agency, it has not enacted any national space legislation. We recommend that Peru establish a legislative framework for space activity in accordance with the requirements in the five U.N. treaties on outer space, to which it is party.

The government should seek to ensure that the education system can produce enough students to pursue advanced degrees in space-related fields. To begin with, Peru should consider providing opportunities for children in rural areas to have access to schools. Having a sufficient number of schools can raise the level of education and facilitate the development of a smarter workforce. Also, long-term education infrastructure in the space industry seems to be lacking. Peru should consider developing and maintaining education capacities within its own country. Moreover, the space organization should continue supporting students to study space science and engineering in foreign countries, with the goal of fostering professional excellence and building international relationships.

**Recommendation One:** Develop a legislative framework to guide space activity and ensure space sector human resource capabilities by improving educational infrastructure.

The launch of PeruSat-1 in September 2016 gave the country its first Earth observation satellite. Peru can now take advantage of satellite technology to tackle issues like illegal mining, forest monitoring, and natural disasters (Popkin and magazine, 2016). We recommend that the country build on its satellite services and establish solid cooperation between the space industry and the concerned industries. This can be realized by engaging in a series of talks and forums with these industries, thereby opening different opportunities for these industries to benefit from the space activities and add to the foundation of the space program.
Recommendation Two: Facilitate cross-sectoral cooperation between the space industry and agriculture, mining, and tourism industries.

Peru has been a member of UNCOPUOS since 1994 and is also a member of ITU. To further increase its visibility in the international community and open the door to future collaborative projects, Peru should consider applying to host the ISU SSP or SH-SSP, IAC, or similar events. This will create an influx of space experts to Peru and will put Peruvian expertise and capabilities in the international spotlight.

Recommendation Three: Pursue increased involvement in the international space community by hosting key space sector events.

As larger space nations consider sending humans to Mars in the near future, there are many research efforts to understand human performance and psychology for deep space crew members. Many of these studies are conducted as analog missions in remote areas. Peru could leverage the Martian-like quality of the Pampas de La Joya desert to contribute to this research by hosting analog missions or rover testing facilities. This would provide economic benefits and increase national prestige within the planetary science and human space flight communities.

Peru could also leverage its experience in mining by encouraging technology transfer between the terrestrial and space mining industries. Autonomous systems proposed for space mining will need to be tested on Earth, so there are potential opportunities for Peru to bridge its space and mining sectors.

Finally, Peru’s location near the magnetic equator and the South Atlantic Anomaly provides an ideal location for magnetic field research. With the ongoing operation of the Van Allen Probes mission, which provides high-quality data from within the radiation belts, there are many opportunities for Peru to support the international science community with ground stations, balloon platforms, and sounding rocket missions. Peru is already involved in this research and should continue to build on its existing capabilities.

Recommendation Four: Peru should consider expanding space activity to contribute to hot topic opportunities.

6.5. The Philippines

6.5.1 Rationales

The Philippines is a tropical country abundant in natural resources and prone to calamities and severe weather conditions. Approximately 15-20 typhoons enter the Philippine region each year and six to nine make landfall. The Philippines has experienced the effects of El Niño and La Niña that brought either severe drought or heavy rains. These meteorological events resulted in the loss of countless lives and the destruction of millions of dollars in property (Yumul et al., 2011).

The government is now exploring space technology to help address these challenges. This led to the creation of an initial and pioneering initiative, the PHL-MICROSAT program (Constante
et al., 2017). One objective of the program is to use remote sensing and observation for post-disaster analysis, disaster risk reduction and mitigation, and resource assessment.

6.5.2 National Strengths and Weaknesses

In 2016, the economic growth of the country increased from 5.9% in 2015 to 6.8%, making it one of the most dynamic economies in the East Asia region. Between 2012 and 2015, there was an income increase of 16% for the lowest 20% of the income earning population. This led to a decline in the poverty rate from 10.5% in 2012 to 6.6% in 2015. Looking forward, the Philippines is expected to remain a strong economic contender with a projected growth at 6.9% in 2017 and 2018. Growth in capital investment is expected though it will be tied to the successful implementation of the investment push by the government (World Bank, 2017).

Geographically, the country is composed of more than 7,000 islands and a total land area of 300,000 square kilometers. It is relatively close to the equator and to many of Southeast Asia’s main bodies of water. This presents an advantage if the country wants to venture into rocket launch services in the future as it can cater to near-equatorial launches.

Results from the National Statistics Office 2010 Census of Population and Housing showed that 97.5% of the population is literate, which is an increase from 92.3% in 2000 (Literacy Worldwide, 2017). The Philippines is an English-speaking country, making international collaboration easier. Although it has a significant number of courses in the fields of science and engineering, the Philippines does not currently offer any space-specific university courses or degrees, like aerospace engineering or space sciences.

The country’s first microsatellite, DIWATA-1, was released from the ISS in April 2016. It was developed by a group of Filipino engineers under the guidance of professors from Tohoku and Hokkaido Universities in Japan (Constante et al., 2017). Currently, the satellite passes over the country two to four times per day, capturing images. These are then downloaded using a Filipino ground station for analysis, post-processing, and archiving. The country is also undertaking capacity building efforts to ensure the sustainability of space endeavors. These include establishment of the academic Microsatellite Research and Instructional Facility to support continuous development of human resources in this area.

The country has established the National Space Development Program to sustain the recent progress in space development. It will lay the preliminary groundwork and required infrastructure for the creation of a national space agency (NSDP, 2017).
6.5.3 Opportunities

The successful development, launch, and operation of DIWATA-1 has opened different opportunities for the Philippines to continue its space programs. In 2010, a government initiative led to the deployment of more than a hundred automated agro-meteorological stations all over the country. These stations gather different weather-related parameters and send them wirelessly to a central server for analysis. Results are then used for different areas such as the study of climate change patterns (BSWM, 2012). A richer set of data can be generated if these can be correlated to the scientific information extracted from the images of satellites like DIWATA-1. This can then be used for more avenues of research in such fields as agriculture and forestry.

With the knowledge gained from its initial space program, the Philippines can also venture into other fields of research related to space science and astronomy, such as space weather research, astronomical observation, and computational astrophysics.

6.5.4 Recommendations

Filipino universities and colleges offer a vast array of engineering, science, and technology courses are available. Before the establishment of the PHL-MICROSAT program, there were no space-related course offered. Now, through the valuable experiences and knowledge acquired in the PHL-MICROSAT program, an elective course has been introduced in one of the universities. This course covers satellite technology and space systems engineering and is offered to junior and senior undergraduates (Constante et al., 2017). This is a good step to create awareness among the students about space technologies. Looking forward, if the Philippines wants to sustain its space program initiatives, it should establish an avenue to develop local space experts. An excellent way to do this is by offering space-related undergraduate courses at universities like aerospace engineering and space science. Students who finish these courses could find jobs in government space programs or help boost the growth of the space industry by venturing into the local commercial space market.

Harold Bryan Paler - The Philippines Senior Science Research Specialist at Advanced Science and Technology Institute, ARESS team member

—What does space mean to you?

“Space is like an area of possibility. It's something that can really advance the Philippines in terms of its technological capabilities, because right now there are different technologies in the international scene and slowly we are trying to reach that one. For now, it's a dream we are trying to get to.”

—How would you describe your experience with the collaboration with Japan?

“It was very insightful. We learned so much about building a satellite, because when we went to Japan we had no clue on how to build a satellite or on the fundamentals, so when we were there the Japanese professors were really helpful enough to really show us the ropes on what to do. Then we had some hands-on activities which I think is the biggest take on the project itself. It's not about the satellite itself, but it is more like the capability of the students or the Philippine engineers that went there and experienced all these activities personally so that they could take it back to the Philippines. The Japanese professors were very helpful in helping us realize this path.”
The Filipino engineers that developed the first satellite have Masters degrees in space-related courses. We recommend that the country sends more delegates abroad to attain academic degrees in similar fields. Upon completion, these delegates could teach space courses at national universities.

Recommendation One: The Philippines should introduce space-related university courses and concentrate on the creation of a community of space specific professionals.

Currently all the space programs in the Philippines are within the government and are dependent on collaboration with Japanese universities to develop satellites. For the space sector to have a strong foundation and rapid growth, it should involve the participation of local industries in its activities.

The country should engage industries, like electronics and agriculture, as well as private sectors, in a series of forums and discussions to gain input on how to create a cooperative relationship. Such insights into how the Philippines can participate and use satellite technology in its specific industries would be valuable.

One example to look at is the thriving semiconductor and electronics industry of the country. Many firms have invested in the Philippines, including such well-established companies as Texas Instruments and Toshiba Information Equipment, Inc. This industry can be used to produce space-grade electronic components that will support the different satellite development programs of the government.

Recommendation Two: The Philippines should establish cooperation between the space sector and the local industries through a series of forums and discussions.

The Philippines is currently developing small satellites. These are DIWATA-2, which is another 50kg microsatellite, in partnership with Tohoku and Hokkaido Universities, and a cube satellite under the BIRDS-2 program of Kyushu Institute of Technology. These programs are another step to build capacity in satellite development (PHL-MICROSAT, 2017).

If the Philippines wants to attain a full satellite development capability locally, it is recommended that it invest in satellite infrastructure like testing facilities. Avenues to conduct different tests like vibration tests, radiation tests, and vacuum tests should be established. Otherwise, it would have to build its satellites in another country as it does now, or develop satellites locally and ship them abroad for these tests. By establishing these facilities, all the activities could be performed in the country, thus enhancing local capability in satellite development.

Recommendation Three: The Philippines should invest in the establishment of satellite testing facilities to fully enhance local capability in satellite development.
6.6. Vietnam

6.6.1 Rationales

Vietnam, as a developing country, suffers from various problems including the effects of natural disasters. The development of space technology could result in economic and social benefits to Vietnam: prevention and mitigation of the damage from natural disasters and climate change; configuration of telecommunications and television infrastructures; and navigation applications of satellites (Anh Tuan Pham, 2017). Satellite applications are an important factor in the development of Vietnam’s space sector.

Vietnamese space activities are mainly performed by the Space Technology Institute (STI), established in 2006, and the Vietnam National Satellite Center (VNSC), established in 2011 under the Vietnam Academy of Science and Technology (Iwata et al., 2016). VNSC currently leads the Vietnam Space Center project, which consists of policies that support infrastructure development, technology transfer with satellites, and human resource development. These policies meet the demands of developing and using space technology and provide technology skills, resulting in construction of small Earth observation satellites in Vietnam (Anh Tuan Pham, 2017). Vietnamese space development is an attempt to configure and use satellites for Earth observation with space technology and human resource development.

6.6.2 National Strengths and Weaknesses

Education plays an essential role for the dissemination of space technology to the population. The Vietnamese government, in 2006, approved the Strategy for Research and Application of Space Technology until 2020, including the aim to train talented people in aerospace technology. Indeed, VNSC collaborated with some universities to acquire domestic professionals as human resources (Anh Tuan Pham, 2017). Vietnam can supplement its internal training programs and foster international cooperation by sending students to foreign universities.

Vietnam’s geographic location close to the equator is ideal for a spaceport from which to efficiently launch satellites into geostationary orbit. With such a facility in place, Vietnam could see large economic growth in the upstream space sector. VNSC’s attention to satellite technology research and development is an area of focus that can allow for economic growth both in the upstream and downstream applications services sectors (Vietnam National Space Center, 2017). Vietnam’s Pico series of satellites, which is the first satellite project by VNSC with PicoDragon being the first to orbit, gives Vietnam the capability to be a leading manufacturer of these CubeSat satellites.

Vietnam’s economic growth in the past decade has steadily increased, partly attributed to electronics manufacturing and the mobile phone sector, which constitute 23% of Vietnam’s exports. This sector has huge potential within the space domain, in particular for collaborating with VNSC. These industries employ large numbers of the Vietnamese population and, as they rise in the value chain, will continue to do so. Vietnam’s interest in free trade agreements and political stability encourages foreign businesses to migrate there, which is a big strength for NewSpace actors and foreign investors (Business Development Group Vietnam, 2016).
6.6.3 Opportunities

The PicoDragon is a good example of Vietnamese capability in the satellite and electronics-in-space arena (Vietnam National Space Center, 2017). Vietnam’s strong focus on creating infrastructure for entrepreneurial start-ups can contribute to the development of the emerging commercial space sector with these capabilities in satellites and electronics. Another key technology area where Vietnam can play a large role could be telecommunications, which is expected to grow rapidly as space tourism and space exploration increases, with large electronics and telecommunication manufacturers such as Samsung and Intel (Up, 2015). Commercial space exploration is also a growing sector and is forecast to grow rapidly in the coming years (STCI, 2017). Vietnam’s geographic location could be beneficial for the development of this sector.

6.6.4 Recommendations

Cooperation between Japan and Vietnam would enable further development of educational infrastructure and space center development. Building on the Pico series of satellites and international collaboration, Vietnam could see more user-centered and downstream services being provided for its population, which would provide local infrastructure for company growth and capacity building in the space sector (European Commission, 2013).

Recommendation One: Vietnam should develop its space center and space education through strategic collaboration with Japan.

Since Vietnam is located in a low latitude and is very close to the equator, it can use the advantage of launch cost reduction. Construction of launch sites in Vietnam enables opportunities to test satellites as well as more effective satellite launches. Besides providing the launch site, Vietnam can establish relationships with other countries. International cooperation leads to sharing space technologies, resulting in the development of its human resources and the acquisition of new knowledge. A strategy and policy that makes use of this geographical opportunity has the potential to offer significant investment and economic return for Vietnam.

Recommendation Two: Vietnam should investigate the feasibility of constructing and operating a space launch facility, either as a national project or through private industry.

A clear government policy and legislative framework would better enable Vietnam to have transparency for foreign investors entering the space sector. Vietnam should demonstrate commitment to this strategy with funding oriented towards space-related projects. Vietnam could potentially see a larger investment from space actors, which would help implement entrepreneurial infrastructure. This facilitation of the private space sector can be beneficial for Vietnam as the commercial space market opens up. With a focus on incremental progress and reasonably achievable goals, the space sector in Vietnam could see dramatic growth.

Recommendation Three: Vietnam should create a national policy that promotes the private space sector in line with strategic goals that target national economic growth.

Vietnam has experienced rapid economic growth in the electronics sector and has the opportunity to apply this technology to the space sector. As a similar example, Luxembourg
used the advantage of its financial sector, and then enacted legislation to favor investment in emerging or start-up space actors (Space Resources, 2017). The Vietnamese government should promote investment and a well-organized environment adequate to industry deployment for electronic application to the space industry. On top of that, it is possible to build collaboration in the electronics sector with foreign countries or international organizations for space development. This enables the country to obtain more opportunities to improve its technology and to be supported by established space countries.

Recommendation Four: Vietnam should promote and incentivize the growth of the electronics-specific space applications sector, paying particular attention to potential international collaborations.

Although Vietnam has useful programs in educating professionals with specific skills, the public awareness of space development is also crucial. Space science furthermore needs a proficient national knowledge base across interdisciplinary fields. Early space-related education is likely to inspire younger generations. The government should promote the academic benefits of space research to students. Additionally, space-related organizations should directly disseminate firsthand experience to students and schools by organizing partnerships and collaborations that possibly offer internships, workshops or events related to space, inspiring education. This allows the country to foster the youth, Vietnam’s next generation skilled workforce in its future space sector.

Recommendation Five: Vietnam should engage in a long-term plan of outreach and education oriented around the space sector.

Vietnam has significant potential to enter into the space sector, with companies that focus on electronics manufacturing and a growing space community within VNSC, and because of its unique geographic location. There is a distinct opportunity for Vietnam to be a major actor in the space domain following political stability and motivation to develop entrepreneurial infrastructure.
7. Conclusion

The ARESS report has been developed for organizations, both private and governmental, of emerging space states who are interested in entering the space sector, either on a national or international basis. ARESS sets out, in detail, the findings of our initial objectives:

△ To investigate how established space states developed their strong space presence.
△ To understand the geographic context of the space economy.
△ To develop a model of engagement for governments and decision-makers.
△ To develop a strategy to promote space and non-space sector interaction.
△ To propose recommendations that assist the development of emerging space states.

The content of this report was developed using skills, knowledge, and expertise from a team of 28 individuals from 15 nations. This intercultural, interdisciplinary, and international effort is reflected in the wide-reaching scope of the ARESS project.

One of the major outputs of this report are the 21 general recommendations developed from analysis of 13 established space nations. Case studies were used to collect information on the different space sectors, as well as the lessons learned by these existing space actors. Our evidence-based recommendations are to be used by emerging space states that desire to advance their national space sectors. This report also outlines a comprehensive method to apply these recommendations to specific cases using six emerging space states as examples: Ireland, Hungary, Oman, Peru, the Philippines, and Vietnam.

The ARESS team hopes that the discussion, analysis, and recommendations in this report will prove a valuable resource to those from all nations engaged in space sector capacity building.

ARESS Mission Statement:

“To identify recommendations for emerging space states that will inspire and enhance social and economic growth”
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Appendix A. Case Studies

Each selected case study country is summarized in the following section.

A.1 AUSTRALIA

Rationale

Australia has no national space agency and minimal government investment in space activities (OECD, 2014). During the 1960s and 1970s, the Australian Woomera rocket range was one of the world’s busiest launch sites, launching Australian, European, and American rockets (Australian Senate Standing Committees on Economics, 2008). In 1967, Australia became the seventh country to place a satellite into orbit and the third to launch a satellite from its own territory. Despite being an important actor in the early space race, Australia is generally perceived globally as not being active in space (Asia Pacific Aerospace Consultants, 2016) and relies heavily upon other countries for satellite services.

Following a 2008 Senate report entitled Lost in Space? The Australian government released a space strategy in 2011 and a space policy in 2013. These state that the rationales for current space activities in Australia are primarily socioeconomic factors (Department of Industry, Innovation and Science, 2013). Australia has limited interest in satellite manufacturing, launch vehicles, or human spaceflight and seeks to advance in select niche areas aligned with the country’s existing strengths. Like most nations, Australia relies on satellite technology for communication, positioning, and precision timing (Australian Senate Standing Committees on Economics, 2008; Australian Government, 2011). Earth observation capabilities are also important because of Australia’s large uninhabited areas of the mainland, vast coastal waters, and Antarctic territory which it claims. Space technology is also becoming a critical aspect of infrastructure for Australia’s mining and agriculture industries. Australia’s goal is to ensure

Figure A.1 Distribution of case study countries
continued access to space systems for the benefit, safety, and security of its citizens (Australian Government, 2011).

**Industry Landscape and Geopolitics**

Australia’s industrial strengths are in its service sector, mining, agriculture, and livestock production, all of which can benefit greatly from space applications (Asia Pacific Aerospace Consultants, 2016; Space Industry Association of Australia, 2017).

Australia is a desirable location for ground stations because it is equidistant from both Europe and North America, providing a critical link for satellite tracking and downlink. In fact, contributing ground infrastructure to international collaboration projects is part of Australia’s policy to share satellite operations with other countries (Australian Department of Industry, 2013). Australia’s southern location provides an outstanding astronomical view of the center of the galaxy. Additionally, large electromagnetically quiet areas throughout the country make Australia a desirable location for radio astronomy. The Square Kilometer Array, a large multi radio telescope project, will be partially built in Australia because of these electromagnetically-quiet areas (Storey, Thomas and Sarkissian, 2001).

The Woomera launch site was built for land-based launches and recoveries and is an attractive site for suborbital launches, rocket testing, and space tourism. Currently, the site is only used for atmospheric missile and aircraft testing; the space launch sites have fallen into disrepair. While the government is open to commercial investment in launch infrastructure, it will not support such activities with taxpayer funds (Department of Industry, Innovation and Science, 2013).

Launch sites at Darwin, Christmas Island, and Cape York have been proposed because of their equatorial proximity, but plans have never been elaborated (Australian Senate Standing Committees on Economics, 2008).

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**Andrea Boyd - Australia**  
**ISS Flight Operations Engineer at EAC**

*What do you think are the top short-term main goals the Australian space sector should focus on?*  
“Creating a central agency and leveraging international partnerships and very generous international offers to access all the data. [We] could have an Australian participant to astronaut analogue missions in CAVES and NEEMO [as well as] create our own capacity (learn from ESA, DLR, etc.) to manufacture satellites domestically.”

*What do you hope the Australian space sector will look like in 5 (or 10) years?*  
“A 50% export industry worth US$6 billion at a federal level, a space agency with mandate authority and technical competences that has 10-year partnerships with ESA, bilateral [agreements] with DLR and KARI etc.”
**Policy and Strategy**

Despite significant space activities in the 1960s and 1970s, Australia had no national space legislation until 1998 (Space Activities Act 1998). The government undertook a legal framework review for Australia’s space sector in March 2017. It recommended replacing the Space Activities Act of 1998 with a new act. Australia has never established a national space office or program and therefore lacks a single governmental organization dedicated to implementing and managing national space projects.

Australia is party to the five major UN treaties on outer space and has been a member of UNCOPUOS since 1959 (United Nations Office for Outer Space Affairs, 2009).

**Model of Sector**

![Diagram of Australia’s space sector model](image)

*Figure A.2 Overview of Australia’s space sector model*

The Australian space sector model is currently under review, which is due to report in March 2018 (Australian Government, 2017). A potential outcome is the establishment of an Australian space agency.
A.2 AUSTRIA

Rationale

The Austrian Space Agency, officially known as the Austrian Aeronautics and Space Agency (ALR) was established in 1972. The primary purpose of this agency is to promote Austrian business and science, both at national and international level. Within the aims of ALR, as well as other national space programs, there is a principal emphasis on developing the nation’s international status, the main results of which will benefit employment opportunities, strengthen international cooperation and pave the way for private companies wishing to work in the global space sector (Austrian Research Promotion Agency (FFG), 2017).

Industry Landscape and Geopolitics

A report from the Federal Ministry of Transport, Innovation and Technology (2014) highlights that Austria has a wealth of well-established high-tech space-related companies. As a result, Austrian companies are commonly selected by fellow ESA member states as suppliers of various critical components for satellites and launchers. In comparison to other EU countries, the Austrian government has invested heavily in developing an infrastructure for high-tech industries, offering them unique and advanced opportunities for stability and growth (ABA - Invest in Austria, 2017).

Internationally, Austria has a well-known reputation for their skillset and excellence in technology areas. In addition, from a geopolitical perspective, Austria is central within the EU, making it a valuable asset between eastern and western Europe.

Policy and Strategy

To accomplish the main objectives set out by the public and private Austrian space sector, the following factors were considered (Federal Ministry of Transport, Innovation and Technology, 2014):

- Development of international status by cooperating in international space based and non-space based programs, for example ESA programs run by ESA member states.
- Development of existing high-tech industry by fostering new skills, enhancing scientific knowledge and building innovative technologies.
- Diffusion of technologies in other nations and sectors.
Contribution to issues of national concern by considering the potential offered by space-based satellites.

Improved use of space technologies and applications (e.g., for navigation, communication, etc.).

Development of new and existing services by using and integrating multiple space assets.

Development of research, technology, and procurement policies to be used for international space business.

Austria is party to the five major international treaties on outer space, including the Moon Agreement, and enacted the Austrian Outer Space Act in 2011 (Austrian Outer Space Act, 2011; United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

The Austrian government is a major supporter of the nation’s space activities. For example, it has supported ALR in its efforts to make Austria an ESA member state. ALR manages the Austrian space program, which was an initiative set up by the Federal Ministry of Transport, Innovation and Technology in 2002. The Austrian government supports various other space programs that are not directly associated with ALR, such as the 114 organizations that are currently active in the Austrian space sector. In collaboration with high-tech space and non-space-related private companies, ALR brings its expertise, skills, and knowledge to international projects. Scientific excellence, economic benefits, and societal benefits are the expected return from this model.
**A.3 BRAZIL**

**Rationale**

Brazil is one of the world’s top 10 economic powers and envisions itself as a major player within the space industry. National autonomy is the principal driving factor for Brazil’s space efforts, with the goal to establish independent space capabilities in exploration, commercial development, and military operations. Brazil has identified competency in science and technology, telecommunications, and meteorology as key areas for development and is dedicated to advancing specialist training and recruitment, and to retaining qualified space experts. Through education, innovation, and entrepreneurship, Brazil will drive the industrial progress needed to claim a share of the multi-billion-dollar space industry. A primary goal of Brazil’s space efforts is to identify, study, monitor, manage, explore, and protect its extensive natural resources. It has a clear interest in using Earth observation to find solutions for national concerns such as natural disaster monitoring, agriculture, and environmental management (Moltz, 2015).

**Industry Landscape and Geopolitics**

Brazil’s size at 8.5 million km², its underpopulated borders, vast coastline, tropical regions, and large areas with restricted land access and sparse population distribution offer huge potential for expanding space activities. The country has already received international recognition for its work in remote sensing, geo-processing, space sciences, and meteorology, which has enabled international partnerships of great strategic value, for example the China-Brazil Earth Resources Satellite Program (CBERS) (Oliveira Lino, Gonçalves Rodrigues Lima and Hubscher, 2000).

**Policy and Strategy**

Brazil recognized that to raise its economic growth and to develop its national security, the nation needs more expertise in research and development, technology, and innovation. It is also crucial to improve the country’s education of space-related disciplines, particularly STEM, in universities and other academic institutions. (Rosa, A.C., Scavuzzi dos Santos, J. and Viana, T., 2014).

In 2005, Brazil’s space agency, Agência Espacial Brasileira (AEB), established its National Program of Space Activities which is based on Brazil's political, economic, and military rationales for space and describes the technological and overall vision for Brazil’s space activities up to 2021.
Brazil is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of the Space Sector**

![Diagram of the Brazilian space sector model](image)

**Figure A.4 Overview of Brazil's space sector model**

The Brazilian space sector model is a centralized one. Space activities are developed within the framework of the National System for the Development of Space. AEB is the central coordination agency and reports to: 1) the Ministry of Science and Technology; 2) other governmental agencies such as the Ministry of Defense; and 3) entities of civil society that are represented at the Superior Council of the AEB. The National Institute for Space Research (INPE), an executive agency, reports to the Control of Research Institutes of the MCT. Under the Ministry of Defence is the Research and Development Department (DEPED), which has three subordinates: 1) the Aerospace Technical Center; 2) the Alcantara Launch Center; and 3) the Barreira do Inferno Launch Center (Garvin, 2014).
A.4 CANADA

Rationales

Canada became one of the first spacefaring nations in 1962 with the launch of its first satellite, Alouette-1. The country’s first interest in space was to help govern its vast expanse of land and the economy (Aerospace Industries Association of Canada, 2016). Canada lists space as one of its prioritized areas of research, emphasizing that “the aerospace and space sectors make critical contributions to Canada’s prosperity and security.” (Government of Canada, 2014). Canada sees significant benefits from its space activities, including CA$5.3 billion in space sector revenue (Canadian Space Agency, 2017). Ice monitoring, resource management, coastal, and maritime situational awareness are immediate priorities for the government (Aerospace Industries Association of Canada, 2016).

Industry Landscape and Geopolitics

Canada, a world leader in science and technology (Scientific American, 2017), engages in strategic partnerships with the E.U. and others through the Open Government Partnership (Open Government Partnership, 2017). It has become a pioneer in space robotics, championing rover technologies and having built the ISS robotic arm, Canadarm.

Canadian industry has remained at the forefront of global space telecommunications and Earth observation technologies. The RADARSAT Constellation mission, scheduled to launch in 2018, will further support Canada’s space rationale by providing daily revisits of Canada’s land mass, as well as 90% of the world’s surface (Canadian Space Agency, 2011). Canada’s space industry is concentrated in five major firms (Dingman and Gravenor, 2014) and 200 SMEs (Canadian Space Agency, 2017). The private sector comprises the largest proportion at 75%, with research at 25% (Aerospace Industries Association of Canada, 2016).

Policy and Strategy

Historically, Canada’s space strategies were based on international collaborations, particularly with NASA and ESA, to develop solutions and programs. Though Canada is be planning to build its own launch facility (Ruskin and Williams, 2017), Canada does not have a long-term space policy or strategy. The Canadian Space Agency Act laid foundations for space efforts in 1990 specifying intent to “ensure that space science and technology provide social and economic benefits for Canadians.” (Minister of Justice, 1990).

Canada’s Space Policy Framework, published in 2014, outlines the principal goals of the space sector to be implemented through four main avenues of action (Canadian Space Agency, 2014):

- Commercialization – focusing on private industry where feasible, and supporting business models tailored to space operations.
- Research and development – encouraging technology development in proven and emerging technologies.
The exploration of space – Canada sees value in the science and derived benefits from space that are in the national interest.

Stewardship, management, and accountability – the Canadian Space Advisory Council represents the stakeholders and contributes to setting future space priorities.

These actions are guided by the principles of (1) keeping Canadian interests first; (2) positioning the private sector at the forefront of space activities; (3) progression through partnerships; (d) excellence in key capabilities, and (4) inspiring Canadians.

Canada is party to the Outer Space Treaty, the Rescue Agreement, the Liability Convention, and the Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Diagram of Canada's space sector model]

Canada’s broad strategy for implementing policy is a centralized system. CSA acts as the hub for Canada’s space sector and programs, while the Space Advisory Board consultants with the public - a named stakeholder in Canada’s space efforts.
A.5 CHINA

Rationale

China’s space program was born during military tensions of the 1950s from a desire for independent defense capabilities. Since then, the political and economic environment in China has seen large upheavals on many occasions, yet the space program has demonstrated remarkable resilience. The space program flourished during the Cultural Revolution of the 1960s and 70s, despite tumultuous political climates. This was because Chinese authorities viewed the space program as a symbol of national prestige and demonstration of China’s ability to conduct advanced scientific programs. Consequently, the space program continually received high-level government support. During the period from 1977 to 1986, however, the space program declined, as government leaders following the Cultural Revolution placed less importance on space activity to focus on modernization and economic stability (Chen, 1991).

A significant shift occurred in 1985 when China announced its intention to offer commercial space products and services to the world and in 1993 the CNSA and CASC were formed (Lania, 2016). In 1988, China and Brazil entered into the joint Earth Resources Satellite program, which was considered a successful collaboration between two countries engaged in expanding their space sector capabilities (Oliveira Lino, Gonçalves Rodrigues Lima and Hubscher, 2000).

From the late 1980s to the present day, China has grown into a world leader in the space industry, with indigenous capabilities in launch vehicles, satellites, deep space missions, and extended crewed spaceflight. Today, China is committed to peaceful use of outer space to enhance its understanding of the cosmos, promote social progress, stimulate economic, technological, and scientific development, and improve the cultural status of the Chinese nation (The State Council Information Office of the People's Republic of China, 2016). China’s vision to become a space power is closely related to Chinese culture. Chinese writer Sun Shuyun addresses how space, along with industrialization, engagement in the 21st century, and social reform, is one of many “Long Marches” that the Chinese feel they must undertake, following in the footsteps of the historical military Long March of the 1930s Red Army (Shuyun, 2008). This attitude is underscored by the fact that the Chinese launch vehicle program is known as the Long March.

Industry Landscape and Geopolitics

The Chinese space program has thrived under stable funding, whether domestically or internationally sourced, since its establishment. This achievement is largely attributable to the adaptability of its space policy, which has changed significantly as the country’s rationales have changed.

In 2016, China’s GDP was US$11199.15 billion. This value represents 18.06% of the world economy. From 1989 to 2017, the average GDP growth rate in China was 9.71%. Over the past decade, funding for space activity has increased consistently from US$2.1 billion in 2010 to US$3.5 billion in 2013. In 2016, this value peaked as China invested US$4.9 billion into its space sector (Euroconsult, 2017).
This stable source of funding and consistent support has allowed China to develop good infrastructure for its thriving space industry, both on a national and international basis. Since 2011, the most notable result of this development is the undertaking of major space-related projects such as Beidou, a national GNSS, as well as achievements in space science, technology, and space applications such as communication satellites.

Policy and Strategy

China’s space industry is focused on development according to four principles laid out in the official government policy: innovative, coordinated, peaceful, and open. China aims to achieve self-reliance and national independence while still coordinating internationally and promoting peaceful use of space to benefit all humankind.

Considering these principles, CNSA has described the following policies, several of which are discussed in more detail below:

- Prioritize construction and application of space infrastructure.
- Enhance innovation in space technology.
- Transform and upgrade space capacity.
- Accelerate industry applications of satellite technology.
- Strengthen relevant legislative framework.
- Diversify system of funding.
- Strengthen professional development for space industry personnel.
- Disseminate knowledge of space science to the public.

To enhance innovation in the space sector, the government has clearly defined the roles of various players, forming a framework of innovation to coordinate efforts of the government, private sector, universities, research organizations, and consumers. Though the government has developed upstream technologies, there is also a clear focus on downstream applications and opportunities with emerging trends from other industries, such as the big data revolution and the Internet of Things. Finally, China acknowledges the importance of outreach and is investing in public awareness. Events have been organized to celebrate Chinese space culture and inspire the nation, including China Space Day, World Space Week, and Science and Technology Week (The State Council Information Office of the People's Republic of China, 2016).

China is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).
Model of Space Sector

Figure A.6 Overview of China’s space sector model
A.6 INDIA

Rationales:

India’s space program started with sounding rockets in November 1963 and, in 1969, the Indian Space Research Organisation (ISRO) was formed. ISRO comes under the jurisdiction of the Department of Space (DOS) and its vision is to “harness space technology for national development while pursuing space science research and planetary exploration.” The founder of ISRO, Dr. Vikram Sarabhai said, “To us, there is no ambiguity of purpose; we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society.” (Indian Department of Space, 2017).

Industrial Landscape and Geopolitics:

India is one of the largest economies in the world by GDP. The country is classified as a newly industrialized country, and one of the G20 major economies, with an average growth rate of approximately 7% over last two decades. The space industry has held a steady share of its economic contribution at 26% of GDP (Deloitte, 2010).

A strong and healthy relationship exists between ISRO and Indian industries, and public and private corporations have started to play a major role in the space sector. ISRO’s annual budget is US$1.4 billion and it has a spending blueprint of US$3 billion for its crewed mission. More than 500 industries associate with ISRO in hardware and system development, software, and other services. Indian industries handle around 60% of launch vehicle expenditures and 100% of the ground system equipment and services in tele-education and telemedicine. DOS has developed and transferred more than 289 technologies to industries (Deloitte, 2010).

ISRO has executed more than 270 consultancy projects to support industries, enabling DOS to handle complex jobs and increasing demand for space services without significant increase in its in-house workforce. Indian capabilities are in information technology and software development, educated talent pool, low production costs, and a strong manufacturing industry base. A current development is that of launching a common purpose civilian satellite to be shared by all member countries of South Asia, and the expansion of the footprint of Indian Regional Navigational Satellite System (IRNSS), which will help in the development of the region (Deloitte, 2010).

Policy and Strategy:

DOS focuses on policy initiatives and proactive measures which enhance effectiveness and outreach of its space programs (Deloitte, 2010). This policy structure covers:

- Communication and remote sensing satellites, data management and distribution;
- Active participation with industries and commercialization;
- Development of skilled human resources;
International cooperation with other space agencies; and

Public awareness and user participation.

To fulfil the above objectives, the DOS has established the following programs:

- Indigenous launch vehicle program;
- Insat and Gsat program for telecommunications, broadcasting, meteorology, and education;
- Remote sensing program for various applications; and
- Research and development in space science, technology, and applications for national development.

India is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. The Moon Agreement was signed by India but not yet ratified (Indian Department of Space, 2017).

**Model of Space Sector**

DOS falls under the authority of Prime Minister of India. The Space Commission formulates policies with concurrence of the government and assigns task to DOS. DOS monitors and executes the activities through various ISRO centers and laboratories. Antrix is the marketing wing of DOS (Indian Department of Space, 2017).
A.7 ISRAEL

Rationales

Israel entered the space sector in the 1960s when it created the National Committee for Space Research in 1963, which focused on research and indigenous development of space science and engineering. During the Yom Kippur War in 1973, Israel failed to obtain imagery from U.S. satellites, highlighting the importance of acquiring or having control over its own satellites. Israel spent years developing independent space-based Earth observation capability, which led to the creation of the Israel Space Agency (ISA) in 1983 (Bhattacharjee, 2016).

Industry Landscape and Geopolitics

Israel, a small country with limited natural resources, has a long history of conflicts with its surrounding countries. Israel is host to more start-ups than any other country: revenues from the start-up sector are twice that of U.S. venture capital. Israel attributes its start-up success to its STEM capabilities, which are highly regarded by the general population as reflected in public opinion surveys (Drori, 2011).

The Israeli space industry focuses on three main areas: small satellites, ground launchers for small satellites, and communication satellites. Israel is working on a project to develop nanosatellites for geolocation. The project is managed by the Israel Institute of Technology in Haifa. The institute also participates in collaborative projects such as Venus, a French-Israeli microsatellite designed for monitoring the environment and providing agricultural imaging (Bhattacharjee, 2016). Various countries approach ISA to acquire satellites for their military infrastructures. ISA maintains relationships with space agencies from all around the world and more than 30 companies within Israel.

Policy and Strategy

In 2009, Israel created a task force focused on science and civil applications to develop industry and increase competitiveness in the global space market. The task force made a series of recommendations that were adopted and implemented as the National Civil Space Policy in 2012 (Bhattacharjee, 2016). These recommendations include:

- Maintaining an Israeli presence in space for scientific, national, and commercial uses;
- Maintaining its strategically leading position among the top five countries engaged in space science and space research technologies, in areas in which Israel has relative advantages;
- Engaging public-private partnerships to develop the Israeli space program while increasing domestic space market revenues;
Enhancing Israel’s bilateral and multilateral cooperation in space to expand business opportunities, upgrade relations with partner countries in space science and exploration, and encourage the peaceful use of outer space for the benefit of humanity;

Improving Israeli knowledge and upgrading its industrial infrastructure in research and development areas that are suggested for funding, such as: satellite miniaturization, remote sensing and communication; fundamental and applied research; and

Strengthening the interrelationship between space research and applications, and Israeli society.

Israel has ratified the Outer Space Treaty, Rescue Agreement, and Liability Convention. It has neither signed nor ratified the Registration Convention or the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Diagram of Israel's space sector model](image)

Israel’s space sector model is research and industry focused, through the collaboration of ISA and the academic sector, and through government support to aerospace-related businesses. Israel also participates in collaborative projects with members states of ESA, as well as, CNES, ASI, and NASA.
A.8 LUXEMBOURG

**Rationales**

Luxembourg is looking to combine its economic power and its experience in space to establish a new space mining start-up market in Europe. The rationale behind this decision is that Luxembourg seeks to be the Silicon Valley for the space mining and space innovation companies. According to the Luxembourg, government space mining will bring a new era of sustainable use of space resources for the benefit of humankind (Space Resources, 2017).

**Industry landscape and geopolitics**

Luxembourg is one of the smallest countries in the world, bordering France, Belgium, and Germany, yet it has the 2nd highest GDP per capita and a growing economy with 4.2% annual GDP growth rate in 2016 (IMF, 2017; World Bank, 2017a). Luxembourg provides an attractive financial environment for new and innovative companies. The government funds innovation and has a legal framework supporting venture capital and equity investment firms in the space sector. Luxembourg’s space sector focuses on satellite communications, with Société Européenne des Satellites (SES), a major satellite communication company, based in Luxembourg (Innovation Public, 2016).

**Policy and Strategy**

In 2016, Luxembourg published a new legal framework that includes a new space sector model for space mining. The policy acknowledges that Luxembourg does not have a national space agency, therefore there was a need to establish the Space Resources.lu Initiative, which is responsible for preparing the legal and financial framework for space mining. The Space Resources.lu Initiative published the new legal framework for space mining in August 2017, making Luxembourg the second state in the world and first state in Europe to have a legal framework on space mining. This Act’s first provision states that “Space resources are capable of being appropriated,” which has led to discussions on the interpretation of international law, especially of Outer Space Treaty Articles I and II (Ministry of Economy, 2016).

Luxembourg is party to the Outer Space Treaty and the Liability Convention and has signed, but not ratified, the Rescue Agreement (United Nations Office for Outer Space Affairs, 2009).
The Luxembourg space industry model is sector-oriented. The Ministry of the Economy is responsible for international space sector partnerships and supervises every aspect of the space industry in Luxembourg.
**A.9 NIGERIA**

**Rationale**

The Nigerian National Space Research and Development Agency (NASRDA) was established in 1999 to consolidate all space science and technology related activities. NASRDA develops and deploys space technology systems in communication, Earth observation, and terrestrial transportation systems. It also supports infrastructure development, resources and environment management, agriculture, water resources, education, and healthcare using satellite applications.

Nigeria launched its first satellite in 2003 in collaboration with the U.K. It was an Earth observation satellite providing early warning signals of environmental disasters like flooding and for detecting, monitoring, and controlling desertification. Nigeria built communication satellites NIGCOMSAT-1 and 1R, in collaboration with China, to improve communication and socioeconomic activities (NASRDA, 2017).

**Industry Landscape and Geopolitics**

Africa is Nigeria’s leading producer of oil. The country produces over 2 million barrels of crude oil daily. As this brings approximately 95% of the nation’s foreign earnings, it is an extremely valuable national asset (Economy & Industry, n.d.).

Nigeria has a large manufacturing industry for chemical products, textiles, and automobiles. The country wants to capitalize on its manufacturing infrastructure, for space asset development with a declared intent to manufacture spacecraft hardware and software (Lagos Business School, 2016). The government expresses a key interest in developing Nigerian technologies that enhance foreign exchanges (Ekekwe, 2015).

**Policy and Strategy**

NASRDA’s mission statement (Akinyede, 2008) highlights the aim to use Nigeria’s capabilities by:

- develop and manage agricultural and forestry resources through the establishment of a database for project planning, crop performance assessment, yield production for sustainable food production promoting food security;

- assessment and management of national resources, such as oil exploration, exploitation and management, assessment of the quality and quantity of both surface and underground water and monitoring of marine water;

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Funmilayo Erinfolami - Nigeria Scientific Officer at ARCSSTEE, SSP17 Staff, Dipterons

“For the space industry in Nigeria, we have very beautiful policies, covering every aspect that you can think of, but the main issue that we are still dealing with is implementation. Some of these policies are getting implemented in teeny-tiny doses, but I believe we can do much more than that.”

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development of an effective and efficient communication system;

enhancement of transportation and tourism enterprises;

development of education and health care delivery systems, both rural and urban;

development and management of energy Resources;

human safety and mitigation of disasters; and

national defense and security.

Nigeria is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

Model of Space Sector

![Diagram of Nigeria's space sector model]

Figure A.10 Overview of Nigeria’s space sector model

The model is a government-centralized model, controlled by the NASRDA, with oversight and strategy provided by the National Space Council, which is chaired by the Nigerian president.
A.10 NORWAY

Rationale

Norway has engaged with space research and science since the start of the space era. Early participation placed them in a strong position as the space sector developed. This was augmented by their geographical location and pioneering astrophysics research center at the University of Oslo (University of Oslo, 2017). Norway is an ESA member state.

Norway launched its first research rocket from Andoya in 1962 and currently has two sounding rocket launch sites, Svalbard and Andoya. These sites regularly contribute to NASA and ESA projects (Norwegian Space Center, 2017a).

Norway aims to, in the words of Dr. Stein Vidar Hagfors Haugan, “contribute to knowledge of space research as a social good.”

Norway’s current policy focuses on economic return which remains significant, through use of their world leading space research facilities. The country is also heavily involved in Earth observation and civilian navigation (Norwegian Ministry of Trade and Industry, 2013).

Industry Landscape and Geopolitics

Norway’s geographic location offers unique opportunities in research, especially in geophysics. Research continues to attract investment from foreign governments and was a key driving force for the development of the Norwegian Space Policy (Røberg and Collett, 2004).

Two-thirds of space-related services and products in Norway are delivered by Telenor, a former telecommunication company. Winning ESA contracts played an important role for the growing economy of Norway, with contractors Kongsberg and Raufoss notable for providing deliverables for ESA launchers and satellites. Norway would like to further enhance its ability to provide good infrastructure for profitable companies to maximize employment for its technically skilled citizens and augment the number of skilled bureaucrats able to assess proposals relevant to Norway’s space sector interests (Norwegian Space Center, 2017a).

Policy and Strategy

The four main areas outlined in Norway’s national space policy are characteristic of an experienced space actor are:

- build on international collaboration and winning ESA contracts held by the forty space based companies that reside there, providing significant export profits (Norwegian Space Center, 2017b);
- provide a national administration on space activity with experts in the industry identifying Norwegian interests through adequate review of technical proposals;
Maintain and develop international collaboration—ensure bureaucrats are knowledgeable regarding the space domain and procure the proper implementation of national policies; and

Meet the needs of society through the development of downstream applications and engagement with user groups (Norwegian Space Center, 2017a).

Norway is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified, the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Model of Space Sector Diagram]

*Figure A.11 Overview of Norway’s space sector model*
A.11 SOUTH AFRICA

Rationale

South Africa started its space journey with the GreenSat project, a governmental program that aimed to develop a South African satellite and launch vehicle. Unfortunately, due to political transitions, this project was abandoned in 1994. A later project, SunSat, became South Africa’s first ever operational satellite. SunSat was developed through the University of Stellenbosch. Professors brought skills that they had acquired while studying on international programs. Students worked on developing the SunSat satellite as the project component of their studies. The infrastructure from the original GreenSat project was also used in its construction and funding given by commercial partners who had interests in satellite technology, such as telecommunications. In 1999, the satellite was launched as part of a NASA payload. In 2011 South Africa went on to host the International Aeronautical Congress and founded its National Space Agency (Wood and Weigel, 2011).

Industry Landscape and Geopolitics

South Africa is a parliamentary republic and it has the second largest economy in Africa. Despite this, it remains in the top 10 countries for income inequality. A large proportion of its GDP comes from the thriving tourism industry; it also has a strong transport industry, including South African Airlines, a strong railway network, and many high-volume ports. South Africa is developing and investing in electric power and, unlike other African countries, agriculture only accounts for 10% of its industry. Through research and development, South Africa pioneered the first heart transplant, the vaccine against yellow fever, and the development of CT topography. It also has an impressive astronomical capability with the South African Large Telescope, the MeerKAT radio telescope, and the Square Kilometer Array that is currently under construction.

Policy and Strategy

Aim:

“The pursuit of Space activities in South Africa is informed by the overarching principle that these activities contribute to the country’s economic growth and social development.” (South African Department of Trade and Industry, 2009).

The objectives of the South African government (South African Department of Trade and Industry, 2009) are:

- Strengthening international cooperation;
- Extending the benefits of the space program to the whole African continent and cooperate with other African countries;
- Developing capacity building initiatives to enhance current space capability to support national priorities;
Developing the space sector according to relevant legislation and law;

Developing the space industry to improve self-sufficiency and become an international competitor through domestic commercial space capability;

Strengthening science and technology base;

Optimizing use of resources; and

Enhancing awareness of space.

South Africa is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Diagram of South Africa's space sector model]

*Figure A.12 Overview of South Africa’s space sector model*
A.12 UNITED ARAB EMIRATES (U.A.E.)

Rationale

The United Arab Emirates (U.A.E.) first demonstrated an interest in space following a meeting between the late Highness Sheikh Zayed bin Sultan Al Nahyan and NASA in the 1970s. The Emirates Institution for Advanced Science and Technology was established in 2006 and merged with the Mohammed bin Rashid Space Centre in 2015. U.A.E’s Space Agency was formed in 2014 by a federal decree (U.A.E. Space Agency, 2017).

The U.A.E.’s current focus is the development of a probe to explore the atmosphere of Mars. This will be the first Arab and Islamic probe to reach Mars and will enhance national pride but also “It’s beyond that...It’s about taking the whole Arab region and making them active in generating knowledge,” says His Highness Sheikh Mohammad Bin Rashid Al Maktoum (RT News, 2017).

The U.A.E. considers space as an opportunity for future investment and as a diversification of its economy, particularly for reducing its current reliance on the oil economy. U.A.E. also recognizes the potential of the space sector to support sustainable development (UAE Space Agency, 2017). The National Innovation Strategy outlines the goal of developing an increasingly knowledge-based and innovation-focused economy. The U.A.E. government also notes that space science and space applications can be beneficial for the development of its nation and for the well-being of its citizens.

Industry Landscape and Geopolitics

The U.A.E. has a strong economy, with a gross GDP of US$371 billion (OPEC, 2017). The economy largely depends on petroleum and natural gas. However, there is an increasing contribution of non-petroleum sectors, such as tourism. U.A.E. is working to diversify its economy. Its free-trade zone, with full ownership rights and no taxes, offers attractive opportunities for foreign investors.

Geographically, the U.A.E. is located in the southeast of the Arabian Peninsula. Its proximity to the equator, coastline, and desert make it a suitable for a launch site.

U.A.E is an important regional actor in satellite communications services, with two companies, Thuraya and Yahsat, providing mobile and fixed communication services. Yahsat provides commercial and governmental communication in the Middle East, Africa, and Asia. Thuraya offers mobile communication services across two-thirds of the globe.

Policy and Strategy

The U.A.E. Space Agency was founded on five principles: 1) enhance lives of citizens, 2) support U.A.E. national interests, 3) drive economic growth and diversification, 4) promote collaboration and the U.A.E.’s status, and 5) respect international laws and treaties. Building on these principles, the U.A.E. space policy pursues five goals: 1) expand use of space to support critical sectors, 2) develop a competitive commercial space industry, 3) conduct scientific space missions, 4) promote a safe and stable space environment, and 5) establish
and expand U.A.E.’s leadership in space. It employs several foreign experts to advise on strategic decisions and ensure strict adherence to U.A.E.’s international obligations. One uncommon rationale of the U.A.E. space policy is to improve the happiness of the Emirati people. The agency was established in 2014 and is currently working to draft national space legislation (U.A.E. Space Agency, 2017).

The U.A.E. is party to the Outer Space Treaty, Liability Convention, and Registration Convention (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Diagram of the U.A.E. space sector model]

The U.A.E. adopted a collaborative satellite development approach, which as described by Wood, “strikes a balance between acquiring useful technology, enabling local participation in designing and building the satellite and accessing robust training for local engineers,” (Wood and Weigel, 2014).

The U.A.E. started using this model in 2006.
A.13 UNITED KINGDOM (U.K.)

Rationale

The British Government has recognized the importance and relevance of space for public services, national security, science and innovation, and the economy (U.K. Space Agency, 2015). The U.K. is a research nation, with four of the top 10, and 29 of the top 200 universities in the world, despite representing only 0.9% of global population (Kumar, Moss and Johnson, 2017). Satellite technology is an enabler of economic growth in the U.K. (UKspace, n.d.), particularly of the telecommunication sector. U.K.’s space sector consistently achieved growth of over 8% per year for 2004-2014 (Sadlier et al., 2014). The U.K. has a very strong scientific landscape, ranked second in the 2014 Global Innovation Index, with 3% of global funding for research spent in the U.K. (UK Space Agency, 2015).

Industry Landscape and Geopolitics

The U.K. space landscape involves companies clustered by industry, driven by government funding and incentives (Sadlier et al., 2014). One example of a successful cluster is the U.K. Space Gateway at Harwell, a leading science, innovation, technology, and business campus (Harwell, 2017). The success of the collaboration is referred to as the “Harwell effect” (Sadlier et al., 2014). The sector’s growth is attributed to companies using space-derived data or downstream services. The U.K. is also one of the leading countries in orbital debris research (UK Space Agency, 2015). In 2010, the government establish the U.K. Space Agency (UKSA) to coordinate and collaborate space activities. UKSA replaced the British National Space Centre (BNSC) and is responsible for government policy and key budgets for space exploration, space technology, and innovation.

Among the most important vehicles for international civil space collaboration in the U.K. are the European Space Agency (ESA), the European Union (EU) space programs, and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). International collaboration facilitates U.K. participation in more ambitious projects, enables it to benefit from economies of scale, and creates new opportunities for public services, science and innovation, security, and the economy (UK Space Agency, 2015).

Future plans in the U.K. include the development of its first spaceport for small satellite launch and suborbital flights in the U.K. by 2020 (UK Department for Transport, n.d.).

Policy and Strategy

In 2015 the U.K. government published its first National Space Policy, which focused on four interrelated policies:

△ Recognizes that space has a strategic importance to the U.K. because of the value that space programs deliver back to public services, national security, science and innovation, and the economy;

△ Commits to preserving and promoting the safety and security of the unique space operating environment;
Supports the growth of a robust and competitive commercial space sector, underpinned by excellent academic research; and

Commits to cooperating internationally to create the legal frameworks for the responsible use of space and to collaborating with other nations to deliver maximum benefit from the U.K.'s investment in space.

Space is becoming increasingly important to the U.K. The government, through its National Space Policy, will support the growth of the space sector in public services, national security, science and innovation, and the economy. The U.K. supports innovation and research related to space. It will support current and future space businesses through partnerships, collaboration, and financial incentives to enhance U.K. business capabilities and attract global companies to the U.K. It works with established international space partnerships and will forge new partnerships with emerging space players (UK Space Agency, 2015).

The U.K. is party to the Outer Space Treaty, Rescue Agreement, Liability Convention, and Registration Convention. It has neither signed nor ratified the Moon Agreement (United Nations Office for Outer Space Affairs, 2009).

**Model of Space Sector**

![Model of Space Sector](image)

*Figure A.14 Overview of U.K.'s space sector model*

The U.K. model for the space is based on collaboration and corporation.