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Executive summary

This master's thesis is a report following an exploratory research process into the theme of economic viability of Norwegian space companies. Little previous information of scientific value was available on this specific field. For this reason, the research process was based on an inductive approach to theory using qualitative methods to create and gather data. A literature review provided a generic understanding as to what factors impact economic viability of commercial space companies in general, while interviews provided insight into the Norwegian commercial space sector specifically. In total two in-depth interviews were performed with informers from different sides of the commercial sector. A substantial amount of data was created which was categories according to a PESTEL (political, economic, social, technological, environmental, legal) and SWOT (strengths, weaknesses, opportunities, threats) model. These categories were also the perspectives used for parts of the research discussion to answer the critical issue of economic viability of Norwegian space companies.

The main findings of the research process were 1) that the Norwegian commercial space market can best be characterised as an immature market. There are many reasons for this argument, but the main reason is the commercial sector's high degree of dependency upon state spending to achieve economic viability. 2) There are three main market failures that must be addressed prior to that market maturity can be achieved: State dependency, high economical risk level and the lack of complementing elements within markets. 3) The political category appears to be the strongest determinator when it comes to the ability to mature and evolve these markets efficiently, and therefore has a decisive role when it comes to addressing the market failures to ultimately enable a mature and self-sustaining market. 4) The majority of these market failures appear to be addressed to some extent in Norway, but the problem is a low rate of change since the maturation is mainly tied to increased state spending. 5) State spending through funding of European Space Agency (ESA) programs was found to be particularly useful and efficient for maturing Norwegian space markets mainly due to the geographical return mechanisms that ensure that the majority of the money spent toward these programs flow back into the Norwegian space economy. 6) Another particularly useful mechanism to mature Norwegian space markets was the efforts of the Norwegian Space Agency (NSA). By pro-actively scanning the Norwegian commercial landscape for contenders for ESA contracts and awarding them funds for feasibility studies, NSA was found to efficiently lower the barrier of entry for new entrants into the commercial space sector.

Preface

This master's thesis represents the end of my studies for a Master of Business and Administration (MBA) degree at Nord university, Norway.

I would like to thank my supervisor Ove D. Jacobsen for the constructive criticism, insightful guidance and enthusiasm for the project throughout the research process.

Also, I would like to extend a special thank you to Bjørn T. Hansen, for his time, perspectives and excellent support throughout my studies as in life in general. Thank you, coach!

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List of terminology

Space sectors

"The space sector includes all actors involved in the systematic application of engineering and scientific disciplines to the exploration and utilisation of outer space, an area which extends beyond the earth's atmosphere" (OECD, 2012, p. 19). And:

"Space endeavors are grouped into sectors: Civil, national security (i.e., defense and intelligence), and commercial. Each sector operates with its own goals and assets, although they all rely on a common space industrial base, workforce, and infrastructure" (Space Foundation Editorial Team, n.d., first section).

Commercial space sector

"All space-related endeavors — including goods, services and activities — are provided by private sector enterprises with the legal capacity to offer their products to non-governmental customers. Commercial space efforts range from satellite communication to space tourism" (Space Foundation Editorial Team, n.d., forth section).

Commercial space activities

In the context of this master's thesis commercial space activities "…refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment…" (President of the United States, 2010, p. 10).

Space economy

"The Space economy is the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space. Hence, it includes all public and private actors involved in developing, providing and using space-related products and services…It follows that the Space Economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society" (OECD, 2012, p. 20).

Space industry

The Space Industry consists of "…private firms that produce, as at least part of their output, launchers, satellites, rocket engines and other kind of space hardware and services" (Bromberg, 1999, p. 1).

Economically viable

The term viable is defined as something that is "capable of existence and development as an independent unit" or "financially sustainable" (Merriam-Webster's online dictionary, 2022). And further that sustained is understood as "maintained at length without interruption or weakening" (Merriam-Webster's online dictionary, 2022). From this we can extract that the total income must exceed the total costs over time for a company to be considered economically viable.

New Space

"The terminology of "New Space" has come to represent not just a new generation of companies (after all, well-established firms like Boeing and Orbital Sciences are also important players) or a steady growth in space-sector revenues, but rather a new approach. In the centralized model, private firms working with NASA were largely insured against the enormous risks of investments in space through cost-plus contracts, but they had little ability to participate in the potential gains from a commercialized space market. In the "New Space" approach, private firms share in the enormous risks and (potential) returns of investments in space (Achenbach, 2013, as cited by Weinzierl, 2018, p. 180).

Spin-off

"A product that develops from another more important product" (Cambridge Dictionary, 2022).

Synergy

"The combined power of a group of things when they are working together that is greater than the total power achieved by each working separately" (Cambridge Dictionary, 2022)

Driver

In this context a driver is understood as a factor, cause or source that serves as a motivation or accelerator towards increased economic viability of commercial space activities.

Barrier

In this context a barrier is understood as a factor or cause that impedes, hinders or reduces the economic viability of commercial space activities.

Trend

In this context a trend must be understood as a prevailing direction, movement or tendency within the commercial space sector that has happened over some time and will most likely continue along the same path in the short- to medium-term.

Short-, medium- and long-term

In the context of this thesis these terms will be understood as:

- Short-term: Less than two years.
- Medium-term: Two to ten years
- Long-term: Ten years or more.

Acronyms

COTS	Commercial Orbital Transportation Service (a NASA program). The more widely known significance of “Commercial-Off-The-Shelf” will be written in plain text, when used.
CRS	Commercial Resupply Services (a NASA program)
ESA	European Space Agency
ISRU	In-Situ Resource Utilisation
IPR	Intellectual Property Rights
LEO	Low Earth Orbit. A stabilized orbit around earth in the space between 200km-1600km the surface.
NASA	National Aeronautics and Space Administration
NSA	Norwegian Space Agency
NTNU	Norwegian University of Science and Technology
R&D	Research and Development

1.0 Introduction

This master's thesis is a report following an exploratory research process. The main theme of the research process is economic viability within the context of the Norwegian commercial space sector. Most theoretical markets in space are currently not economically viable in the classical sense, since most of the activity in space is highly dependent on substantial state spending for commercial companies to take part. If or when activities in space prove to be economically viable *and* self-sustaining it would likely signify a substantial change across multiple domains. Further, it would be a sign of a market that has reached a point of maturation where it is no longer dependant on state spending for growth. A self-sustaining market is likely to expand and, in this context, increased activity in space may result. Increased activity in space will arguably have a cascading effect where increased activity leads to increased demand, which leads to an increased amount of service providers and better value propositions, which again leads to increased demand and activity and so forth.

The anticipation of such a future cascading effect is why many consider space to be the final economic frontier, vast in resources and opportunities for growth. Renowned astrophysicist Neil deGrass Tyson and X-price founder Peter Diamandis are both credited with the statement that the world's first trillionaire will be a person who exploit space resources (Kaufman, 2015). Such a statement reflects the possibilities and potential for growth and prosperity that off-earth activities represent to an increasing amount of people. And if one considers the argument that the current economic system is based on a continuation of growth, combined with the fact that the earth's resources are finite, a leap into space is arguably inevitable if human prosperity is to be upheld.

In this thesis I discuss the most crucial factors that impact economic viability for companies in general and for Norwegian space companies specifically. I will both discuss historical events that have impacted economic viability in space in the past and examine what factors are impacting the current situation. Further, I will present a rare insight into the Norwegian commercial space sector. I will cover some of the perceived strengths, weaknesses, opportunities and threats to Norwegian actors as well as some of the country specific mechanisms that were found to be impactful in the sector.

1.1 Actualisation

Human activity in space already has a substantial impact on the society of today. Services such as global positioning systems, satellite TV, satellite communications, earth monitoring and in-flight internet would be impossible without the use of space. However, research conducted in the name of space has also led to many significant implications for a better and more efficient life on earth as well. Examples of this come from areas such as: Aircraft engine-, battery-, wireless charging-, automation-, navigation-, cybersecurity-, data transfer-, telemedicine-, mining-, and medical technology (Tauri Group, 2013).

The long-term implications of the use of space are virtually limitless. In our solar system alone there are many times the resources available than what is available on earth. As an example, the asteroid Psyche is estimated to contain "…iron and nickel resources [that] are estimated to be worth $10 quintillion dollars at current commodity prices (100,000 times the size of the Earth's GDP) "(Gilbert, 2021). It is reasonable to argue that should humankind one day be able to extract just a small percentage of the off-planet resources, the earth-based economy would dwindle in comparison. Needless to say, such a scenario has a substantial impact on our society. Knowledge and insight regarding human activities in space is important, and in the future increasingly so.

1.1.1 Theoretical actualisation

The commercialisation of space is a relatively young discipline. At least in its current form, where agencies such as NASA act more as a customer buying services rather than a supervisor overseeing the development of a service. The failure of the Space Transport Services, widely known as the NASA Space Shuttle, is to a large part attributed to the new course for NASA, the growth of New Space and the following boost of motivated space entrepreneurs intending to make a business based on space activities (Weinzierl, 2018).

Even though much has been written and learned both on subjects such as entrepreneurship and the commercial space sector in general. Little has been created on the Norwegian commercial space sector, or the public or national security sector for that matter. It must be mentioned that theoretical framework that works well to study other parts of the economy provides much value when applied to the commercial space sector as well. However, operating in space involves particularities that are like no others such as the inherent level of

risk, third party liability, long payback periods, operating conditions, technological dependencies and political dependencies.

Theoretical knowledge about the subject of commercial activities in space is important due to:

- The vast potential that lies within the space domain to impact multiple areas like society, economy, politics, technology, environment and legal matters.
- The impressive growth of the commercial sector in recent years and with it the increased likelihood that our world in fact will be impacted in multiple areas by increased space activity in the long-term.
- Proper insight gives an opportunity to react proactively instead of reactively towards the changes that are likely to occur in the near-, medium- and long-term. This applies to the policy makers that are intended to supervise the space activities, the private actors that are interested in a stake in the business of space, as well as the private actors that are not necessarily interested in making a business of activities in space, but will still be impacted by those activities whether they like it or not.

Even though no new theoretical framework will be presented in this thesis, it will provide a unique insight into an area that is understudied: The Norwegian commercial space sector. Further, a number of models and figures have been developed and presented in this thesis, some of which may be expanded upon for future research.

1.1.2 Practical actualisation

This thesis may prove useful for practitioners in the field that face strategic decisions as to whether to attempt an entry into the Norwegian commercial space sector, or not. It may provide an increased understanding of the mechanisms that are in play in commercial space sectors in general and in the Norwegian commercial space sectors specifically. For the established companies in the commercial space sector, it may provide increased insight and updated information as to the maturity of the Norwegian space market, especially since informers from the political level in Norway were included as sources to the data analysis of the research process.

Finally, this thesis may be useful for different political organisations such as the Norwegian Department of Commerce or the Norwegian Space Agency (NSA), as an informer from a Norwegian company was included as a source to the data analysis of the research process.

This may help provide the political level in Norway an understanding of what is important for the Norwegian companies in the commercial sector.

1.2 Research question

The main aim of this master's thesis is to answer the critical issue that is overarching the research questions:

- "What makes commercial space activities economically viable for a Norwegian company?"

This is a broad and challenging issue to answer. And it needs to be operationalised further to enable the opportunity to answer it. This is achieved by formulating and answering the four research questions:

- Research question 1 (RQ 1): "What are the drivers and barriers that impact the economic viability of commercial space activities?"
- Research question 2 (RQ 2): "What have been the historical events on the path toward a viable space economy?"
- Research question 3 (RQ 3): "What are the current trends towards an economic viable commercial space economy?"
- Research question 4 (RQ 4): "What are the strengths, weaknesses, opportunities and threats for a Norwegian company intending to perform commercial activities in space?"

1.1.3 Operationalisation

This sub-chapter will clarify what is meant by the central terms of the critical issue and research questions, and how these can be reduced down to measurable and tangible elements.

To operationalise the critical issue the four research questions were formed. RQ 1 through 3 is about drivers and barriers (labelled as factors when combined) that impact economic viability for commercial space companies in general, while RQ 4 covers these factors in a Norwegian setting specifically.

Through RQ 1 this thesis aims to bring to light the most relevant drivers and barriers that could potentially impact economic viability for a commercial space company. This entails

that these factors do not need to be found to be applied in reality, but are rather theoretical factors that possibly could impact reality. RQ 1 is encouraging a form of brainstorming process based on reliable sources such as literature. In a sense RQ 1 can be seen as a form of library of factors that could be activated at a given time to produce a result.

RQ 2 on the other hand is asking how drivers and barriers have been found to impact economic viability in the past. This section is more tangible and enables the possibility to look at historical events and decisions and evaluate what implications they had. The aim is to understand some of the mechanisms that currently exists in the sector by learning from history.

RQ 3 is asking what drivers and barriers are actually active at this point in time. If RQ 1 can be understood as a library, then RQ 3 represents what books are currently being read and applied. With RQ 3 the aim is to understand the current situation, the current time and the current mechanisms and forces that are in play in a better way.

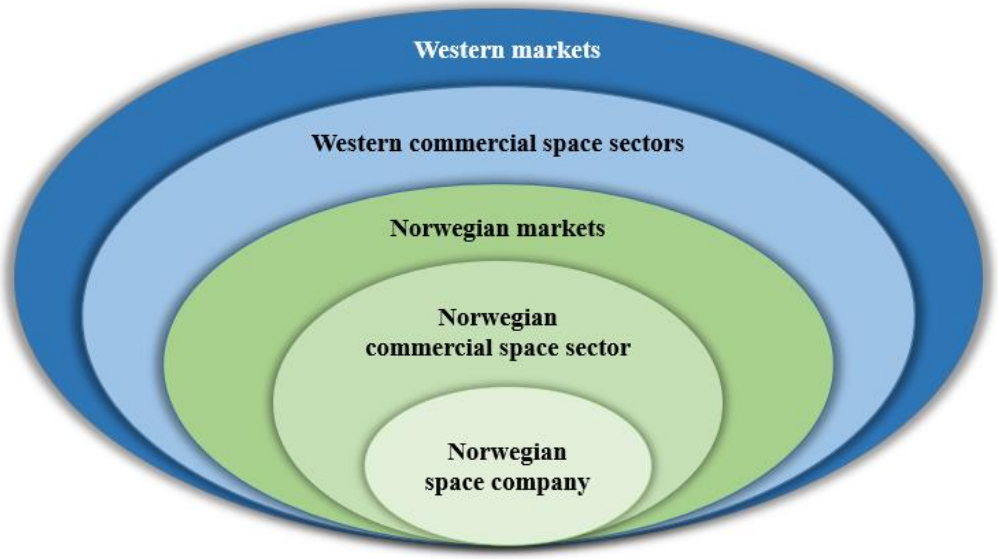
Finally, RQ 4 asks how the combination of RQ 1-3 has, is and will impact the economic viability for the Norwegian commercial space sector specifically.

1.1.4 Introduction to methodology

To answer the research questions a combination of exploratory and qualitative research methodology was chosen for the research process. Specifically, the qualitative methods of a literature review and interviews were assessed as the best and most realistic methods of answering the research questions. This thesis requires gaining multiple layers of insight before reaching the destination of answering the critical issue of economic viability of Norwegian commercial space. The literature review was required to gain an understanding of the initial layers of insight: Understanding the background of the commercial space sectors based on an understanding of the markets and economies of the western world. To access the final layers of insight interviews were required as information regarding Norwegian conditions, mechanisms and markets is limited on the topic of commercial space. The interviews were performed with informers from different areas in the Norwegian space segment. This provided a deeper understanding of the factors and mechanisms that are in play in a Norwegian setting in general, but also first-hand experiences from the informer's point of view. The figure below illustrates the levels of insight that was required to reach the final understanding of how the world is seen from the standpoint of a Norwegian space company,

and as a result being able to answer the critical issue of economic viability to Norwegian commercial space companies. Methodology will be covered in detail in chapter 3.

Figure 1.1: Levels of insight required to answer the critical issue of economic viability



1.1.5 Limitations

Western space economies. The sources for this thesis have all been based on western sources and primarily on US, European and Norwegian sources. The results may not be comparable to, and are expected to be quite different from, the economies and cultures of other space faring nations such as China, Russia, India and United Arab Emirates.

Time scope. When looking back at historical events this thesis looks all the way back to the start of the space race in the late 1950's. When examining current trends this thesis focuses on the time between 2010 until 2022. When attempting to look to the future this thesis aspires to remain within 15 years of the current date, to avoid speculation as much as possible and remain rooted in observed facts.

Satellites. The satellite market is a success story where the market is to a large degree privatised and economically sustainable. The satellite market is also the largest part of the space economy. For this reason, this thesis aims to mainly focus on the opportunities and challenges that lie beyond the satellite market and this market will only be covered superficially.

1.3 Main findings

- The Norwegian commercial space market can be characterised as immature.
- There are three main market failures that must be addressed prior market maturity can be achieved: State dependency, high economic risk level and a lack of complementing elements of the market.
- The action of the political category appears to be the strongest determinator when it comes to maturing and evolving immature commercial space markets.
- The political level has a decisive role when it comes to addressing market failures to ultimately achieve market maturity and self-sustainability.
- European Space Agency (ESA) and the geographical return (geo-return) mechanisms has a profound positive impact of addressing Norwegian market failures.
- NSA funding and pro-activity has a profound positive impact for lowering the barrier for entry for new companies into the commercial space sector.
- Collaboration with research institutions is a significant cost reducer and force multiplier during research & development (R&D) processes for companies.

1.4 Reader's guide

Chapter two contains a brief introduction to the theoretical framework for this thesis. In chapter three I will present the methodology that was used for the research process and reflections as to the validity and reliability of the process. Chapter four presents the aggregated data from the data collection process in an unprocessed state. That chapter will be most useful as a point of reference, both for increased transparency of the research process and for any future researchers that would like to expand on this thesis. Chapter five contains a research discussion following my data analysis process. The chapter is divided into two parts, where in part one I will discuss the data from different perspectives according to the PESTEL

model. In part two I will discuss the research questions and finally present a case study. Chapter six will contain the conclusion to the thesis.

My recommendation to most readers will be to read chapter one for an underlying understanding of the thesis first and then read chapter six to find the conclusions. If a higher level of detail is desired, I would then recommend reading the entirety of chapter five for the research discussion. Finally, I would recommend reading chapter three and two to understand the methodology and theoretical framework.

2.0 Theoretical framework

This chapter will explain the theoretical framework for this master's thesis. As will be explained in detail in the methodology chapter, this thesis was based on an inductive approach to theory with an exploratory research methodology. This means that the research process was not based on a theoretical framework from the onset: The formulation of the research questions and the data gathering process did not reference a theory that was sought to be tested or validated, but data was gathered with the intention of gaining new insights as per the intentions of exploratory research (Makri & Neely, 2021).

There was one exception to the inductive principle of not basing the research process on theoretical framework prior to starting the data gathering. This exception was to how the data gathering would technically be performed and organised: It was decided to attempt to use the analytical tools of PESTEL and SWOT as categories when gathering data from interviews and literature review. In this respect PESTEL and SWOM became tools for viewing an issue from different perspectives. According to inductive principles, I was open to move away from the PESTEL and SWOT perspectives should they not suit the research process, however they were found to be particularly useful, and they were therefore retained as the main categorisation methods.

2.1 PESTEL

PESTEL is a tool for analysing external factors that impact a business. These are factors outside of the company's control (Erichsen et al., 2018). The method is widely used when studying markets and companies and when developing business strategies. It was a central element of the research process conducted in connection with this thesis, since it was used for categorising the data as explained in chapter three and visible in chapter four. In this thesis,

PESTEL was used as a perspective by viewing the matter of economic viability in space through the different lenses of the PESTEL categories.

The man accredited with creating the PESTEL method was Francis Aguilar through the book Scanning the business environment from 1967. PESTEL is an acronym for various categories of forces or elements that impact a company and constitutes its macro environment (Marmol & Feys, 2018). There are many variations of PESTEL that are used according to the context (ETSP, PEST, STEPLE, PESTLE etc.), but in this context the PESTEL acronym will be used.

The P in PESTEL stands for political. This category contains all the political factors that can affect a company. These can be policies, elections, grants, public organisations, international relations etc. Further, the significant role of a country's governmental actions often impacts the other categories of (P)ESTEL.

The first E stands for economic. This category contains all the economic factors that impact a company such as tax rates, interest rates, financial accessibility, economic growth, market demand and purchasing power. Since PESTEL is an analytical tool to study macro environments, inherently this category does not contain within company factors such as business strategy, risk acceptance, work culture etc. On that point this master's thesis diverges from the standard use of the PESTEL tool: This thesis also includes microenvironment factors in the economic category, as these factors were assessed as too important to be overlooked and that this was the most logical place to include these factors.

S stands for social. These are social factors that impact a company such as the population, its culture and its needs and thereby understanding how individuals act when purchasing goods and services in a market (Marmol & Feys, 2018).

The T represents technological factors that impact a company. In a market that is highly technological dependant, such as the space sectors, the ability to attain and exploit technology is a substantial factor for success. This category is about the ability to innovate, perform efficient R&D, create profitable products and enabling the company to gain new capabilities.

The second E stands for environmental. This category is about how the company impacts the environment through its activities, such as pollution. But it is also about how the environment impacts the company where it intends to operate, such as radiation, temperature and pressure in space. The environmental category is increasingly important to the average consumer as

more attention is directed towards issues such as global warming, micro plastics and waste disposal, and therefore demand higher standards for companies.

L stands for legal. Distinguishing the political and the legal categories can be challenging. In general, the legal category contains elements that decide what a company can and cannot do, such as laws, regulations and licensing arrangements, while the political category contains the interaction between the state and the company such as state contracts and policies.

2.2 SWOT

While the PESTEL model covers factors external to the company, the SWOT model covers both external (macro environment) and internal factors (microenvironment) and can be used as a tool for situational analysis. SWOT is an acronym that stands for Strengths, Weaknesses, Opportunities and Threats (Erichsen et al., 2018)

A company's strengths are areas where the company has an advantage over most comparable companies. These can for instance be material resources such as infrastructure, equipment or tangible resources or the immaterial resources such as talented personnel with high-tech knowledge, experience, motivation and skill or a company's good reputation.

A company's weaknesses are areas where the company has a disadvantage as compared to other companies. These can for instance be limited size, low access to funds, inefficiencies, low experience or negative coverage by media.

The O stands for opportunities which is a category that represents a company's possibilities to gain a further advantage. Examples can be opportunities to be awarded a contract that will enable the company to grow, or a cooperation/ partnering with another company.

A company's threats are factors that potentially could lead to the company suffering a future disadvantage as compared to status quo. Threats to company's could for instance be impeding market slowdowns, increasing taxes and operational risk.

2.3 Summary – theory

This master's thesis had an exploratory approach to methodology and an inductive approach to theory. As per the intent of exploratory research processes, the thesis was not based on a theoretical framework when formulating the research questions or starting the data gathering

process. Inductive processes allow for theoretical framework to impact the direction of research processes at a later stage, such as after data the analysis. That was not case with this thesis, however. Instead, this thesis aims to uncover new insights and descriptions of a relatively un-explored field that potentially could lead to new theories or adjustments of existing theories in the future.

PESTEL and SWOT are tools for analysing different companies' macro and microenvironments. For this thesis those tools were successfully implemented to form a basis of the data gathering and analysis part of the research process.

3.0 Research design and methodology

This master's thesis can be considered a report documenting a scientific research process. The main goal of the research process was to answer the critical issue of economic viability of Norwegian space companies. To be able to support an answer to the critical issue four research questions were formed. In order to reach answers to the research questions that are scientific, valid, reliable and as close to an objective truth as possible the methodology of obtaining the answers is vital. This chapter will describe the choices themselves and the reasoning behind the choices that were made with respect to research design and methodology to enable a reliable and useful conclusion in the work with this master's thesis.

3.1 Research design and methodology

This chapter will contain the rationale for the chosen research design and research methodology. The critical issue of this thesis requires examination of a specific field were little existing theory or literature existed in advance, or that the theory and literature that dis exist was found to be unsuitable to answer the critical issue. Due to this fact an exploratory approach to methodology was chosen for the thesis. Exploratory methodology is suited to "seek new insights", "find out what is happening" and "assess phenomena in a new light" (Saunders et al., 2009, as cited by Makri & Neely, 2021, p. 3).

Exploratory methodology is well suited for cases where inductive research is required. Inductive research is performed when the researcher performs data collection and let the results of an analysis of the data subsequently guide the research process further along (Makri & Neely, 2021). The research process in this case was inductive, since the initial steps of the

research process was performed without referencing an existing theory in advance and that existing theory did not influence the formulation of the research questions.

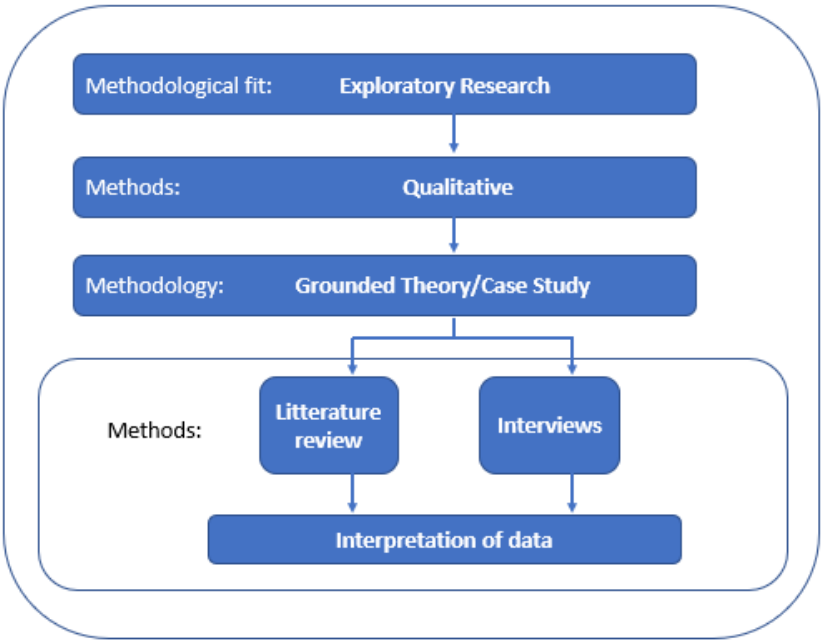
The critical issue and the research questions of this thesis required deeper insight into a field where little quantitative data pre-existed and would arguably not provide adequate insight to enable an answer to the questions involved. This thesis is based on a qualitative approach to methodology. A qualitative approach was chosen as it was assessed to be the best and most efficient way of answering the research questions. A decision which is seemingly supported by Autry (2013) which argues that qualitative methods are better suited than quantitative methods when researching emerging entrepreneurial environments.

To answer the research questions, insight and understanding had to be established on multiple levels. This understanding was found to be best achieved by utilising a combination of two qualitative methods: Literature review and interviews. The literature review provided the required insight on a generic level, while the interviews provided insight on a specific level. Obtaining an understanding on a generic level was especially important to answer RQ 1-3. These RQs contain elements that is generally true across commercial space sectors in most western countries. Through a thorough literature review the required insight was obtained on the first three levels: theoretical-, historical- and current factors. However, a literature review did not provide adequate insight into the Norwegian space sector specifically, since there was little literature available on this topic. For this reason, conducting interviews was considered an efficient method of gaining the required specific insight for these parts of the thesis (especially RQ 4).

Another reason to conduct interviews is that this thesis is explorative in nature: Since the Norwegian commercial space sector has not been extensively covered by previous research, this thesis partly covers new ground. An interview is well suited to uncover new insight as a result of the dynamics of two-way dialogue (Makri & Neely, 2021).

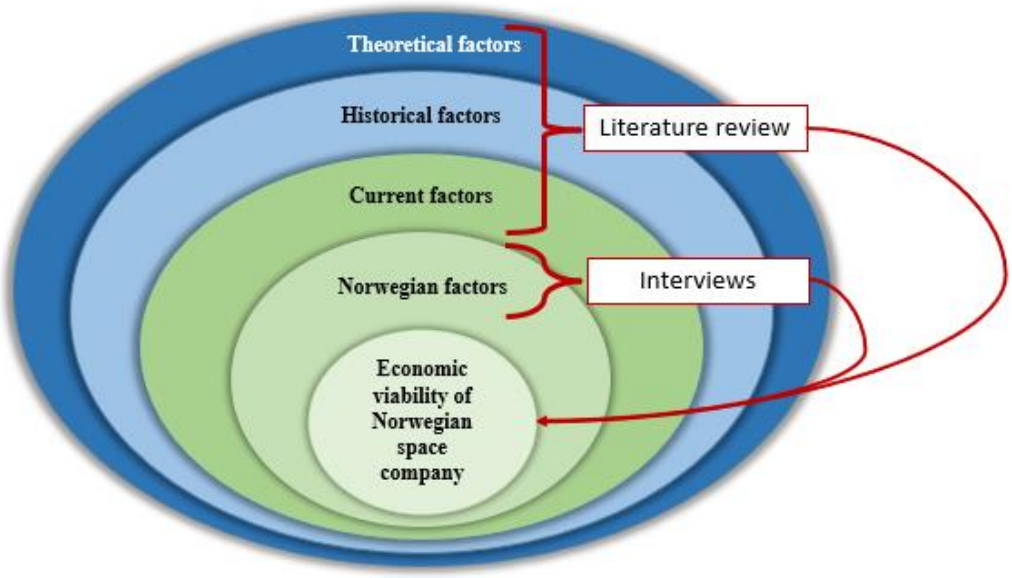
There are two figures below. The first figure is an illustration of the research design, and the second figure is an illustration of how the combination of qualitative methods provided the necessary insight to achieve an answer to the critical issue of this thesis.

Figure 2.1: Research design



The figure is adapted from Grounded Theory: A Guide for Exploratory Studies in Management Research, Makri & Neely, 2021, SAGE, DOI: 10.1177/16094069211013654)

Figure 2.2: Layers of insight required to uncover the critical issue and the main methods used to gain insight.



3.2 Data collection

In preparation for the data collection an excel spreadsheet was produced. The excel spreadsheet provided a matrix where the PESTEL categories were placed on the vertical axis and the research questions on the horizontal axis. During the literature review and the interviews notes were taken and the most relevant of the data was subsequently placed in the corresponding box in excel spreadsheet matrix. This matrix became the main tool for capturing, saving and systematically categorising the data.

After the literature review and the interviews were completed the excel spreadsheet provided the basis for data analysis and proved to be an efficient source for analysis and research discussion. The data is presented in chapter four and the research discussion based on the data is presented in chapter five.

Table 3.1: An example of the excel spreadsheet matrix used as a stencil for data collection in RQ 1-3.

	Theoretic		Historic		Current	
	Drivers	Barriers	Drivers	Barriers	Drivers	Barriers
POLITICAL						
ECONOMIC						
SOCIAL						
TECHNOLOGICAL						
ENVIRONMENTAL						
LEGAL						

3.3 Literature review

The literature review was started by gaining oversight of applicable literature through internet and database searches. In general, all searches returned a substantial amount of hits. A particular challenge is that the word “space” has many meanings both within architecture, phycology, interior design etc. Consequently, finding the relevant literature proved to be an exercise in narrowing down searches with accuracy. Of particular use was to use the advanced search functions (search block functions) of databases such as Oria and Scopus. The illustration below provides an example of a search in Oria that was used to identify relevant literature for the literature review.

Table 3.2: Search block technique used to identify relevant literature for literature review

Search block 1	Search block 2	Search block 3
«outer space» OR outerspace OR «commercial space» OR «new space» OR newspace	entrepreneurship OR «commercial activity» OR «private enterprise» OR «economic activity» OR «economic developement» OR «space economy» OR «space ecosystems»	drivers OR accelerators OR facilitators OR barriers OR motivation

AND AND

When conducting literature review all information that were assessed as relevant with regard to RQ 1-4 was placed in the appropriate place in the excel spreadsheet. Each book or article processed through the literature review produced an individual excel table. These tables proved to be valuable during the data analysis as it was easy to identify what sources provided what information with respect to the various categories. At the end of the literature review all individual excel spreadsheets were merged into a master document. This master document is what is presented in chapter four, according to category.

What literature that was included in the literature review was a result of a conscious decision. The literature that was prioritised for review was: 1) Literature that was relevant, sources covering both economy and markets were preferred, 2) literature that was relatively new, 3) literature covering both the US and Europe were preferred, 4) literature with a scientific value.

3.4 Interviews

The process of conducting interviews was prepared by gaining an oversight into relevant sources in the Norwegian space sectors. When selecting informers for this thesis, depth and not width was the principle: Basing the data on one case, but with informers from different sides of the space sector, was assessed as the best, most realistic and most efficient way to gain the required specific insight into the Norwegian commercial space sector.

The desired informers were contacted and provided a brief information packet about the research project. A guide to the interview was developed to provide a framework for the interviews which were performed in a semi-structured way. The semi-structured interviews provided the ability to go "off script" when needed, while still answering the most important questions. During the interviews notes were taken and the data was subsequently entered into the same type of excel spreadsheet matrix that was utilised for the literature review. At the end of all the interviews the data was merged into a master document. This master document is what is presented in chapter four, according to category.

3.5 Informers

The strategy of selecting informers for this thesis was to select informers from different sides of the commercial space sector. This was chosen to highlight factors and bring forth different perspectives of the same case. In total two interviews were conducted. Through this thesis the sources will remain anonymised. This was chosen as the best way to enable the sources to speak freely and thereby being able to extract the most accurate data.

Source 1 represents the state side of the Norwegian commercial space sector. He is employed by the Norwegian state and serves in an organisation that has Norwegian space activity in their portfolio. Source 1 has knowledge and experience with ESA, NSA and NASA space contracts. The interview took place in the spring of 2022.

Source 2 represents the company side. He is a CEO of a Norwegian company that develops and produces technology that is used both in space and on earth. He has knowledge and experience with contracts from ESA, NSA and the Norwegian Armed Forces. The interview took place in the spring of 2022.

3.6 Data analysis

In this chapter I will describe how the process of analysing the data was performed. The extracted information from the literature review and the interviews was what constituted the data in this context. This data was categorised in accordance with the matrix as illustrated in table 3.1. Each source of literature or interview was assigned an individual excel spread sheet.

Aggregation of the data was performed by merging the excel spreadsheets produced through the literature review and the interviews into two respective master documents: One for the literature review and one for the interviews. Next these master documents were analysed with

regards to conformity and quality: Are all the sources agreeing or do different views exist within the data? Conformity could indicate increased validity and reliability, while differentiating views could serve as interesting points for the research discussion.

The data was also analysed with regards to repetitiveness and perceived importance: Do multiple sources repeat the same factors? If they do this can be an indication of a more crucial factor than those mentioned few times.

The final part of the data analysis was to discuss the findings that was assessed to be the most significant for answering the research questions. The results of the data analysis and a research discussion is presented in chapter five, while the conclusion is presented in chapter six.

3.7 Research quality

This chapter is dedicated to a reflection regarding the quality of the scientific research that was achieved through the process of writing this master's thesis. The quality of the research is to a considerable extent the result of correct handling of the data. The following chapters contain my assessment as to two significant terms within scientific research: Reliability and validity.

3.7.1 *Reliability*

Reliability is tied to accuracy and authenticity of the research process. It is about the accuracy of the data gathering process, how data is measured, what data is being used, how the data is gathered and how the data is processed (Johannessen et al., 2020).

The data in this context stands on two pillars: The literature review and the interviews. The reliability of the literature review depends on the reliability of the research process conducted by the scientists and authors of the respective piece of literature. Since a literature review contains multiple sources of literature it is likely that reliable data will stand out and be repeated multiple times. As described in the previous chapter, this is a mechanism that is enhanced by the process of data analysis of this thesis itself, since repeated information is generally interpreted as information that multiple researchers found to be true.

The reliability of the interviews is to a large part dependant on if the information given by the informers is reliable or not. It is reasonable to assume that the information given by the

informers is reliable as there is no obvious reason why the informers should lie in this case. The reliability of the interviews is increased by: Selecting informers with knowledge and experience in their professional field, giving informers the guide to the interview in advance to allow them to reflect on the questions prior to the interview, and allowing the informers free speech without concerns of future accountability of statements by anonymising the informer's identity.

Johannessen et al. (2020) describes that scientists can strengthen the reliability of their research by providing an open and detailed description of the research process. The content of chapter three is an effort to that respect.

3.7.2 *Validity*

Johannessen et al., (2020, p. 250) describes validity in the following way: "…Validity in qualitative studies is about to what extent the scientist's scientific approach and findings adequately reflects the purpose of the study and represents the reality".

A part of ensuring the validity of the research is being open and accurate as to the research process. This process is covered in detail throughout chapter three to ensure transparency as to the quality of the research process. However, is an unavoidable fact that a qualitative study is subjective in nature and that most likely it is impossible to eliminate all biases completely, both of the researcher of this thesis, the scientists of the literature the thesis is based on and of the informers in the interviews (Johannessen et al., 2020).

As to the transferability of the conclusions found in this thesis a distinction must be made between what data is based on generic information and what data is based on specific information. The main source of the generic information is the literature review. In the literature review the sources are multiple and are derived from multiple sources. It is reasonable to assume that much of this information is transferrable across country borders and markets, especially within the western world. The specific information, however, is based mainly on two interviews that have professions on different sides of the commercial market. Much of this data will likely be transferrable to other situations within the Norwegian market, but not all the data. The transferability to other countries and markets such as the EU or the US may be even more limited. This fact is a result of a conscious choice as to the design of the research to be able to answer the research questions adequately with the resources at hand. For this reason, it is important that the reader is aware of this aspect of the thesis.

3.7.3 *Reflection of own role as a scientist*

It is in the nature of the qualitative method that the results will never be completely objective, as it is assumed and expected that qualitative scientists include their unique perspective into the research that they perform (Johannessen et al., 2020). For this reason, it is important with traceability and openness in all parts of the research process. A thorough description of the scientific methodology is the main contribution in this respect.

3.8 Ethical issues

Through research processes scientists may access information that is sensitive in the sense that the information may inflict negative consequences should the information from the informer be known for a 3rd party. For this reason, it is important to be cognizant of the ethical guidelines that exist and the issues that can arise through research processes. Johannesen et al. (2020, p. 45) discusses three key issues scientists must be cognizant of: 1) An informer's right to self-determination and autonomy, 2) The scientist's duty to respect the informer's privacy, and 3) the scientist's responsibility to avoid damage.

Before conducting the interviews, the informers where sent an information packet containing the guide to the interview and a declaration of consent. By reading the information packet the informers were made aware of the fact that participation was voluntary, that they were free to retract their participation in the research process at any point in time without any consequences to the informers, that the scientist is obligated to abide to confidentiality of personal information and finally, that the informers would remain anonymous.

3.9 Summary – Research Methodology

This master's thesis can be considered a report documenting a scientific research process. The methodology used to reach the answers to the critical issue and research questions were described in detail in this chapter. The critical issue of this thesis required examination of fields were little theory or data existed in advance, or where the existing data was unsuitable or inadequate to fully explain the issue. Due to this fact an exploratory approach to research methodology and an inductive approach to theory was chosen. Further, the research process was based on qualitative methods since a deeper understanding of a relatively un-examined field was required. The thesis was based on two qualitative methods: A literature review and interviews. The data from these sources were extracted in excel spreadsheets and placed in a

matrix according to research question and the different PESTEL/SWOT categories. The data was aggregated into two master documents, one for each type of source. This aggregated data constitutes the empirical data of this research process and is presented in chapter four.

The aim of the research process was to gain a as high scientific value as possible by maximizing objectivity, validity and reliability. However, it lies in the nature of the qualitative methods that full objectivity cannot be fully achieved. This fact is countered by committing to openness and transparency as much as possible by a thorough description of the research process through chapter three.

4.0 Empirical data

4.1 Introduction to empirical data

In this chapter the data produced by the research process will be presented. The chapter is divided chronologically corresponding to research questions one to four (RQ 1-4).

In chapter 4.2 the drivers and barriers (labelled as factors when combined) that were assessed to have a theoretical impact on the economic viability of space activities will be presented (RQ 1). In that chapter the factors are standalone, meaning that to what extent they are found to be true in the real world is not assessed. They are merely identified factors and whether or not they are observed to be true in the real world is not assessed in that specific chapter.

In chapter 4.3 the historical events that were identified to have contributed toward the economic viability of space activities will be presented (RQ 2). Only the factors that were found to be historically true and most impactful were included.

Chapter 4.4 builds on the theoretical factors presented in chapter 4.2, but here the current trends of the factors are assessed where data was available. As opposed to chapter 4.2 this gives an indication on what factors that were found to be true at the current moment in time (RQ 3).

Chapter 4.5 presents the identified strengths, weaknesses, opportunities and threats for Norwegian companies conducting space activities (RQ 4).

As explained in the methodology chapter (chapter three) the research has been based both on a study of literature and interviews of a relevant Norwegian space company and a public

agency. The results are presented with the differentiation between literature and interviews clearly marked. The reason being that the results of the study of literature are applicable in more general terms since they are based on primarily US and European sources. The interviews on the other hand have a narrower focus and go more in depth through the Norwegian space sector.

In chapter four the empirical data will merely be presented and not analysed. The analysis and research discussion will take place in chapter five and the conclusions will be presented in chapter six.

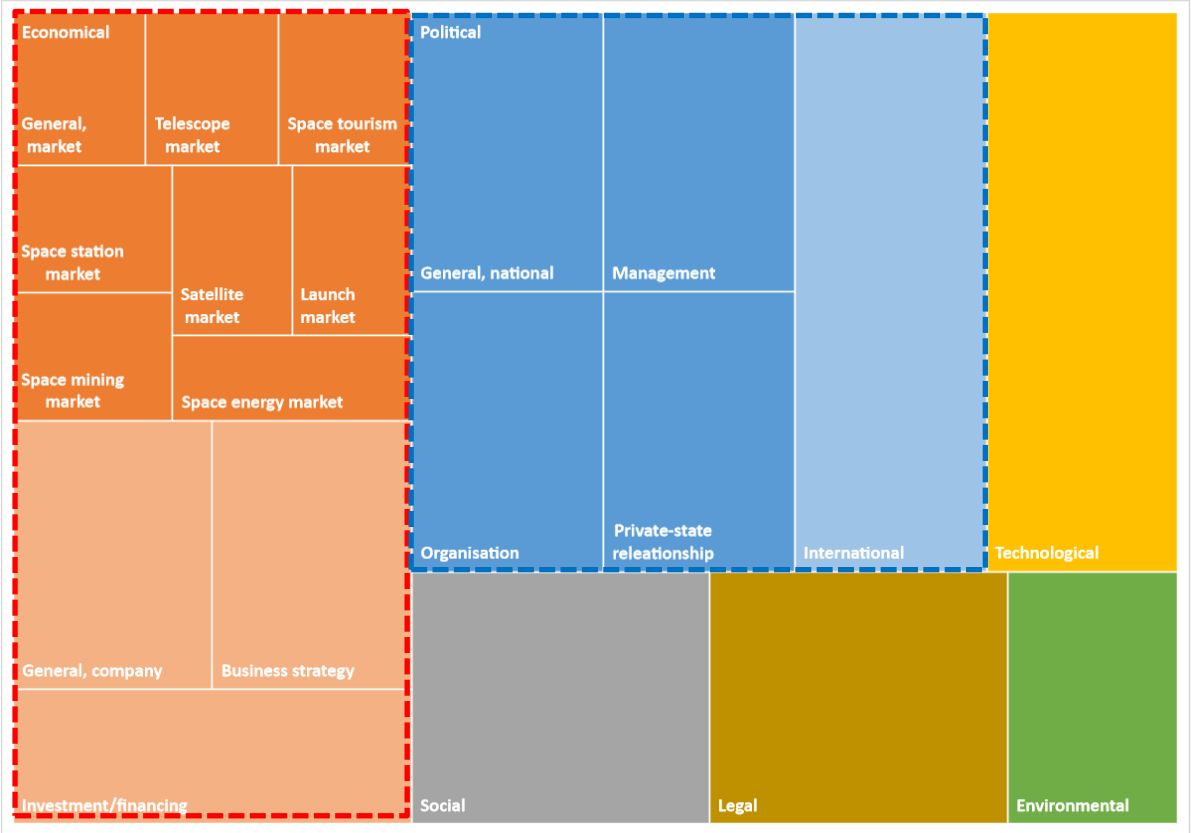
4.1.1 *Categorisation*

The results have been categorised according to the PESTEL acronym (political, economic, social, technological, environmental, legal). The political and economic categories were found to be so substantial that it was found appropriate to add multiple sub-categories. The political category was divided into an international (between and above states) and a national (within the state) category. The international category contains factors that were found to be applicable at the above or outside of the state level. This category contains international factors, factors that apply between states and factors for multi-national organisations. The national category contains political factors that was found to be applicable within a state. This category does not reference a specific country/state: It can contain a factor based on data from Norway, US or other countries. The category merely points at what level the factor was found to have an impact. The national category was further sub-divided into management, organisation and private-state relationship sub-categories.

The economical category was divided into a market (external to the company) and company (internal to the company) sub-category. The market category contains factors that are external to the individual space company and is beyond a company's realm of control. The market category is further sub-divided into telescope-, space tourism-, space station-, space mining-, satellite-, launch- and space energy market sub-categories. The company sub-category on the other hand, contains company internal factors that lie within the individual space companies sphere of influence. The company category is further sub-divided into a general, business strategy and investment sub-categories. Since PESTEL traditionally is an analytical tool to investigate a company's external factors this modification is a special case that was found necessary to not exclude these important data points.

The figure below illustrates the categories, sub-categories and sub-sub-categories and their relationship.

Figure 4.1: Categorisation, sub-categorisation and sub-sub-categorisation of the results.



4.2 Theoretical drivers and barriers for economic viability in the commercial space sector

Chapter 4.2 presents the theoretical drivers and barriers (factors) that were identified during the study of literature and interviews. The drivers and barriers are loosely connected to reality in a sense that they do not need to be observed to be listed. They are factors that would impact the commercial sector if they were found to be true or observed.

The data in this chapter is gathered in an effort to answer research question 1 (RQ 1): "What are the drivers and barriers that impact the economic viability of commercial space activities?"

4.2.1 *Number of drivers and barriers – identified through literature review*

As a part of the literature study all relevant factors with regards to the economic viability in the commercial sector were noted and categorized following the PESTEL acronym. The PESTEL factors were labelled as either drivers or barriers for the economic viability of the commercial space sector. Factors that were not suitable to be placed in either the driver or barrier category where ignored.

The process of codifying and categorizing the literature provides an opportunity for quantitative analysis: If certain categories are mentioned more often than others, it may be an important data point that could be investigated in more detail.

The following table provides the number of theoretical drivers and barriers that were made as a part of the literature study.

Table 4.1: Number of theoretical drivers and barriers for economic viability of commercial space activity, identified during literature review

Category	Drivers	Barriers
Political	16	11
Economic	26	16
Social	1	1
Technological	3	3
Environmental	2	2
Legal	6	6

4.2.2 *Theoretical drivers – Identified through literature review*

The following table lists theoretical factors that can be interpreted as drivers for economic viability for space activities. These drivers were identified through a literature review.

Table 4.2: Theoretical drivers for economic viability of commercial space activities identified through literature review

ID		Reference
	POLITICAL	
	International	
1.1	Rivalry between states based on prestige and national pride.	Weinzierl, 2018; Cahan & Sadat, 2021
1.2	Declaration of Space as critical infrastructure.	Cahan & Sadat, 2021

1.3	Developing the space economy as a part of long-term elements of national security	Cahan & Sadat, 2021
1.4	Private actors taking a prominent role in conducting space-based activities, independent of governments.	Vernile, 2018
1.5	Increased number of space-faring nations.	Vernile, 2018
	National	
1.6	Public investment in space.	Vernile, 2018
1.7	The combination of effective public strategies and favourable business conditions.	Vernile, 2018
1.8	Public policies that refine the market by addressing market failures and ensuring a healthy market structure.	Weinzierl, 2018
1.9	Predictable demand of space assets or services.	Cahan & Sadat, 2021
1.10	Stable and predictable funding and prioritisation of state space programs.	Weinzierl, 2018
1.11	Long-range economic policymaking ensuring transparency, clarity and coordinated cooperation.	Cahan & Sadat, 2021
1.12	Cancellation of costly space programs running over budget that risk over-shadowing other programs.	Weinzierl, 2018
1.13	Public-private partnerships.	Weinzierl, 2018
1.14	New public procurement schemes, such as award contracts, as opposed to cost-plus contracts.	Vernile, 2018
1.15	Effective collaboration between public and private actors.	Vernile, 2018
1.16	Exploration of new partnership schemes, such as award contracts.	Vernile, 2018
	ECONOMICAL	
	Market (external)	
2.1	In general, an increased market demand for space activities.	Vernile, 2018; Paladini, 2019
2.2	Cheaper access to space.	Paladini, 2019
2.3	A complete space solution that offers true complementaries.	Weinzierl, 2018
2.4	New entrants in the space market providing fresh solutions to problems and increased market demand.	Vernile, 2018; Paladini, 2019
2.5	Permissible economic environment.	Vernile, 2018
2.6	Access to robust updated business intelligence as to the competitive landscape.	Cahan & Sadat, 2021
2.7	Reduced launch costs through technological innovation in the private sector.	Lordos et al., 2019
2.8	Continued market demand for Commercial Observation Satellites	Paladini, 2019
2.9	New users and uses of Commercial Observation Satellites/ Earth Observation/Remote Sensing Satellites as reduced costs of satellites provides competition to traditional earth-based providers of similar services.	Paladini, 2019
2.10	Continued market demand for space tourism. Demand is expected to increase as cost of kg to orbit is reduced.	Paladini, 2019
2.11	Market demand for commercial space stations.	Paladini, 2019
2.12	Continued market demand for satellites.	Paladini, 2019

2.13	Reduction of the "entry barrier" for new entrants to the satellite market.	Paladini, 2019
2.14	A largely "privatised" satellite market.	Paladini, 2019
2.15	NASA ambitions for new purposes - space mining.	Paladini, 2019
2.16	Ambitions of multiple companies from multiple countries to utilise space for resource extraction.	Paladini, 2019
2.17	Increasing market demand for mass to space.	Paladini, 2019
2.18	Demand for non-polluting energy.	Paladini, 2019
	Company (internal)	
2.19	Full reusability of launch vehicles.	Weinzierl, 2018
2.20	Willingness to take financial risk in the private sector.	Partnerships to Advance the Business of Space, 2013; Cahan & Sadat, 2021
2.21	Efficient cost cutting and availability of new mass markets.	Vernile, 2018
2.22	Availability of outside investment in start-up new space firms.	Weinzierl, 2018
2.23	Private investments complementing the public spending by addressing short term industrial objectives and supporting start-up and scale-up phases.	Vernile, 2018
2.24	A substantial investment base.	Vernile, 2018
2.25	Financial market infrastructure that understands the space economy.	Cahan & Sadat, 2021
2.26	Financial equity and instruments that match the lifecycles typical for space activities.	Cahan & Sadat, 2021
	SOCIAL	
3.1	Leadership from highly esteemed space enthusiast tycoons.	Vernile, 2018; Weinzierl, 2018
	TECHNOLOGICAL	
4.1	Space transport solution that provides sufficiently safe space access.	Paladini, 2019
4.2	Space transport solution that provides low-cost space access.	Paladini, 2019
4.3	Technological achievements based on private initiatives.	Partnerships to Advance the Business of Space, 2013.
	ENVIRONMENTAL	
5.1	Commercial development that does not interfere with science needs, but accelerates scientific research.	Weinzierl, 2018
5.2	Reducing or mitigating the risk connected with space debris.	Weinzierl, 2018
	LEGAL	
6.1	Clear and permissive regulatory framework when it comes to property rights in space.	Weinzierl, 2018
6.2	Allow private companies to shape own design by cutting costs and increase economic viability through fixed price contracts or award programs.	Weinzierl, 2018

6.3	Ability of private firms to design and produce their own product without the oversight of NASA (as was the case with cost plus contracts).	Weinzierl, 2018
6.4	Retainment of intellectual property when moving away from cost plus contracts.	Weinzierl, 2018
6.5	Logical and uncomplex legal and regulatory requirements to space activities.	Cahan & Sadat, 2021
6.6	High regulatory responsiveness and agility with respect to space company needs.	Cahan & Sadat, 2021; Weinzierl, 2018

4.2.3 *Theoretical barriers – Identified through literature review*

The following table lists the theoretical factors that can be interpreted as barriers for economic viability for space activities. These barriers were identified through a literature review.

Table 4.3: Theoretical barriers for economic viability of commercial space activities identified through literature review

ID	Barriers	Reference
	POLITICAL	
	International	
1.1	A too tight connection between a country's space activities and need for national prestige and pride	Weinzierl, 2018
1.2	High dependency on government support for private actors.	Weinzierl, 2018
1.3	Low number of space-faring nations. Limited access to global expertise.	Vernile, 2018
	National	
	General	
1.4	Failed or inefficient public space programs leading to budget drains with an inadequate return.	Weinzierl, 2018
1.5	Lack of interagency commitment to coordinate space policies, planning, budgeting and program needs.	Cahan & Sadat, 2021
1.6	Uncertainty of governments future demand for space assets or service.	Cahan & Sadat, 2021
	Leadership/top level	
1.7	Lack of efforts to develop, fund and use space infrastructure	Cahan & Sadat, 2021
1.8	Frequent shifts in priorities and funding for state space programs.	Partnerships to Advance the Business of Space, 2013; Weinzierl, 2018
	Organisation	
1.9	Centralized model: Undermines progress on public and commercial priorities in space.	Weinzierl, 2018
	Private-state relationship	

1.10	Bureaucratic inefficiencies.	Partnerships to Advance the Business of Space, 2013.
1.11	Complex, siloed, opaque procurement practices to the private sector.	Cahan & Sadat, 2021
	ECONOMIC	
	Market (external)	
	General	
2.1	The "destination problem" outside of the earth orbit satellite market and ISS	Paladini, 2019
2.2	High cost of access to space, in general.	Paladini, 2019; Partnerships to Advance the Business of Space, 2013.
2.3	High costs of entry into the space market (entry barrier).	Paladini, 2019
2.4	Market failure 1: Lack of complementaries. A space economy is only viable when the sum of all the parts are functioning. I.e.: Cheap launch, scalable habitat, protection from debris and radiation. Only a cheap launcher leads to a destination problem and is dependent on a scalable habitat. A scalable habitat is not possible without adequate protection and not economical without a cheap launcher.	Weinzierl, 2018
2.5	Market fragmentation.	Vernile, 2018
2.6	Low demand in the market, especially outside of the satellite market.	Vernile, 2018; Paladini, 2019
2.7	Lack of access to business intelligence or insight into competitive landscape	Cahan & Sadat, 2021
2.8	Questions of commercial economic viability not convincingly addressed.	Lordos et al., 2019
2.9	High risk level of space activates: 1. Risks to income (fluctuating market demand, lack of complementaries, scaling risks, profitability risks due market inflation, profitability risk due to emerging technologies etc.) 2. Risks to costs (technological immaturity, transportation risks, risk to scalability, known and unknown effects of long-term exposure to space, external factors such as space debris etc.)	Weinzierl, 2018; Paladini, 2019
	Company (internal)	
	General	
2.10	Centralized model: Weak incentives for the efficient allocation of resources, poor aggregation of dispersed information	Weinzierl, 2018
	Business strategy	
2.11	Long payback-time of investments	Partnerships to Advance the Business of Space, 2013.
2.12	High costs of entry into the space market	Paladini, 2019
	Investment/financing	Paladini, 2019

2.13	Lack of availability of investors in a start-up phase for new space firms.	Paladini, 2019
2.14	Lack of availability of private investors to space companies.	Paladini, 2019
2.15	Impersistent availability of financing and financing that does not understand the space economy.	Cahan & Sadat, 2021
2.16	Venture capital ill-suited for the relatively high risk and long payback periods of current space products.	Cahan & Sadat, 2021
	SOCIAL	
3.1	Lack of interest in space from public figures and the general public.	Vernile, 2018; Weinzierl, 2018
	TECHNOLOGICAL	
4.1	Risk of loss of personnel and equipment during space launch.	Paladini, 2019
4.2	Cost of access to space.	Paladini, 2019
4.3	Centralized model: Resistance to innovation due to lack of competition	Weinzierl, 2018
	ENVIRONMENTAL	
5.1	The risk of space debris impacts.	Paladini, 2019
5.2	Harmful Space weather	Paladini, 2019
	LEGAL	
6.1	Unclear legal framework when it comes to property rights in space.	Weinzierl, 2018
6.2	Heightened risk for private firms when moving from cost plus contracts.	Weinzierl, 2018
6.3	Process of attaining vehicle type and production certification.	Partnerships to Advance the Business of Space, 2013.
6.4	Cost plus contracts that moved the intellectual property rights away from the private firm to NASA.	Weinzierl, 2018
6.5	High complexity of legal and regulatory requirements.	Cahan & Sadat, 2021
6.6	High complexity of regulatory compliance & oversight.	Cahan & Sadat, 2021

4.2.4 *Number of drivers and barriers - identified through interviews*

The following table provides the number of theoretical drivers and barriers for economic viability in space in total that were identified through interviews.

Table 4.4: Number of theoretical drivers and barriers for economic viability of commercial space activities, identified through interviews

Category	Drivers	Barriers
Political	17	13
Economical	15	16
Social	1	1

Technological	1	1
Environmental	0	0
Legal	1	0

4.2.5 *Theoretical drivers – Identified through interviews*

The following table lists the theoretical drivers for economic viability of space activities that were identified through interviews.

Table 4.5: Theoretical drivers for economic viability of commercial space activities identified through interviews

ID	Drivers	Reference
	POLITICAL	
	International	
1.1	Increased stake of private actors in space	Source 1
1.2	High international interest for space mining from both state and private actors.	Source 1
1.3	ESA geographical return arrangements: Resources states contribute towards space feeds back into the national economy.	Source 1; Source 2
	National	
1.4	Synergies between private and state actors for growth of commercial space activities.	Source 1
1.5	State desire, encouragement and backing for private companies to partake in space activities.	Source 1
1.6	State sponsored surveys of companies that investigate the relevancy of in-country businesses for space activities.	Source 1
1.7	Increased state spending on space projects.	Source 1
1.8	Access to initial contracts through public or defence sector	Source 2
1.9	Cooperation between industry and research institutions such as universities to bring fresh solutions to problems.	Source 2
1.10	Attainment of national security contracts.	Source 2
1.11	Acquisition of defence contract that provide a stable and predictable customer after initial phases of development	Source 2
1.12	Geo-return mechanisms of state contributions to ESA that encourage and force a growth of Norwegian space sector	Source 1; Source 2
1.13	A proactive government agency that acts as a coordinating body between ESA and Norwegian industry and service providers	Source 2
1.14	Public programs for initial feasibility studies to enable companies to take an initial step into the space sector.	Source 2
1.15	Access to funds for initial feasibility studies	Source 2
1.16	Access to "first flight" opportunities	Source 2
1.17	Political interest in and motivation to increase the Norwegian space sector.	Source 2
	ECONOMICAL	

	Market (external)	
2.1	A space market that is large enough to sustain private companies without substantial support from state actors.	Source 1
2.2	Access to space contracts that are both predictable and recurring, permitting a strategic investment in space.	Source 1; Source 2
2.3	Leasing opportunities onboard space infrastructure providing a) for the owner, a source of income and b) for the tenant, a low entry barrier solution for research or other purposes.	Source 1
2.4	Increased access to satellite data increases downstream commercial activity.	Source 1
2.5	Lower entry barrier to space as a result of a) reduced cost of launch of mass to orbit, b) higher use of off-the-shelf-technology, c) reduced cost of mission due to use of equipment with a lower specification.	Source 1
2.6	Reduced launch costs that permit smaller projects to be launched, lowering the entry barrier and fewer compromises within involved projects.	Source 2
2.7	Contracts and demand that allows for a high-volume sale of the same product. Series of delivery.	Source 2
2.8	Access to "first flight" opportunities.	Source 2
	Company (internal)	
2.9	Space spin-off: A developed product for earth-based use, may need only minor adjustments to reach space requirements. The company gains access to new markets through minimal efforts. In return company can achieve synergies of space activities making a stronger product overall and a stronger company.	Source 1
2.10	Space synergies: Fulfilling a contract to a space grade specification can lead to stronger and enhanced products both in the space- and earth segment. The end result is a stronger product and a stronger company.	Source 1
2.11	Sale of services based on previous R&D (that counteract the drain of further R&D efforts and enables further growth of the company's portfolio).	Source 2
2.12	Developing a product where demand is recurring in nature, broadening the market both with respect to width and length (time).	Source 2
2.13	Ability to extract synergies through adaptations of existing products.	Source 2
2.14	Core products that can be reused for multiple purposes by building on the core technology using a modular design philosophy and adjusting for new purposes and environments.	Source 2
2.15	Gaining the IPR (intellectual property rights) part of the value chain.	Source 2
	SOCIAL	
3.1	Access to personnel with the right skills. Particularly product developers with a technological understanding with an ability to adapt.	Source 2
	TECHNOLOGICAL	
4.1	A generic core technology that allows for reuse both for earth and space-based purposes and environments. This increases the probability of spin-off and spin-in effects, increases the ease of manufacturing and economies of scale.	Source 2
	ENVIRONMENTAL	
	LEGAL	
6.1	New opportunities for income by nations ratifying the Artemis accords.	Source 1

4.2.6 *Theoretical barriers – Identified through interviews*

The following table lists the theoretical barriers for economic viability of space activities that were identified through interviews.

Table 4.6: Theoretical barriers for economic viability of commercial space activities identified through interviews

ID	Barriers	Reference
	POLITICAL	
	International	
1.1	For states that do not have a developed space industry: State investment in space diverts resources out of country, without a geo-return arrangement.	Source 1
	National	
1.2	High degree of dependency upon state agencies for initiation of space activities.	Source 1
1.3	Lack of state desire, encouragement and backing for private companies to partake in space activities.	Source 1
1.4	Lack of knowledge of national businesses that potentially could be relevant for the development of space industry and services.	Source 1
1.5	Decreased state spending on space projects.	Source 1
1.6	Lack of means to attain initial funding for feasibility studies.	Source 2
1.7	Lack of means to attain cooperation with relevant research institutes.	Source 2
1.8	Lack of means to attain national security contracts.	Source 2
1.9	For states with an underdeveloped space sector: Without an arrangement for geo-return, much of the space investments would end up outside of the national economy.	Source 1; Source 2
1.10	Difficulties connected to the coordination between ESA and the national businesses. The businesses would not know of the contracts, and the ESA would not know what businesses are relevant without a coordinating body at the state level.	Source 2
1.11	Lack of interest and funding for feasibility studies from the public sector.	Source 2
1.12	Lack of opportunities for "first flight". Equipment must fly to be "flight proven".	Source 2
1.13	Lack of political interest in and motivation to increase the Norwegian space sector.	Source 2
	ECONOMICAL	
	Market (external)	
2.1	The space market is too small and unpredictable for Norwegian companies to base their business model on space activities alone	Source 1
2.2	Lack of recurring contracts in the market. Most of the contracts are related to a single project or delivery on a one-time basis.	Source 1
2.3	Deliveries to space contracts are often substantial and heavy for the companies to carry and have long payback periods.	Source 1
2.4	High entry barrier for space infrastructure.	Source 1

2.5	The "first flight" barrier. Things must have flown and been used in space to be attractive for use in space. This creates a "chicken or the egg" challenge.	Source 2
2.6	Fluctuating cost of currencies, raw materials and components.	Source 2
2.7	Unpredictable and long delivery times of components	Source 2
	Company (internal)	
2.8	High entry costs	Source 1
2.9	Costly projects and long payback periods	Source 1
2.10	Private companies with a short-term focus are an ill fit for the current space business model.	Source 1
2.11	R&D is cyclical in nature creating a cyclical need for investments.	Source 2
2.12	The challenge of creating a product that better or cheaper than that of competitors.	Source 2
2.13	The challenge of identifying market segments that allow for spin-off effects and synergies of already developed hardware or software.	Source 2
2.14	The challenge of identifying market segments that allow for a modular design that can be used for multiple purposes by draining little to no further R&D costs.	Source 2
2.15	The challenge of identifying market segments that enable high volume production of the same product.	Source 2
2.16	Inability to retain the IPR of the developed product.	Source 2
	SOCIAL	
3.1	Lack of personnel with the right skillset. Mainly product developers with a technological understanding and ability to adapt.	Source 2
	TECHNOLOGICAL	
4.1	The challenge of creating a generic core technology that allows for reuse both for earth and space-based purposes and environments.	Source 2
	ENVIRONMENTAL	
	LEGAL	

4.3 Main historical events toward economic viability for the space economy

This chapter lists the identified historical events that were assessed to have made an impact on the economic viability of the commercial space sector. By examining the past, the expectation is that we will be better able to understand the present and the mechanisms that played a part to bring us to status-quo. The data in this chapter is gathered in an effort to answer research question 2 (RQ 2): “What have been the historical events on the path toward a viable space economy?”

4.3.1 *Historical drivers – Identified through literature review*

The following table lists the historical drivers for economic viability of the commercial space sector that were found to have made an impact in some way. The drivers were identified through a literature review.

Table 4.7: Historical drivers for economic viability of commercial space activities identified through literature review

ID	Drivers	Reference
	POLITICAL	
	International	
1.1	Rivalry between superpowers such as USA and USSR, international prestige	Weinzierl, 2018; Cahan & Sadat, 2021
1.2	China's belt and road initiative, space information initiative and digital silk road.	Cahan & Sadat, 2021
1.3	US national pride: The embarrassment of not having a way to transport humans to space after the space shuttle retirement.	Weinzierl, 2018
	National	
	General	
1.4	The termination of the space shuttle.	Weinzierl, 2018
	Leadership/top level	
1.5	Reagan signing the Commercial Space Launch Act in 1984	Weinzierl, 2018
1.6	Cancellation of the Constellation program, due to overrunning budgets, increasing the importance of COTS	Weinzierl, 2018
	Organisation	
1.7	From a centralized (apollo, space shuttle) to a de-centralized model (2004).	Weinzierl, 2018
	Private-state relationship	
1.8	Development of the commercial satellite market by a de-centralized approach.	Weinzierl, 2018
1.9	NASA's relationship with commercial providers had shifted from contingency to dependency.	Weinzierl, 2018
1.10	Public-private partnerships, COTS (commercial Orbital Transport Services) 2005-, provided and maintained a competitive market structure through a diversified set of award contracts.	Vernile, 2018
1.11	Commercial Crew Development. Competitive market through awards of contracts.	Weinzierl, 2018
1.12	NASA transition and authorization act, 2017	Weinzierl, 2018
1.13	Next step & next step 2	Weinzierl, 2018
	ECONOMIC	
	Market (external)	
2.1	Reduction of costs to insert satellites to earth orbit.	Weinzierl, 2018
	SOCIAL	
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	
6.1	Commercial Space Launch Competitiveness Act, 2015. grants property rights to the resource for whoever "gets there first"	Weinzierl, 2018
6.2	Fixed priced contracts for the CRS missions	Weinzierl, 2018

6.3	New space welcomed the move away from cost plus contracts, investors were comfortable with the heightened risk as innovation and efficiency were their advantage over established players	Weinzierl, 2018

4.3.2 *Historical barriers – Identified through literature review*

The following table lists the historical barriers for economic viability of the commercial space sector that were found to have made an impact in some way. The barriers were identified through a literature review.

Table 4.8: Historical barriers for economic viability of commercial space activities identified through literature review

ID	Barriers	Reference
	POLITICAL	
	International	
1.1	The tight connection with the Apollo program and the competition with the Soviet Union made NASA budget vulnerable to budget cuts as the mission was sensed to be accomplished	Weinzierl, 2018
	National	
	General	
1.2	The failure of the Space Shuttle program.	Weinzierl, 2018
1.3	(US) Lack of long-range perspective regarding planning, funding, coordination, sustainability and implementation of space efforts. Leadership/top level	Cahan & Sadat, 2021
1.4	Frequent and drastic revisions of NASA funding and priorities.	Weinzierl, 2018
	ECONOMIC	
	SOCIAL	
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	

4.3.3 *Historical drivers – Identified through interviews*

The following table lists the historical drivers for economic viability of the commercial space sector that were found to have made an impact in some way. The drivers were identified through conducting interviews.

Table 4.9: Historical drivers for economic viability of commercial space activities identified through interviews

ID	Drivers	Reference
	POLITICAL	

	International	
1.1	The assistance from Norwegian Space Agency to identify attractive ESA contracts was instrumental for the decision to increase space segment efforts for the company.	Source 2
1.2	The geo-return mechanisms of state contributions to ESA created a demand for a Norwegian space industry that in turn forced the growth of the Norwegian space sector.	Source 2
	National	
1.3	Initial ESA contract acquired in 2013 to manufacture hardware for use in space	Source 2
1.4	Collaborated with local university, and science communities to develop technology.	Source 2
1.5	Cooperation with Norwegian Armed Forces was instrumental for the decision to increase space efforts for the company.	Source 2
1.6	A contract with the Norwegian Armed Forces led to an expansion of the space efforts for the company.	Source 2
1.7	Norwegian Armed Forces contract: Strict requirements for national control of component production drove further expansion of space efforts for the company.	Source 2
1.8	The Norwegian Space Agency provided funds for initial feasibility studies of technology that in turn allowed the company to compete for ESA contracts. After the product has flown it is "flight proven" which opens up commercial opportunities for the company.	Source 2
	ECONOMIC	
	Market (external)	
2.1	The New Space wave has allowed the projects to grow smaller, but more frequent, and it lowered the barrier for entry into the field for the company. Also, it allowed a higher degree of tailoring of the flight profile as fewer compromises had to be made with the ride sharers.	Source 2
2.2	New Space and cube satellites contribute to lowering the barrier for first flight for the company.	Source 2
2.3	If was not for Norwegian Space Agency and ESA, the company assesses that it would never be part of the space sector. It would most likely not have been able to enter the market.	Source 2
2.4	The tele broadcasting and satcom sectors are the largest parts of the Norwegian space sector.	Source 1
2.5	Norway has strong SATCOM traditions.	Source 1
	Company (internal)	
2.6	The company has a core technology that remains unchanged, but it can be built on and adjusted for multiple purposes using a modular design philosophy. Enabling flexibility for future needs.	Source 2
2.7	Access to funds was sufficient for the company in general and was not seen as the bottle neck for the growth of the company.	Source 2
	SOCIAL	
	TECHNOLOGICAL	
4.1	New Space provides cheaper and new frequent launches and thereby broadening the market. It also allows companies to make fewer compromises, such as choice of orbit altitude and inclination.	Source 2
	ENVIRONMENTAL	

	LEGAL	
6.1	Fixed contracts allowed the company to focus on cost cutting and increasing profitability.	Source 2

4.3.4 *Historical barriers – Identified through interviews*

The following table lists the historical barriers for economic viability of the commercial space sector that were found to have made an impact in some way. The barriers were identified through conducting interviews.

Table 4.10: Historical barriers for economic viability of commercial space activities identified through interviews

ID	Barriers	Reference
	POLITICAL	
	ECONOMIC	
	Market (external)	
2.1	The market situation is conceived as government driven at this point in time, with very little purely commercial competition at this point. The company focuses on acquiring enough human competency to be awarded state contracts (ESA and Norwegian Armed Forces).	Source 2
	SOCIAL	
3.1	Lack of personnel with the right skillset. The company needs developers. Personnel that understand hardware and software and their interactions with a graphical interface. Typically, engineers with bachelor, master, PhD. People with a technological understanding and ability to adapt.	Source 2
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	

4.4 Trends toward economic viability for the space economy

This chapter lists the identified trends with regards to economic viability that were identified through literature review and conducting interviews. As opposed to the factors listed in chapter 4.2, this chapter aims to uncover what factors are currently in play and actually make an impact in the commercial space sector today.

The data in this chapter is gathered to answer research question 3 (RQ 3): “What are the trends towards an economic viable commercial space economy?”

4.4.1 *Trending drivers – Identified through literature review*

The following table lists the drivers for economic viability of the commercial space sector that were found to be currently making an impact in some way. The trends were identified through literature review.

Table 4.11: Current trending drivers for economic viability of commercial space activities identified through literature review

ID	Drivers	Reference
	POLITICAL	
	International	
1.1	Increasing possibilities of rivalry between US/ESA and China for space superiority. Increasing number (quantity) of states with a space capability. Increasing ability (quality) of states with regards to space capabilities.	Cahan & Sadat, 2021; Paladini, 2019
1.2	More prominent role of private actors pursuing goal of conducting space business independently of governments	Vernile, 2018
1.3	Increasing number of space-faring nations	Vernile, 2018
1.4	Increasing cooperation between space agencies both on a national and international level	Paladini, 2019
	National	
	General	
1.5	Innovative public procurement and support schemes.	Vernile, 2018
	Leadership/top level	
1.6	NASA has returned to its core mission of research and development, and technology demonstration. NASA is now looking to the commercial Spaceflight industry for vital services.	Partnerships to Advance the Business of Space, 2013
	Organisation	
1.7	Gradual increase in trust of private companies.	Weinzierl, 2018
	Private-state relationship	
1.8	NASA maintaining a competitive market through the award of diversified contracts.	Weinzierl, 2018
1.9	Loosening agencies top-down control over industrial processes.	Weinzierl, 2018
1.10	A challenging of the traditional dynamic for space companies.	Weinzierl, 2018; Vernile, 2018
	ECONOMIC	
	Market (external)	
	General	
2.1	Increased market demand for space activities.	Vernile, 2018
2.2	Multiple service providers are ready to provide space services, but are waiting for a suitable transport solution (risk, cost and technology).	Paladini, 2019
2.3	NASA is moving from the role of a supervisor (old space) to the role of customer and partner in new space	Weinzierl, 2018

2.4	Disruptive, commercially driven schemes	Vernile, 2018
2.5	New entrants in the space sector, including non-space companies (such as google, Facebook, internet communications technology).	Vernile, 2018
2.6	Disruptive market solutions.	Vernile, 2018
2.7	New industry verticals and space markets targeting new space applications.	Vernile, 2018
2.8	Reduced launch costs provided by innovation in the private sector.	Weinzierl, 2018
	Space tourism	
2.11	Increased commercial interest for the space tourism segment.	Paladini, 2019
	Space stations	
2.12	Increased private interest for private space station and space hotels. Multiple companies with concrete plans and timelines for building a space station (i.e. Axiom in LEO and Orbital ATK in LUO)	Paladini, 2019
	Satellite market	
2.9	Cost reductions for launch in general and continued market demand for Commercial Observation Satellites.	Paladini, 2019
2.10	Number of Commercial Observation Satellites on the rise	Paladini, 2019
2.13	Reduction of costs to insert satellites to earth orbit.	
2.14	Small satellites and cube satellites enable more numerous launches, less compromises between customers and a lower barrier for entry.	Paladini, 2019
2.15	Private dominance in the satellite market, substantial growth expected in small sat constellation market.	Weinzierl, 2018
	Space mining	
2.16	Space mining. NASA has concrete ambitions/plans for the initial phases of space mining. Still at an early stage.	Paladini, 2019
	Launch market	
	Company (internal)	
	General	
2.17	New space approach involves enormous risk (for the private firms, but also) potential returns	Weinzierl, 2018
	Business strategy	
2.19	Innovative industrial approaches, aimed at cutting costs or address new mass markets.	Vernile, 2018
	Investment/financing	
2.20	Increasing outside investment in start-up new space firms (500mn/y in 2001-2008, 2.5bn/y in 2015-2016)	Weinzierl, 2018
2.21	Substantial private investments	Vernile, 2018
2.22	Increased willingness from private actors to take financial risk in the commercial space sector	Partnerships to Advance the Business of Space, 2013; Weinzierl, 2018
	SOCIAL	
3.1	Public engagement and involvement on the rise among the general public	Paladini, 2019
3.2	The rise of private actors in the space segment is finding place in US and Europe	Paladini, 2019

	TECHNOLOGICAL	
4.1	Commercial drive to work towards partial or full re-usability of launch vehicles	Weinzierl, 2018
4.2	Recent technological accomplishments in the commercial sector	Partnerships to Advance the Business of Space, 2013
	ENVIRONMENTAL	
	LEGAL	
6.1	New space is moving away from cost plus contracts, new space is willing to do this due to the potential of large returns	Weinzierl, 2018

4.4.2 *Trending barriers – Identified through literature review*

The following table lists the barriers for economic viability of the commercial space sector that were found to be currently making an impact in some way. The trends were identified through literature review.

Table 4.12: Current trending barriers of economic viability of commercial space activities identified through literature review

ID	Barriers	Reference
	POLITICAL	
	International	
	National	
1.1	Continued financing of problematic space programs (such as STS)	Weinzierl, 2018
1.2	Financial engineering of US space that is unaddressed or omitted from public economics and policymaking.	Cahan & Sadat, 2021
1.3	Frequent and drastic revisions of NASA funding and priorities.	Weinzierl, 2018; Partnerships to Advance the Business of Space, 2013
	ECONOMIC	
	Market (external)	
2.1	Relatively low market demand outside of the earth orbit satellite market.	Vernile, 2018
2.2	Market failure 1: Lack of complementaries. A space economy is only viable when the sum of all the parts are functioning. I.e.: Cheap launch, scalable habitat, protection from debris and radiation. Only a cheap launcher leads to a destination problem and is dependent on a scalable habitat. A scalable habitat is not possible without adequate protection and not economical without a cheap launcher.	Weinzierl, 2018
2.3	Questions of commercial viability not convincingly addressed	Lordos et al., 2019
	Company (internal)	
2.4	New space approach involves enormous risk for the private firms, (but also potential returns)	Lordos et al., 2019

2.5	Venture capital ill-suited for the relatively high risk and long payback periods of current space products	Cahan & Sadat, 2021; Partnerships to Advance the Business of Space, 2013.
	SOCIAL	
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	
6.1	Unclear legal framework when it comes to property rights in space	Weinzierl, 2018

4.4.3 *Trending drivers – Identified through interviews*

The following table lists the drivers for economic viability of the commercial space sector that were found to be currently making an impact in some way. The trends were identified through conducting interviews.

Table 4.13: Current trending drivers of economic viability of commercial space activities identified through interviews

ID	Drivers	Reference
	POLITICAL	
	International	
1.1	A proactive Norwegian Space Agency that aids in identifying attractive and suitable ESA contracts.	Source 2
1.2	Geo-return mechanisms of state contributions to ESA ensures demand of delivery from Norwegian space industry.	Source 2
1.3	NASA and ESA are gradually moving focus from LEO to Moon, Mars and beyond. LEO activity is increasingly handled by private actors (i.e. ISS sunset). This time the intention is to form a permanent lunar research settlement.	Source 1
1.4	There is a high interest for space resource extraction internationally on both a state and private level.	Source 1
1.5	ESA is looking into establishing a base on the Moon and are announcing possibilities for contracts in this respect.	Source 1
1.6	ESA operates with a geographical return principal. This means that the majority of the public spending utilized this way gets fed back to the Norwegian economy.	Source 1
	National	
1.7	For this company a defence contract drives expansion of space efforts, after an initial product has been made through ESA contracts.	Source 2
1.8	The NSA is pro-actively aiding commercial space activities.	Source 1
1.9	There is a desire from Norwegian state to encourage companies to partake in in-space activities.	Source 1
1.10	Norway is surveying the geo technical field to identify possible Norwegian partners relevant for ISRU on the moon.	Source 1
1.11	Increased state spending on space projects in Norway leads to a secondary spin-off effect for private companies, especially for upstream space.	Source 1
	ECONOMIC	
	Market (external)	

2.1	Private companies increasingly define their own missions independent of being reactive to government contracts. This is a trend that is also seen in Norway.	Source 1
2.2	Increasing number of concrete plans related to space activities within the private sector.	Source 1
2.3	Downstream space services based on data produced in space is on the rise.	Source 1
2.4	Private companies are increasingly providing infrastructure for rent for research or other purposes (such as research racks in ISS or research panels outside ISS).	Source 1
2.5	There is increased interest from companies that are looking for creating a business based on space-for-space activities.	Source 1
2.6	Increased access to satellite data (sometimes for free) is a driver for space commerce.	Source 1
2.7	The new space wave has also had an impact on the Norwegian sector: Reduced launch costs, use of off-the-shelf-technology, use of equipment that is spec'd for shorter duration space flight has led to the possibilities for more actors to launch satellites (i.e. Norwegian University of Science and Technology, Norwegian Armed Forces, Norwegian Space Agency).	Source 1
	Company (internal)	
2.8	Achieving synergetic effects are important for economic viability for Norwegian businesses conducting space activities.	Source 1; Source 2
	SOCIAL	
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	
6.1	Multiple countries are moving beyond the outer space treaty and are signing the Artemis accords.	Source 1

4.4.4 *Trending barriers – Identified through interviews*

The following table lists the barriers for economic viability of the commercial space sector that were found to be currently making an impact in some way. The trends were identified through conducting interviews.

Table 4.14: Current trending barriers of economic viability of commercial space activities identified through interviews

ID	Barriers	Reference
	POLITICAL	
	International	
	National	
1.1	No or few private companies in Norway has space as their only business domain.	Source 1
1.2	The Norwegian private sector is to a considerable extent dependant on state support to stimulate growth of the space sector.	Source 1
	ECONOMIC	
	Market (external)	
2.1	The size of European space budgets is small as compared to NASA (7%) and are dependent on international cooperation.	Source 1

	Company (internal)	
	SOCIAL	
	TECHNOLOGICAL	
	ENVIRONMENTAL	
	LEGAL	

4.5 Strengths, weaknesses, opportunities and threats for Norwegian space companies

This chapter lists the identified strengths, weaknesses, opportunities and threats that were identified to apply for Norwegian space companies through interviews with source 1 and source 2 (see chapter 3.5 for details).

The data in chapter 4.5 was gathered to answer research question 4 (RQ 4): "What are the strengths, weaknesses, opportunities and threats for a Norwegian company intending to perform commercial activities in space?"

Table 4.15: Strengths, weaknesses, opportunities and threats for Norwegian space companies, identified through interviews

ID	STRENGTHS
1.1	Strong cooperation with research institutions.
1.2	The company has been clear in its communication about what the company wants to achieve and for what it is suitable.
1.3	Flexibility and customer satisfaction
1.4	The company has a developed a technological platform on which it can sell services and continue development. The company has passed the initial barrier of entry into the space sector.
	WEAKNESSES
2.1	The relatively small size of the company does not allow it to grow fast, but at a steady pace.
2.2	It is not possible for the company to capitalize on all identified opportunities due to small size and lack of personnel.
2.3	Lack of resources, mainly personnel
	OPPURTUNITIES
3.1	Access to funds for feasibility studies of new project ideas.
3.2	The company found that the access to public funds (følgemidler) for feasibility studies in an initial phase of projects to be particularly useful to test and evaluate new project ideas.
3.3	The opportunity for rapid low level initial testing of feasibility of project ideas. Relatively easy access to funds for feasibility studies
3.4	Knowledge and experience acquired through earlier space projects, represented an opportunity for the company to build on, part of business strategy since 2018
3.5	First flight opportunities through ESA or Norwegian Armed Forces contracts
3.6	New markets through the maturation of the space sector

3.7	As space technology matures a "space solution" to a problem will be increasingly competitive and at some point, surpass an "earth based" solution to a problem. In some sectors this has already happened, such as global navigation, earth monitoring. This tendency will continue to increase.
3.8	Building satellites under national control of the entire value chain for defence contracts
3.9	Cooperation with national launch site providers
3.10	Increased state interest in the space sector
3.11	The Norwegian space sector is small. For this reason, it should be relatively easy to align interests and act unified within Norwegian borders
	THREATS
4.1	Lack of "first flight" opportunities
4.2	Lack of cost control in projects, meeting the spec and not exceeding it as it is increases cost and decreases profitability.
4.3	Small market based on state contracts: ESA and Norwegian Armed Forces
4.4	The Norwegian space industry is poorly organised as an ecosystem, the national industry should be more aligned in competition with foreign space companies
4.5	A conflict of interest: The state wants to achieve some competition within the national space sector, but the space companies want national alignment in competition with foreign actors
4.6	Reduced financing of ESA and Norwegian Space Agency
4.7	Lack of personnel and components

4.6 Summary of empirical data

Chapter four contains the data from the literature review and the interviews. The data was presented in accordance with research questions 1-4. The data was also presented in such a way that it should be easy to distinguish from where the data was sourced: Literature review or interviews. The aggregated data is what constitutes the input to the data analysis and the research discussion is based on the data analysis. The research discussion will be presented in the next chapter.

5.0 Research discussion

5.1 Background for the research discussion

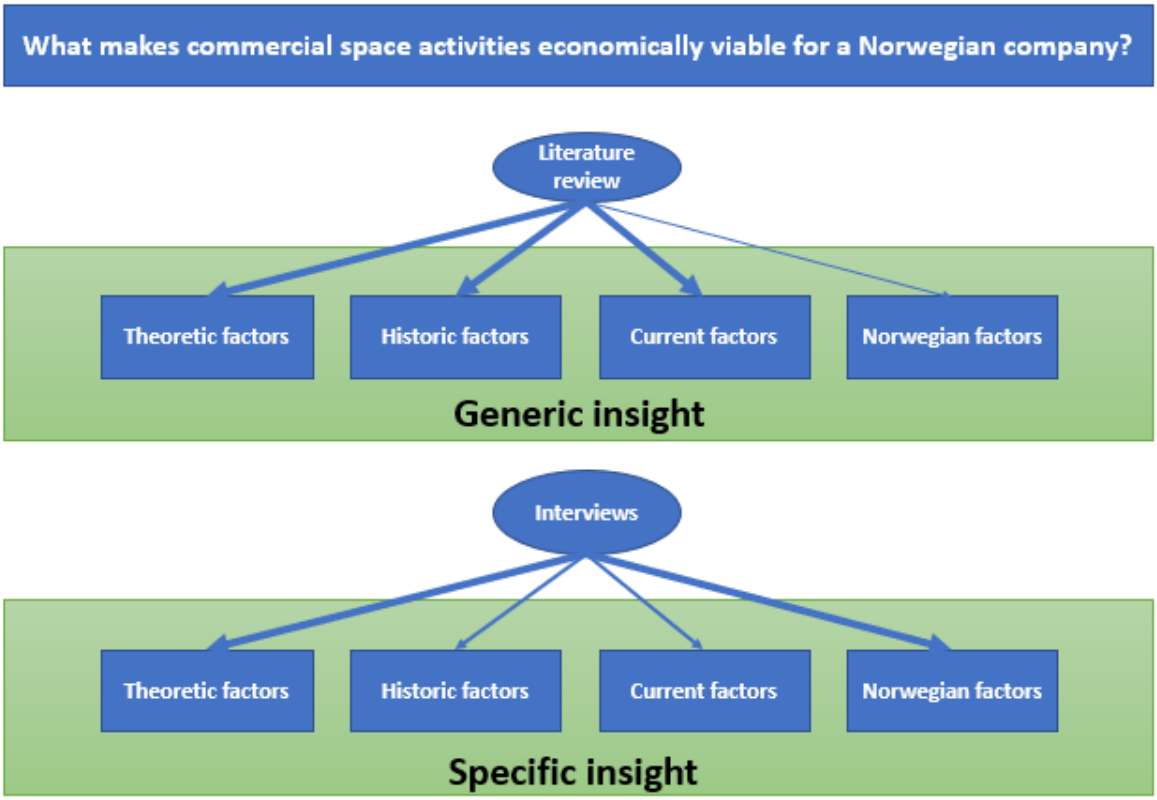
The main aim of this thesis has been to examine what makes commercial space activities economically viable for Norwegian companies. This chapter is divided into two parts, part one will discuss the data in general by going through the PESTEL categories chronologically based on the empirical data from chapter four. Part two of this chapter will address the research questions (RQ 1-4) specifically and chronologically.

Although there is plenty of literature on space activities in general, little exists concerning the Norwegian commercial space sector specifically. The best way to answer the research questions was assessed to base the thesis on two pillars: The available literature and the interviews. The available literature on the subject of the commercial space sector provides an understanding of how the mechanisms work in general in a democratic country with a free market economy. Much of this information is generic and for this reason the insight can be transferred across the borders within the western world, Norway included. Most of the literature that has been written on the subject comes from the US and covers the situation found in the US. The many similarities between Norway and the US makes this literature a relevant source to understand how the Norwegian space sector works as well. However, there are also a number of differences. The US space sector is large compared to Norway's modest space endeavours and the US space sector is further along in its development with numerous space programs and substantial space industry. It is unlikely that Norwegian public spending on space ever will reach the US$48 billion (2018) that the US is currently budgeting for state spending in space (Federal Aviation Administration [FAA], 2018). It is, however, both possible and likely that the Norwegian space segment will grow and mature in the future. In this respect the US space sector provides an insight into a potential future direction, even for the modest Norwegian space sectors.

The interviews provided specific insight into how the informers assess the current status of the Norwegian commercial space sector. As opposed to the generic insight provided by the literature, the interviews apply to the situation of the informers and may not be transferrable to other situations and countries to the same extent as with the literature.

Summarised what the study of literature can provide is an understanding of the commercial space sector in general. It can help to understand the mechanisms that impact economic viability for companies within the western hemisphere generically speaking. The interviews, however, are too narrow both with respect to the number of interviews and selection of informers to be able to provide generic knowledge and extensive transferability. They do, however, provide specific insight to the mechanisms that impact Norwegian companies' search for economic viability specifically. The figure below illustrates the distinction between generic and specific insight and the author's assessment of how these are sourced.

Figure 5.1: Distinction between generic and specific insight for this thesis, and how capable the sources are at providing insight into each research question (illustrated by strength of arrow)



5.2 Research discussion PART ONE: PESTEL

Part one of the research discussion will be covering the main findings from the results in the previous chapter by going chronologically through each PESTEL category. The research discussion is organised in such a way that it goes through the PESTEL categories chronologically. Each of the PESTEL categories will contain elements of theoretical, historical and trending factors. Only the most significant findings will be discussed.

5.3 Political impact on economic viability

The political factors appear to have a substantial impact on the economic viability for companies with a footprint in space. Together with the economical category this category had the highest number of identified factors across all research questions (table 4.1 & 4.4). Let us look at why and how political factors affect economic viability.

5.3.1 *International level political impact*

International level of impact amounts to factors, trends and historical events that occur at an "above the state" level. This can be considerations between states (bi-lateral, multi-lateral) or between a state and a multi-national organisation such as ESA.

5.3.1.1 Role of ESA

In the interviews the importance that ESA has for the Norwegian commercial space sector was emphasised by both (source 1) & (source 2). ESA is funded by the ESA member countries and the ESA mission is to increase European space capability (ESA, 2007). Of special importance was the ESA mechanism of geographical return (geo-return). (Source 1) explained that it is the aim of ESA to reciprocate the same amount that each member state contributes toward ESA back to the member state. ESA does this by awarding contracts, of a comparable size as the original contribution, back to companies of the respective member state.

The geo-return mechanism of ESA ensures that the majority of public spending to ESA finds its way back to the Norwegian economy. Based on this fact it can be argued that the geo-return mechanism of ESA in fact functions as a political tool to stimulate growth of Norwegian space capabilities. And further, from a political standpoint, that the geo-return mechanism ensures that public spending to ESA can be easily justified to the Norwegian public, as the majority of the resources spent flow back into the national economy.

In an interview with (source 2) he stated that in his company's case, the company would not have entered the commercial space sector was it not for the initial contracts awarded by ESA. For the company ESA was a clear driving factor for economic viability of the company's space efforts. This had been true in the initial phase of product development or the company's entry phase into the commercial space sector. This had also been true in the follow-on/growth phase of the company and the informer assessed that the company would be dependant of ESA and/or national security contracts in the future if economic viability was to be ensured.

In general ESA appears to be a clear driving factor for economic viability for Norwegian companies in all phases of company development. It appeared to be instrumental in the market entry/start-up phase, and crucial in the follow-on/growth phase and the sustainment/operations phase.

Even though ESA appears to be a clear positive force for the growth and sustainment of commercial space sector, we should also be mindful of the potential negative consequences such as market dependency of public spending (will partly be covered in following chapter). Another potentially negative consequence is that, in those cases where companies are unable to secure an ESA contract, this in itself could represent a barrier for economic viability for the company, since ESA makes up such a large portion of the European market and the market's relatively immaturity.

This chapter was in reference to table 4.5: 1.3, 1.12; table 4.6: 1.9, 1.10; table 4.9: 1.1, 1.2, 1.3; table 4.11: 1.4; table 4.13: 1.2, 1.3, 1.5, 1.6.

5.3.1.2 Markets independent of governments

Historically public and defence funding has been crucial for the development of the commercial space sector. The high risks to economic viability were carried by the state when space travel was too immature for commercial actors to be willing or able to bear that burden. For one market though, this is about to change. The satellite market is a good showcase of how public investment in space over time has enabled emergence of a sizeable and dynamic market for space-based services (Vernile, 2018). In the satellite market public investment is decreasing as technological capabilities combined with economic viability have increased, allowing for the private actors to take a more prominent role.

The satellite market is the first market in space that appears to have achieved substantial profitability. The satellite market has several signs of maturity with regards to economic viability: There is a broad customer base for satellite services in earth orbit, and there are multiple providers of services that are private actors. These private actors appear to accept the current technological solutions and risk level of space launches and operations to such an extent that they are able and willing to operate with little to no public funding (Paladini, 2019). This independence of governments can be interpreted as a sign of a mature and economic viable market. It can be argued that this independence should be the ultimate aim for all potential markets in space. At least for all the countries and individuals with an interest in increased space capabilities, technological innovation (with technology transferrable to earth), economic growth and reduced exploitation of the finite earth-based resources.

By letting private actors provide for the needs for majority of the services in earth orbit, the governments, space agencies and research institutions are allowed to divert their focus away

from making satellites and to new frontiers of space that will help develop technology and capabilities that will be ultimately beneficial to all of humankind. During interviews (source one) stated that his assessment is that such a shift in fact is taking place, and that NASA and ESA is gradually moving their focus aways from earth orbit and to the Moon and Mars.

This chapter was in reference to table 4.2: 1.4, 1.8, 1.13, 1.14, 2.20, 2.22; table 4.3: 1.2, 2.3, 2.4, 2.5, 2.12; table 4.5: 1.1, 1.5, 2.1, 2.4; table 4.6: 1.2, 1.3, 1.5, 2.1, 2.4, 2.8, 2.9; table 4.7: 1.7, 1.10, 1.11, 1.12, 1.13; table 4.9: 1.6; table 4.10: 2.1; table 4.11: 1.2, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 2.2, 2.3, 2.4, 2.6, 2.8, 2.17, 2.20, 2.22; table 4.12: 2.2, 2.4, 2.5; table 4.14: 1.1, 1.2.

5.3.1.3 Rivalry among states

The ambition for national prestige fuelled the space race between the US and the Soviet Union in the 1950s. It was a not just a space race, but a race between two contrary ideologies with democratic free market capitalism on one side and state planned communist economy on the other.

Arguably the time period with the most amount of innovation, public interest and dedication of resources in and to space was during the space race in the 1950s and -60s. The fight between democracy, capitalism and the free market against communism aggravated the public embarrassment felt by the Americans and the western world when the Soviet Union was able to first insert the first satellite into earth orbit (Sputnik 1 in 1957) and then launch the first human into space (Yuri Gagarin in 1961).

The chase for national prestige fuelled the Gemini and Apollo missions that ultimately allowed humankind to set foot on the moon in 1969. Never in the history of the US or the world for that matter, had so many resources been spent on space activities (Weinzierl, 2018). The Apollo missions alone employed thousands of people, provided technological innovation (much of which would be used for earth-based applications later), inspired generations and spurred industrial and commercial development.

For this reason, it is clear that rivalry among states has been one of the biggest, perhaps the biggest, historical driver of increased space activity and from increased activity comes the potential for economic viability for commercial companies as well. However, after the first landing on the moon the public and political interest in space soon declined. The US has never since been close to spending the same amount for space activities as it did with the

Apollo program (Weinzierl, 2018). And with the end of the Soviet Union the main source of rivalry for prestige also disappeared.

Enter China. The economic development of China has been substantial in most sectors in the past 20 years. This is also the case for the Chinese space sectors. Chinese investment in space was reportedly around US$ 11 billion in 2017, beat only by the USA (Paladini, 2019). China has proven its abilities in space with a manned space station that is currently placed in orbit around the earth, successful rover landings on the moon and it was the first country to make a successful rover landing on Mars on the first attempt. China has clear ambitions, plans and capabilities for the conquest of space (Paladini, 2019). There is a rising concern in the western hemisphere regarding China's rapid increase in space capability. And there is still an ideological dispute between the Chinese autocracy and western democracies. It is not unreasonable to assume that this rivalry may inflate to a race for international prestige and that this contest will be fought in space.

Given that we know from history that rivalry between states can be a strong driver for increased activity in space and with that increased market opportunities and potential for economic viability for space companies, this form of rivalry may be a good thing for the case for space when seen in isolation. At least as long as the rivalry is conducted in an orderly fashion that is predictable for the commercial sector. However, should an escalation occur, and the rivalry escalate to an open conflict, this would naturally be detrimental for commercial viability as well with society as a whole.

The awareness and concerns for increased Chinese dominance in space appears to be mostly rooted in the US. Norway specifically and Europe generally seems to be relatively inattentive of increasing Chinese dominance in space, at least with regards to what has been communicated publicly. One could argue that there is a lesson from history here: An increased focus on the rivalry for dominance in space with the democratic western countries on one side and the autocratic China on the side, is potentially a strong driver for increased space activity, increased market opportunities, increased economic viability for companies and source of public support and unification. It is not unreasonable to assume that should an increase in the level of conflict between the west and China occur, this may produce effects such as an increase in the level of attention and state spending which is awarded to space activities.

This chapter was in reference to table 4.2: 1.1, 1.2, 1.3; table 4.3: 1.1, 1.2; table 4.5: 1.7, 1.8, 1.10; table 4.6: 1.2, 2.8; table 4.7: 1.1, 1.2, 1.3, 1.7; table 4.8: 1.1, 1.3, 1.4; table 4.9: 1.5, 1.6, 1.7; table 4.11: 1.1, 1.3.

5.3.2 *National level political impact*

5.3.2.1 Norwegian Space Agency

(Source 2) emphasised that the NSA had been instrumental to his company both in the start-up phase as well as the follow-on/growth phase. In the start-up phase the company was awarded funds for initial R&D for feasibility studies. The initial R&D revealed that further investment of efforts toward the space sector could be fruitful. Furthermore, in the follow-on/growth phase the NSA provided assistance with identifying relevant ESA contracts, aiding the company to increase its efforts and portfolio within the space sector. (Source 2) was clear when he stated that was it not for the assistance of NSA the company would not have produced hardware and software for space activities today.

According to (source 1) the NSA not only acts as an intermediary between ESA and the Norwegian space sector, but in some cases also proactively surveys Norway for specific capabilities and professional fields where ESA is looking to award contracts. Arguably this is because the Norwegian commercial space sector is so immature that some companies and research institutions have knowledge and products that would win ESA contracts, but the companies do not yet know of these possibilities. Through their efforts, the NSA help provide Norwegian companies a chance for their hardware and/or software to have a “first flight” opportunity. Once hardware and/or software has flown in space it has passed its first test and is “space worthy”. (Source 2) pointed out that after “first flight” had been achieved more commercial opportunities open up, since unproved hardware/software is inherently riskier than hardware/software that has flown and worked in space at least once. The NSA indirectly assists Norwegian companies in reaching a more mature commercial proposition of their products and services, by aiding those companies to obtain a “first flight” opportunity.

This chapter was in reference to table 4.2: 1.8, 1.13, 1.15, 1.16, 2.13; table 4.5: 1.4, 1.5, 1.6, 1.7, 1.8, 1.13, 1.14, 1.15, 1.16, 1.17, 2.8; table 4.6: 1.3, 1.4, 1.12, 1.13, 2.5; table 4.9: 1.1, 1.8, 2.3; table 4.13: 1.1, 1.8, 1.9, 1.10.

5.3.2.2 NSA funds for initial R&D

The NSA has a budget that is dedicated to strengthening Norwegian space commerce. The NSA is instructed to manage the funds to support the R&D conducted by Norwegian companies and research institutions with a footprint in space (følgeprogramforskriften, 2022)

During an interview (source 2) stated that the R&D received by NSA for initial feasibility studies where imperative for his company's initial entry into the space sector. The feasibility study was critical to uncover the company's ability to adjust their existing hardware/software to that required in space. Hence, the NSA funds for R&D helped alleviate a distinct barrier for entry into the space sector for the company.

This chapter was in reference to table 4.2: 2.22; table 4.3: 2.13; table 4.5: 1.14, 1.15; table 4.6: 1.6, 1.11, 2.11; table 4.9: 1.8.

5.3.2.3 Collaboration with research institutions

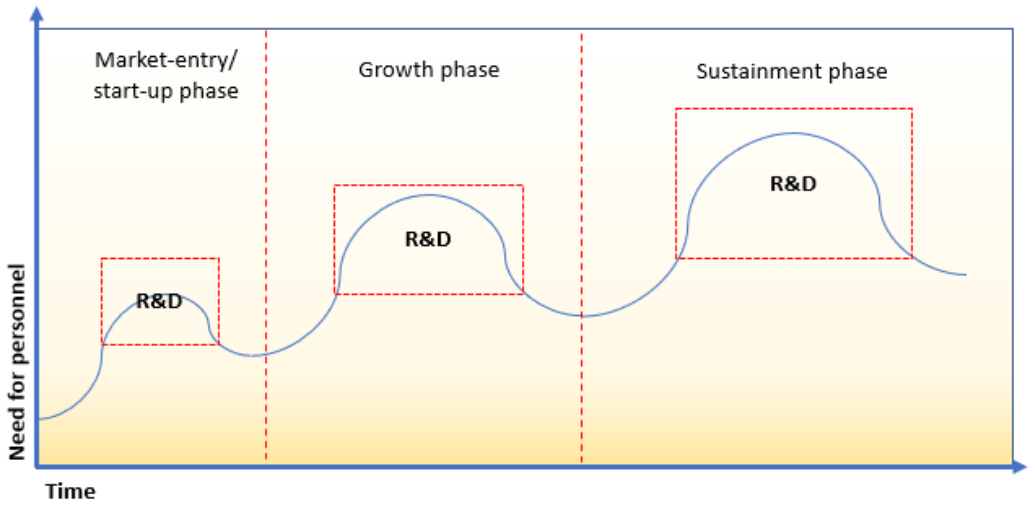
In an interview with (source 2) the informer revealed that he assessed the collaboration with research institutions as particularly important in the R&D phases of product development. In the market-entry phase of his company he had received funds for feasibility studies. The feasibility study was performed in close collaboration of a local university. The feasibility study was aimed at uncovering how the company's existing hardware/software could be adapted and adjusted for space-purposes. The feasibility study uncovered how such an adaption could be made, and it supported the awareness that was necessary to make the strategic decision to attempt an entry into the space sector for the company.

The CEO informed that collaboration with research institutions was not only vital in the market-entry phase for his company. Also during follow-on and growth phases the collaboration would prove important for his company: Being a relatively small company with a limited amount of personnel, collaborating with the local research institution during the R&D of new products for new contracts would provide the company human resources that it needed during the product development phase, but could not afford to employ as full-time employees.

Since R&D is cyclical and manpower-intensive in nature, collaborating with research institutions appears to increase economic viability for small to medium sized Norwegian companies. The alternative would be to employ the personnel needed for R&D full time and

the company would then either be forced to perform more R&D than what was desired or let personnel remain more idle than desired. The informer also emphasised the difficulties in finding the right personnel for his company. Since Norway is a small country the access to talent is limited. For this reason, employing more personnel for R&D may not be desired or even possible for Norwegian companies. The figure below illustrates the cyclical need for personnel during R&D phases of product development and company growth.

Figure 5.2: Illustration of the cyclical need for personnel during growth of a Norwegian space company.



This chapter was in reference to table 4.5: 1.9, 1.14, 1.15, 2.11; table 4.6: 1.7, 1.11, 2.11, 2.14; table 4.9: 1.4.

5.3.2.4 National security contracts

A substantial amount of the yearly space activity is based on national security needs (Federal Aviation Administration, 2018). These needs can amount to the need for satellite communication, satellite navigation solutions, space imagery or surveillance from space. To a commercial company, landing a national security contract most times means dealing with a customer that is financially stable with a predictable demand for goods and/or services (source 2).

As a start-up company or a company new to the space sector it may be difficult to secure national security contracts. Taking a chance on an unproven and inexperienced company may

be too risky for such a customer due to the high technology, high sensitivity and high classification involved on national security missions. However, in the growth/follow-on phase after concepts have been flight proven there is a greater chance of being awarded national security contracts.

In an interview with (source 2) the source revealed that to his company, securing a contract with the Norwegian Armed Forces was ideal in the follow-on/growth phase of the company. The Norwegian Armed Forces represented a well-funded, minimal risk customer with a calculable demand that allowed the CEO to adjust the company as needed to meet the demand with relative ease and predictability.

Furthermore, a national security contract could open up for recurring orders in the future. The rationale being that the Norwegian Armed Forces would likely continue the cooperation with a company with which it had a positive experience with earlier. Recurring orders are particularly profitable for commercial companies as they involve little to no need for R&D. The lack of the need for R&D to service a recurring contract combined with a relatively high revenue would allow resources to be allocated to R&D of other project and thus would provide a chance to expand the company even further, explained (source 2).

A national security contract is also a welcomed source of income that is outside of the ESA sphere. As explained in previous chapters, ESA appears to be a critical element for the Norwegian commercial space sector. Being provided a second source of income spreads the risk for Norwegian companies. For (source 2) the Norwegian Armed Forces has been one of the main customers through the growth phase of the company. However, the CEO was cognizant of not relying on national security contracts alone as it would leave the company vulnerable to a potential reduction of demand from the customer.

This chapter was in reference to table 4.2: 1.2, 1.3, 2.5; table 4.5: 1.10, 1.11, 2.2, 2.11, 2.12; table 4.6: 1.8, 2.2, 2.3.

5.3.2.5 Public procurement and support schemes

Historically space endeavours have had a tradition of being based on public and national security needs. Governments and state organizations such as NASA set the goals and adjusted the resources as needed to achieve those goals. NASA typically owned the public space projects, assumed the financial risk and included commercial actors through use of cost-plus

contracts. NASA was deeply involved with the actual product development, and this combined with the use of cost-plus contracts meant that NASA would need to supervision their commercial contractors closely. This led to a centralized system, where most of the decision making was taken by NASA and little room for creativity was left to the commercial suppliers (Weinzierl, 2018).

Weinzierl (2018, p. 175) explains the reason why this was the case:

> "The economic logic for the centralized model was clear, and for several decades it achieved its (remarkable) goals. Public goods such as national security, national pride, and basic science are typically underprovided if left to the market, and NASA was founded to provide them during the Cold War".

The centralized approach served the space sector well with many remarkable achievements during the space race. It is likely that those achievements would be very delayed, or perhaps never realised, if the commercial sector would be required to take the risk of the necessary development alone. Instead, NASA initially took charge of program development and engaged the commercial sector through sub-contracts. This resulted in the establishment of a commercial base of companies that provided goods and services intended for space, but where most of the risk resided with NASA. As such it is clear that the public procurement of space goods and services have always been a large, if not the largest, driver for establishment of the commercial space sector. Increased demand means a larger market, and a larger market means a higher potential for economic viability in the sector.

However, as discussed in previous chapters, dependency of public and defence spending is not all good for commercial companies when that spending is cut or reduced. This was the case after the Apollo program where NASA received 0,7% of the US GDP in the mid-1960s compared to the todays spending which is around 0,1% of US GDP (Weinzierl, 2018). The centralized system worked well for the race for prestige in space during the cold war, but fell short of adapting to the new post-Soviet world where efficiency mattered more than national pride. According to Cahan & Sadat (2021, p. 46) US policymaking for space had "…lagged in long-range perspective, planning, funding, coordination, sustainability, and implementation" after the cold war. It is reasonable to assume that for the growth of the commercial space sector a predictable demand in the market is key. Since product development is risky and expensive for companies, a cut in demand would be detrimental for economic viability and it

may even threaten the entire company. For companies to be willing to take this elevated risk, they must either be contractually compensated (such as through cost plus contracts) or sufficient trust in the market must be established. With predictability being a prerequisite for efficient growth of the commercial space sector, the space sector is an ill-match with the political systems in the democratic world where politicians typically are focused on political victories within electoral terms, and the resulting frequent and drastic revisions of funding and priorities for the public spending in the space sector, as was seen with NASA post the Apollo program (Weinzierl, 2018).

Based on classic economic analysis, Weinzierl (2018, p. 175) makes a case for the following development of the space economy:

> "1) establishing the market through decentralization of decision making and financing for human space activities; 2) refining the market through policies that address market failures and ensure a healthy market structure; and 3) tempering the market through regulation in pursuit of social objectives."

First, a decentralising process appears to be quite evident today in the western world. The termination of the costly space shuttle program has indirectly led to the advent of multiple innovative private companies standing ready to take its place. Multiple companies like SpaceX, Blue Origin and Orbital ATK are currently working with spacecraft that will move personnel and goods to and from orbit. These companies have developed said products themselves with little direct involvement from NASA. Guidance and oversight yes, but not like before when NASA was hands-on in charge of the development. These companies have been willing to take the risk of product development based mostly on private funding. And the result has been a significant reduction of the price of mass to orbit (Zapata, 2017). This fact is an indication of a trend towards decentralization within the space sector.

If one were to analyse the historical steps of such a successful decentralization process some sources give Reagan the credit of beginning it by signing the Commercial Space Age Act of 1984 (Weinzierl, 2018). However, the decentralization process did not seem to gain much momentum until the 2004 release of the President's commission on Implementation of United States Space Policy where it was stated that: "NASA's role must be limited to only those areas where there is irrefutable demonstration that only government can perform the proposed activity" (Weinzierl, 2018, p. 176). The background was that space shuttle program had

proved to be inefficient, risky and costly to the point where it was overshadowing all other human space flight activity programs within NASA.

When NASA terminated the space shuttle program in 2011 there was no NASA space vehicle ready to take over the human spaceflight capability. Instead, NASA turned to the commercial space sector for the mending of the embarrassment of not having a national human spaceflight capability. The solution became a set of public-private partnerships called Commercial Orbital Transport Services (COTS). The main differences with COTS over the traditional centralised model was that 1) NASA became a customer and a partner instead of a supervisor, that 2) the cost-plus contract scheme was replaced with fixed priced contracts, and that 3) intellectual property rights would remain within the private companies (Weinzierl, 2018). With COTS the risk, responsibility and reward with regards to financing and innovation shifted from NASA to the commercial space sector. This allowed NASA to focus on its core mission rather than product development while the private companies were allowed the freedom to innovate, cut costs and take the appropriate risks where needed.

Summarised it seems evident that the leading space economy in the world (the US) has learned that establishing a decentralised market is the most efficient way to grow the country's space capabilities. The US seems to have efficiently established a decentralized commercial sector and that it has successfully addressed many market failures and gained a healthy market with multiple private companies with strong space capabilities. As the prime example, SpaceX had a higher number of launches in 2021 than all of the other countries or companies combined. Since the introduction of COTS there are more providers of US launch capabilities than before, the launchers are safer and the cost of mass to orbit has drastically reduced (Zapata, 2017).

The lessons from the US are not all directly transferrable to the Norwegian space sectors. First Norway is a smaller country both when it comes to number of inhabitants and GDP. Also, Norway mainly focuses on space through the ESA/ EU framework. However, the main principles for the political category should remain: Aim for the long-term establishment of a decentralized market that can work as independent from state involvement as possible, and address market failures through policymaking to ensure healthy markets.

A healthy and decentralised market entails a certain size and maturity of the involved actors. One proposition for the Norwegian policymakers would in such a respect be that they ensure

an increased number of actors involved in commercial space sector. Increasing public spending to ESA with the geo-return mechanisms seems like a perfect match for Norway's need in such a respect.

This chapter was in reference to table 4.2: 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.8, 1.11, 1.14, 1.15, 1.16, 2.1, 2.4, 2.17, 6.2, 6.3, 6.4; table 4.3: 1.7, 1.8, 1.9, 1.10, 1.11, 2.10, 6.2, 6.4; table 4.5: 1.3, 1.4, 1.5, 1.7, 1.12, 1.17, 2.7; table 4.6: 1.3, 1.5, 1.9, 2.2, 2.16; table 4.7: 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, 6.2, 6.3; table 4.8: 1.1, 1.2, 1.3,1.4; table 4.9: 1.2, 2.1, 2.2; table 4.11: 1.2, 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 2.3, 2.4, 2.19, 4.1, 4.2, 6.1; table 4.12: 1.3. 2.4; table 4.13: 1.2, 1.6, 1.11, 2.1, 2.2.

5.4 Economic impact

When discussing economic impact on economic viability for the commercial space sector, in this context we will discuss external market factors and internal company factors. Through the market chapter we will take a deeper look at the different markets the space economy consists of and how they impact the economic viability for a company. We view the market as external to the specific company and hence all external economic factors will be placed in that category.

On the other side we will have a look at the space companies themselves and what influences them in the context of economic viability. All internal economic factors will be placed in this category. The distinction between external and internal factors was made in the interest of clarifying the economic factors.

Through the study of literature and the interviews the economy category had the highest number of entries/finds than any other category (table 4.1 & table 4.4). Let us look at why this is.

5.4.1 *Market impact*

5.4.1.1 Market size and maturity

Let us start with defining what is understood as the market in the context of space activities. Robinson (2017, first paragraph) defines a market as: "a means by which the exchange of goods and services takes place as a result of buyers and sellers being in contact with one another, either directly or through mediating agents or institutions". In the context of this

thesis the markets we are examining involve companies that are producing, supplying and/or consuming goods and services that are intended for a use in space.

In general, it is natural to assume that the larger a market is, the more potential exists for profitability for an actor in the market. A larger market in this sense would be equal to a higher demand for products, and with it a higher number of providers. In the context of space this would transfer to the principle that an increased activity in space would lead to an increased demand for space goods and services and space. The increased demand would likely lead to an increased number, quality and maturity of the provided goods and services. Hence, an increased space activity would lead to a heightened potential of economic profitability for the commercial space sector as a whole, but also heightened competition.

According to (source 1), there is an increasing number of companies with concrete plans for space activity within the commercial space sector in Norway. This is one indication of an increased market demand in Norway, and with that and enlargement of the commercial space market.

Perhaps the greatest of the barriers for growth of the commercial space sector is the relatively high cost of access to space (Paladini, 2019; Partnerships to Advance the Business of Space, 2013). As discussed in the chapter with political implications, space programs such as COTS and Commercial Resupply Services (CRS) have led multiple private providers of space launch vehicles to step up to the plate and provide a service that are cheaper and safer than before. In this regard, SpaceX stands out with partly reusable space launch vehicles (Falcon 9, Falcon 9 Heavy and Dragon capsule). The ability to re-use as much as 60% of the vehicle significantly lowers the cost per launch as seen in the calculations by NASA analyst Zapata (2017).

The changes seen in the US space sectors have been so substantial that a new term has found its way into the dictionary: New Space. New Space is to a considerable extent attributed to a combination of the results of COTS, the retirement of the space shuttle program and the fact that NASA was forced to become a customer and partner rather than a supervisor of vehicle design (Weinzierl, 2018). According to (source 2) New Space has also influenced the Norwegian markets: In short it has cut costs, increased the number of actors in space and allowed a higher degree of tailoring of flight profiles. The costs have been reduced as a result of: Technological innovation, increasing the use of off-the-shelf-technology, reducing

overspecification and allowing a lower specification in general that matches closer to the actual flight profile. The reduced costs of access to space have lowered the barrier of entry into the space sector for commercial companies and public organizations in general. The increased number of launches have permitted the launches of more frequent, but smaller payloads that are better suited to the needs of the customers. When fewer customers need to be served per launch it means that fewer compromises have to be taken by into account when deciding the flight profile, thus achieving a higher degree of tailoring to the customer which in many cases could lead to a reduced specification, which again reduces costs.

Within the commercial space sector there are multiple potential sub-markets. To name a few: The launch provider market, satellite market, space tourism market, space station market, in-space manufacturing market, space mining market and space energy market. Additionally, you have the manufacturers of all of the equipment needed to perform the activities within all of these markets (upstream space), and the users of all these goods and services (downstream space). Most of these markets are not mature and some of these are most likely decades away from becoming actual healthy markets, but the list does provide some inspiration and understanding of how much economic growth and activity that potentially could take place in space

The only market on the list that can be regarded as a mature and healthy market is the satellite market. The satellite market is to a considerable extent a commercial success story: It has enjoyed a large, predictable and steadily increasing public, private and military demand. Multiple providers have been able to provide satellite services through many years of experience and the technology is sufficiently mature to decrease risk to an acceptable level (Paladini, 2019). The result is that most of the risks connected with the income and costs of operating in the satellite market is thoroughly understood. The state actors have more or less left the satellite market (with the exception of national security) in the hands of capable private actors, and when the state actors need satellite services in most cases the commercial sector can provide the services required. The satellite market is good example of how other markets in space potentially could evolve: From rigid, state dependent and centrally controlled development to a decentralised, privatised, innovative and efficient market.

This chapter was in reference to table 4.2: 1.9, 1.10, 2.1, 2.2, 2.4, 2.5, 2.7- 2.18; table 4.3: 2.1-2.6, 2.8, 2.9; table 4.5: 2.1-2.8; table 4.6: 2.1-2.7; table 4.7: 2.1; table 4.9: 2.1-2.5; table 4.10: 2.1; table 4.11: 2.1-2.16; table 4.12: 2.1-2.3; table 4.13: 2.1-2.7; table 4.14: 2.1.

5.4.1.2 Market failures

Weinzierl (2018) makes a case for that the role of the state for the growth in the commercial space sectors should be refining market through policies that address market failures. The results from chapter four reveal a number of potential market failures that would be beneficial to mend to ensure economic viability. The most important market failures will be covered here.

Market failure 1: State dependency

Historically all space endeavours have initially been highly state dependent both with respect to financing, policymaking, placement of risk, leadership and regulatory framework. Although initially necessary, over time this becomes a problem due to "weak incentives for the efficient allocation of resources, poor aggregation of dispersed information, and resistance to innovation due to reduced competition" (Weinzierl, 2018, p. 176). Public policy should eventually address this market failure with the aim of evolving the markets to become decentralised, open for anyone to enter, with a healthy size and composition of competition.

Market failure 2: High economic risk level

The risk that is associated with spaceflight has historically been substantial both with respect to economic profitability, mission success and actual lives of the people involved. In an immature space market, the state must assume all of this risk as it would be too heavy to bear for a private company to be able or willing to carry. To ensure mission success in those cases the state typically had to assume most of the economic risk (Weinzierl, 2018). Traditionally this has been arranged through cost-plus contracts where the commercial companies are reimbursed for their costs, plus a predetermined margin. This arrangement is inefficient for a number of reasons. First, these risks have to be reflected and offset in some way by state spending. Since state resources are finite, highly contested and often fluctuating this would likely result in an unpredictable demand in the market. Second, cost-plus contracts are widely criticised as being in-efficient, bureaucratic and not incentivising the contractors to cut costs to a sufficient degree.

For the space companies total risk entails a risk to income and a risk to expenses. Risk to income is dependent on how much sale is achieved and the margins which in turn is determined by the market demand for the product and the operating efficiency of the company

respectively. Risk to costs consists of risk of costs connected to operations and product development which in turn are impacted by the operating efficiency and the technology available and the intellectual resources available. Addressing this market failure by alleviating the risks in a space market can be done in multiple ways. On the income side the demand in the market could be artificially ensured or inflated until a sufficient commercial capability was in place. On the cost side efforts could be made to make product development more efficient, for instance by creating incubation centres, technology clusters and research institutions that could support R&D cycles and product development more efficiently. Combined these policies would ensure a more mature and independent commercial sector that has access to relevant technological expertise when needed.

Table 5.1: Total risk to economic viability for commercial space companies

Total risk			
Risk to income		Risk to costs	
Sale of goods or service	Margin	Operating costs	Product development
Demand for goods or service	Operating efficiency	Operating efficiency	Technological maturity and know-how

Market failure 3: Lack of complementaries

Much optimism has come amongst the space enthusiasts based on the falling costs of price of mass to orbit, mostly attributed to technological innovation due to the privatisation of space. The cost of mass to orbit is by many considered as the largest barrier in achieving a breakthrough in the space economy. However, Weinzierl (2021, p. 184-185) makes a good case when he points out that this is only fixes a part of the problem: When a cheap, safe and re-usable space launcher is available it faces what has been known as the “destination problem”. The current space launch provider industry is rigged to the current demand. A lower cost of launch will naturally lead to a higher demand, but it would require much innovation to take advantage of the full potential. And this may take decades to develop.

> Low-cost launches are still expensive if there is nothing to do and nowhere to go in space. Building habitats for manufacturing or tourism is of no use if they cannot be secured from the dangers of space. And so on. If these technologies were realized together, however, they would form a self-sustaining system with potentially enormous profit potential (Weinzierl, 2018, p. 184).

It is reasonable to assume that addressing the lack of complementing elements within future markets in space that will exist once full and rapid re-usability of space launchers is achieved could be very profitable for the companies involved.

This chapter was in reference to table 4.2: 1.7-1.16, 2.3, 2.19-2.21; table 4.3: 2.4, 2.5, 2.9, 2.11, 4.1, 5.1, 5.2; table 4.6: 2.11; table 4.7: 1.4-1.13; table 4.9: 6.1; table 4.11: 2.2, 2.3, 2.4, 2.6, 2.8.

5.4.1.3 The Norwegian space markets

When it comes to Norwegian markets specifically many of the same mechanisms and market failures that are described in the literature also come true when presenting the Norwegian commercial space markets. In general, the Norwegian commercial space market is small and the total demand is too small for any company to be based on space-based activity alone, according to (source 1). The low demand leads to an unpredictable market with few recurring contracts. Most of the contracts gained by Norwegian space companies are a single delivery or a series of deliveries within a short time span. The deliveries are often quite heavy and demanding for the companies to carry as well.

(Source 1) continued to explain that to be a part of such an immature market the main coping mechanism of Norwegian space companies are that they are all based on activities outside of the space sectors and that they usually look for a space-based application of existing products. The companies adjust existing products to space specifications via spin-off effects, this process often improves their product, which in turn enhances their original product via synergetic effects. (Source 2) explained a similar approach to the market is adopted by his company.

Both sources confirmed that the there is a clear current trend that the market is state driven at this point in time: Either through funding of ESA which in turn gives contracts back to Norwegian markets through the geo-return mechanism or directly from the Norwegian Armed Forces. (Source 2) was clear when he stated that was it not for the efforts of state actors such as NSA, ESA and the Norwegian Armed Forces, his company would not be involved in space activities. There appears to be little pure commercial activity outside of the ESA and Norwegian Armed Forces sphere in Norway.

However, the New Space wave appears to also have left its mark in Norway. (Source 1) explained that private companies increasingly define their own missions independent of state contracts and that this is a trend that could also be seen in Norway. (Source) 2 explained that his experience was that the New Space wave has contributed to cut costs and allowed the projects to grow smaller, but more frequent. This has lowered the entry barrier, increased number of actors and allowed fewer compromises to be made for each space mission. An example of this is that both the NSA and NTNU have been able to or are planning to launch their own satellites (source 1). Something that would be unthinkable 20 years ago.

Another trend in Norwegian markets, according to (source 1), is that applications of downstream space services are on the rise. Many of these companies do not identify themselves as companies that are a part of the commercial space sector, but their business is based on products delivered from space. This is especially the case with the companies that are based on satellite data. Much of this data is free as the satellites are funded by ESA projects, such as the ESA Copernicus satellites.

In summary the Norwegian commercial space markets display unmistakable evidence of immaturity mainly based on small size and high state dependency. The market failures appear to be addressed in clever ways, especially through the pro-activeness of the NSA, the advantageous ESA geo-return mechanisms and procurement schemes. The main ingredients that seem to be missing for the growth of the Norwegian space economy is increased funding (political investment) and time.

This chapter was in reference to table 4.2: 1.4, 1.8, 1.9, 1.10, 1.13, 1.14, 1.15, 2.2, 2.4, 4.2, 4.3 ; table 4.3: 2.2, 2.3, 2.4, 2.5, 2.6, 2.8, 2.9, 2.11, 2.12, 3.1, 4.2 ; table 4.5: 1.10, 1.12, ; table 4.6: ; table 4.7: ; table 4.9: 1.1, 1.2, 2.1, 2.2, 4.1 ; table 4.11: 2.4, 2.5, 2.8; table 4.13: 1.1, 1.2, 1.7-1.11, 2.1-2.8 ; table 4.14: 1.1, 1.2, 2.1.

5.4.2 *Company impact*

In the company impact sub-category we will be going through the internal factors that impact a company's abilities to reach profitability. These are elements where the individual company has a degree of influence to change an outcome, as opposed to external factors where the company has little to no actual ability to influence the forces in play. Examples of internal factors are business strategy, culture, organisation and so forth.

In general, the commercial space company operates in an environment which entails though requirements. Activities in space require companies that are able to deal with a: High-cost, high-tech, high-risk and with a long payback period, but also a high potential for return (Paladini, 2019).

High cost

Paladini (2019) argues that traditionally it has been difficult to distinguish between cost and price of a product due to the tendency to utilise cost-plus contracts. This kind of contracts reimburses the contractor and provides a pre-determined profit based on an amount or percentage. The problem with these contracts is that they do not incentivise cost cutting. On the contrary in many cases, it would be more profitable for the contractors to inflate the costs.

As space markets mature and with the entrance of the New Space wave especially, fixed based contracts or award driven schemes have become the new norm. This form of contracts incentivises the companies to cut costs because in the end it will affect their own margin.

According to (source 2) the most important internal factors for profitability for his business where: 1) to have close control over the incurred and projected costs of a project, 2) to meet the specifications of a project, and seek not to overshoot the specification as it is a driver of cost, 3) ensure sustained operations/ recurring sales of previously developed products, 4) ensure efficient operations and R&D processes by recruiting personnel with the right qualification and motivation, 5) seek cost cutting through technological innovation. All these factors directly impact profitability, margins and economic viability.

High-tech

Space is a challenging environment to operate in and spaceflight is at the limits of what is currently possible to achieve for humankind. Virtually all phases of spaceflight involve a need for a high degree of understanding, insight and expertise to complete it successfully. For this reason, securing the right kind of intangible resources such as personnel, engineers and experts with the right combination of abilities, experience, understanding and motivation is vital for any company that wants to ensure mission success in space. This kind of expertise is especially important during product development as it will lead to a more efficient exercise with the right expertise involved in the development, and the fact that product development is a significant driver of cost.

Ensuring collaboration with research institutes or societies was mentioned by (source 2) as a key factor for the success and profitability of his company's product development. The reasons for this are twofold. First, in Norway it is difficult to find, recruit and maintain personnel with the right level of expertise. Research institutions are places that provide relatively easy access to such resources increasing efficiency of R&D processes. Second is the cost and drawback of having all R&D resources embedded in the organisation at all times, as explained in chapter 5.2.2.3.

High risk

Spaceflight involves a high degree of risk. As explained in chapter 5.3.2.1 total risk consists of risk to income and risk to costs. A company has to manage these risks by making strategic choices. These choices involve, among many others: Producing the right product, finding the right market segment for their product, lowering R&D costs, searching for synergies across domains (perhaps also outside of the space sector).

(Source 2) explained that his company's main ways of mitigating financial risks were to base product development on a platform that was modular and could easily be adjusted to many uses, also outside of the space domain. The company would achieve synergies through spin-off and spin-in effects from the R&D process connected to the adjustment of the existing product to space specifications. Another important risk mitigation for the company was to offset R&D costs by ensuring recurring deliveries of existing and flight proven products.

Long payback

Space projects are typically of a substantial size and are heavy to carry for the individual company. They involve a high degree of expertise and take a long time to develop. This means that it also typically takes a long time before any profit is made. For this reason, it is important for the companies to secure investors that understand the space sectors, the complexity involved, and that the investment horizon is a long one (Cahan & Sadat, 2021). The typical investor with a short investment timeline will be an ill-fit for a commercial space company. The success of a company's space endeavour will be dependent on securing the right kind of financial backing that has the ability and patience to "see it through".

On the flipside of the coin there is evidence of increased commercial activity in space, that the commercial markets are getting larger and that there are concrete plans for new markets in

space. All these are indications that there is money to be made in space and as such should be increasingly interesting for investors. Renowned astrophysicist Neil deGrasse Tyson and X-prize founder Peter Diamandis are both attributed to the statement that the world's first trillionaire will be a space miner (Kaufman, 2015).

This chapter was in reference to table 4.2: 2.19-2.26; table 4.3: 2.10-2.16; table 4.5: 2.9-2.15; table 4.6: 2.8-2.16, 3.1, 4.1; table 4.9: 2.6, 2.7; table 4.10: 3.1; table 4.11: 2.17-2.22; table 4.12: 2.4-2.5; table 4.13: 2.8.

5.5 Social impact on economic viability

This chapter will take a look at social factors that influence a commercial space company and how they affect the bottom-line economic viability. Both the literature review and the interviews resulted in only two entries in the social impact category each. At first glance this is in many ways understandable because, as discussed in previous chapters, spaceflight is not crowdsourced, random and happenstance. Rather spaceflight is the result of substantial amounts of concentrated tangible and intangible resources dedicated to solving complex problems over time. Surely such projects can only come to materialisation through political decisiveness and motivated by economic interests, as opposed to a fleeting social influence?

The influence of social factors, such as the general public will, can easily be taken lightly and downplayed as relatively weak forces compared to political and economic forces. However, it is important to note that social influence from time to time has a substantial force behind it: Previous social uproars have toppled kings and forced regime changes, introduced and removed laws and regulations. In many ways the first golden age of spaceflight that was experienced during the space race in the 1960s can be, in part, attributed to social factors. The rivalry among the open market democracy versus communism led to embarrassment in the western world when the Soviets managed to launch both the first satellite and person to space. A whole nation, widely supported in spirit by other western states, came together for a common purpose after the speech where President John F. Kennedy launched his vision of committing to the goal of landing astronauts on the moon within the end of the 1960s. The achievement has since become one of the strongest symbols of US capabilities and an intangible national treasure.

Some argue that the impending Chinese economic dominance will make its way to the space domain, which may spark new public engagement to the case for western dominance in space.

Space activities have, since the Apollo era, had to cope with a relatively low level of public engagement. The technological innovation did not meet the expectations prepared by the Apollo years and low cost, routine access to space was not achieved through the Space Transport Services program that produced the Space Shuttle after the Apollo program.

Increased public engagement is important for space companies due to mainly two reasons. First, increased public engagement means that more people are talking and thinking about space. This increases the likelihood of people wanting to work within the sector. And given that all sectors of the economy have to compete over a finite amount of talented people, this increases the chances of recruiting and securing more of the intangible resources needed to make space flight happen efficiently. Second, increased public engagement and support for space increases the likelihood of increased state spending on space in a democratic country. Hence, social factors indirectly impact economic viability by increasing the force and size of the political impact category. The result would be that more resources are spent on space activities.

In Norway the commercial space sector is small, and the main industries are oil & gas and fish. There is a political ambition for reducing Norway's dependency on the oil & gas sector for revenue. (Source 2) identified lack of abilities connected with recruitment as one of the bottlenecks for rapid growth and expansion of his company. Perhaps these interests are aligned in this respect: The Norwegian oil & gas sector employs the majority of Norway's engineering talent. They have expertise in fields that in many ways resemble what is needed in space (such as pressure, temperature etc.). That expertise is needed, desired and highly transferable to a growing national space industry.

This chapter was in reference to table 4.2: 3.1; table 4.3: 3.1; table 4.5: 3.1; table 4.6: 3.1; table 4.11: 3.1-3.2.

5.6 Technological impact on economic viability

The tight connection between space activities and technology is self-evident. Even the task of leaving earth atmosphere is so complex that only a few countries have accomplished such feat. The technological innovation that took place in the 1950s and 1960s was formidable, but it was also highly risky. A study conducted by NASA in the beginning of the space race concluded that it was "a less than 5% chance" of achieving President Kennedy's ambitions of landing a man on the moon and returning him safely (Jones, 2018, p. 2). NASA came close to

the loss of the space capsule and with it the three astronauts of Apollo 13. After Apollo 17 in 1972 NASA or any other organisation have not yet returned to the moon with a human onboard. Instead, the focus of the US and Soviet Union turned to earth orbit and establishing space stations. Many hastily conclude that technological innovation came to a halt after the Apollo program. Even though the rate of innovation in space certainly slowed it has continued at a steady pace.

With the New Space trend that is currently finding place the world has witnessed a sharp increase in technological innovation. In majority this is attributed to innovative private companies, and we currently enjoy continually reduced cost of access to space combined with increased flight safety. A major contender that must be mentioned in this respect is SpaceX with the Falcon 9 rocket and Dragon capsule. SpaceX has managed to achieve 60-70% of reusability with the Falcon 9 (Brown, 2020), where the first stage (one of two), fairings and Dragon capsule are re-usable as opposed to the traditional ways of conducting spaceflight where millions of dollars would be spent on building spacecraft, and nothing would be re-used. Currently SpaceX is working on a new space vehicle, Starship, which is intended to be 100% reusable and capable of a rapid turn-over for a new flight. If successful, it is expected that the cost of mass to orbit will decrease significantly, perhaps as much as 100 times (Musk, 2017).

Through technological innovation humanity has produced multiple space vehicles that can provide access to space for goods and humans. The cost of this access has declined, and it is likely that this cost will continue to decline, perhaps even substantially, through the coming decades. Many consider the cost of access to space as the greatest barrier to achieving new healthy markets in space. However, as mentioned in earlier chapters, cheap access to space is only part of the remedy on the path to establishing new healthy, independent markets in space. Perhaps the largest barrier for this realisation is the market failure that is the lack of complementaries (as described in chapter 5.3.1.2).

Addressing the lack of complementaries entail the need for technological innovation on multiple areas simultaneously. Since it is unlikely that these complementaries will be addressed simultaneously an immature and state dependent market must be anticipated for some time. Consequently, all markets in space, with the notable exception of the satellite market, require and are dependent on future technological innovation to be able to reach market maturity. It is reasonable to assume that economic viability of the commercial space

sector will be at the mercy of the state policies addressing these market failures before this technological innovation has taken place and self-sustaining markets can be achieved.

This chapter was in reference to table 4.2: 4.1-4.3; table 4.3: 4.1-4.3; table 4.9: 4.1; table 4.11: 4.1, 4.2.

5.7 Environmental impact on economic viability

Commercial space companies have to contend with multiple environments: That of earth, that of space and in some cases that of another celestial body than earth. On earth spaceflight activities that impact the environment are manufacturing, particle pollution, noise pollution and light pollution. Particle pollution is the effect of burning chemicals to achieve enough thrust to leave the atmosphere. Noise pollution is the undesirably high level of sound that is generally connected with rocket propulsion. Light pollution is a relatively new term and occurs when objects in orbit around the earth reflect sunlight and produces a light source in the night sky, having a negative impact on earth telescope's ability to observe the night sky.

Light and noise pollution have so far been a limited problem. There are few spaceports in the world, and they are usually confounded to sparsely populated areas where few people are affected by the noise of the rockets. This could be an increasing problem in the future though, if ambitions of expanding spaceflight to involve earth-earth transportation of goods and passengers would come to fruition.

How much a rocket launch pollutes the atmosphere (particle pollution) is dependent on the chemicals used for the process. Ranging from the highly toxic hydrazine fuel that was a part of the fuel of early rockets, to kerosene and liquid oxygen used on the Falcon 9, to the use of liquid hydrogen. Even though the plume visible at launch of a Falcon 9 is large and is the result of burning kerosene, most of the plume is actually oxygen. Since there is no atmosphere in space all rockets must carry an oxidizer and that is usually liquid oxygen. In fact, the majority of the rocket's propellant is oxygen. Despite all the oxygen in a rocket a typical Falcon 9 launch will emit "27 tons of CO2 per ton to earth orbit" (Brown, 2021), as compared to air travel which emits 1-3 tons of CO2 per passenger on average (Brown, 2021). Although 27 tons is a lot more than 3 tons, the difference is that the number of rocket launches are low compared to the number of airliners that fly every day, so the effects to pollution are currently negligible. However, if the number of rocket launches should increase dramatically, this may change and lead to a need to re-address this issue. One possible solution is to use liquid

hydrogen as a fuel. Here the chemical process produces water and so the process leaves no greenhouse gases other than the water itself (Brown, 2021). The long-term effects of space travel on the atmosphere are unknown and understudies.

On planet earth the activities of commercial companies have to remain within certain limits with respect to particle pollution and noise pollution. With increased activity it is possible that the companies will face tougher regulations perhaps leading to an increase to costs for the sector. One solution to that problem could be to transition to a liquid hydrogen fuel.

In space, commercial companies face a different environment with dangers they have to take into account. Mainly these are space debris, solar flares, radiation and temperature. Space debris are almost exclusively man-made objects of different sizes that have been launched into orbit around earth and stayed there. Solar flares are high energy events that come from the sun that potentially could impact hardware and software onboard spacecraft. Radiation hazards are a combination of high energy particles from the sun and energy remnants of the big bang that is continually present in space. Dangers connected to temperature is due to the fact that space is a near vacuum so objects in earth orbit in the shadow of the sun will be very cold (around -100 degrees Celsius). On the sunny side though, there is no shielding from the intense radiation from the sun, so this side will be very hot (around 120 degrees Celsius) (Libal, 2018).

The companies that aspire to venture to space must construct vehicles, software and hardware that is capable of withstanding most of these events. To construct products to a space specification requires both expertise and resources. It is also a difficult exercise in risk management that must be balanced against the ambition for profitability. It is likely that increasing the specification is safer, but it is also a substantial driver of costs.

Lastly, when space vehicles produced on earth land on a different celestial body than earth, there will be a scientifical value connected to that the respective celestial body remains unspoiled from human particles, bacteria, minerals and so forth. As an example, some theorise that the life came to earth on asteroids. To investigate this hypothesis, we would have to examine asteroids with hardware made on earth, but without bringing any bacteria or life with the spacecraft as this invalidate the results.

This chapter was in reference to table 4.2: 5.1-5.2; table 4.3: 5.1-5.2.

5.8 Legal impact on economic viability

The legal category is in many ways intertwined with the political category since laws, rules and regulations have a political origin. However, in this context the political category involves factors that matter for the relationship between the commercial sector and the state. And the legal category contains factors that define what commercial space companies can and cannot do.

Multiple legal factors impact economic viability for a space company. Some of the major factors were found to be clarity of legal and regulatory framework, methods of oversight, ease of attaining licences, issues connected to intellectual property rights and freedom to cooperate with partners.

The first three factors are about the state, how it shapes the rules the commercial sector must follow, how it examines the sector for compliance of those rules and how it gives a company permission to perform complex and risky activities. For the companies these legal matters are often complex and challenging. Time, effort and resources spent on tending to these matters is a driver of cost for a space company and they do not serve as a source of income. However, if not tended to with care they are likely to create a barrier to income.

A legal factor that does represent a source of income is that of intellectual property rights (IPR). Old space cost-plus contracts often transferred IPR of the product from the commercial companies to the state space agencies such as NASA. Decentralisation, privatisation and new procurement schemes have permitted the IPR to typically be retained by the company performing the R&D. According to (source 2) retainment of IPR was a crucial step of the value chain when designing a product. And a factor that increases profitability for the company.

A final legal matter that is not likely to be applied in the near future, but worth mentioning due to the prospects of substantial profits, is the matter of property rights in space. There are two legal frameworks that are worth mentioning in this respect: The Outer Space Treaty of 1967 and the Artemis accords of 2020. The Outer Space Treaty is a UN treaty currently signed by 111 countries (United Nations, n.d.). Along with banning space from weapons of mass destruction and militarisation it directs that no state can claim sovereignty in space. By many this treaty represented a barrier to space mining and resource extraction in space. However, in 2020 NASA released the Artemis Accords among other elements contain a

chapter dedicated to space resources. The Artemis Accords permits the signees to perform resource extraction within the limits of the outer space treaty. Currently eight nations have signed the Artemis Accords. For companies that wish to perform space mining and resource extraction, state ratification of such treaties may be a condition prior economic viability can be ensured.

This chapter was in reference to table 4.2: 6.1-6.3; table 4.3: 6.1-6.6; table 4.5: 6.1; table 4.7: 6.1-6.3; table 4.9: 6.1; table 4.11: 6.1; table 4.12: 6.1; table 4.13: 6.1.

5.9 Research discussion PART TWO: Research questions

The aim of this thesis is to answer the main theme: "What makes commercial space activities economically viable for a Norwegian company?". Four research questions were formed to be able to answer this main theme. RQ 1 aims to uncover the main factors that could theoretically impact economic viability regardless of it is true or not. RQ 2 aims to find lessons from the past with regards to economic viability. RQ 3 aims to uncover what main factors are currently impacting economic viability. And finally, RQ 4 aims to place these factors into a Norwegian setting.

5.10 RQ 1 & 3: Drivers, barriers and trends

Research question 1 (RQ 1) was formulated as such: "What are the drivers and barriers that impact the economic viability of commercial space activities?". A list off all the findings were presented in chapter four and the main findings were discussed in part one of this chapter. RQ 1 is in many ways intertwined with research question 3 (RQ 3): "What are the trends towards an economic viable commercial space economy?". The difference between them is that RQ 1 asks what drivers and barriers could theoretically impact economic viability, while RQ 3 asks what drivers and barriers are actively impacting economic viability, at the current time. RQ 3 is in many ways based on RQ 1 and this is why they are presented together in this chapter. The following drivers and barriers were found to be the most important and current factors that are impacting the economic viability of the Norwegian commercial space sector.

Based on data analysis it is not unreasonable to state that the political category stands out as the most impactful driver and barrier, especially in a Norwegian context. The main reason for this claim is that the Norwegian commercial space sector is limited in size and maturity, and it is therefore highly dependent on state spending for activity stimulus. State spending consists

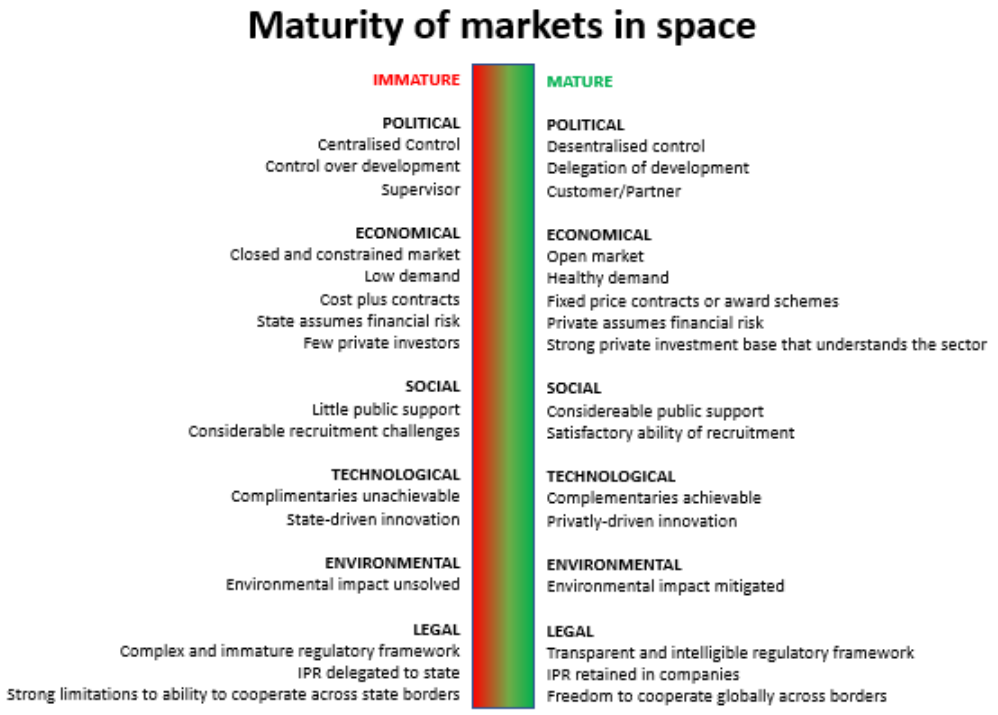
of both public and defence spending. (Source 2) mention both ESA and the Norwegian Armed Forces as his primary customers within the space segment and saw the Norwegian commercial space sector as economically unviable without these actors at the current time.

With regards to public spending the NSA & ESA collaboration seems to be an especially important driver. NSA's proactive actions in matching Norwegian companies with potential ESA contracts and awards was also underlined by (source 2) and to a great extent attributed with his company's success in the space segment. According to (source 1) the ESA geo-return mechanism is also a strong driver since the majority of Norwegian public spending that is diverted to ESA has to find its way back to the Norwegian commercial sector. This ensures market demand on the Norwegian market.

It is perhaps strange to mention the political category as a more important category than the economy category when discussing an economical question, such as economic viability. In this thesis the economic category contains market (external) and company (internal) factors. Further, the greatest barrier to economic viability was found to be an immature market in general. To mend the market immaturities, the best and perhaps only way to provide enough stimulus of the market for it to evolve is through political action. Through state spending governments can grow a commercial space sector with the capabilities that are needed to meet an anticipated future demand. Based on this fact market immaturities are perhaps the largest barrier for economic viability that was found through analysis. Signs of market immaturities were found in all of the PESTEL categories.

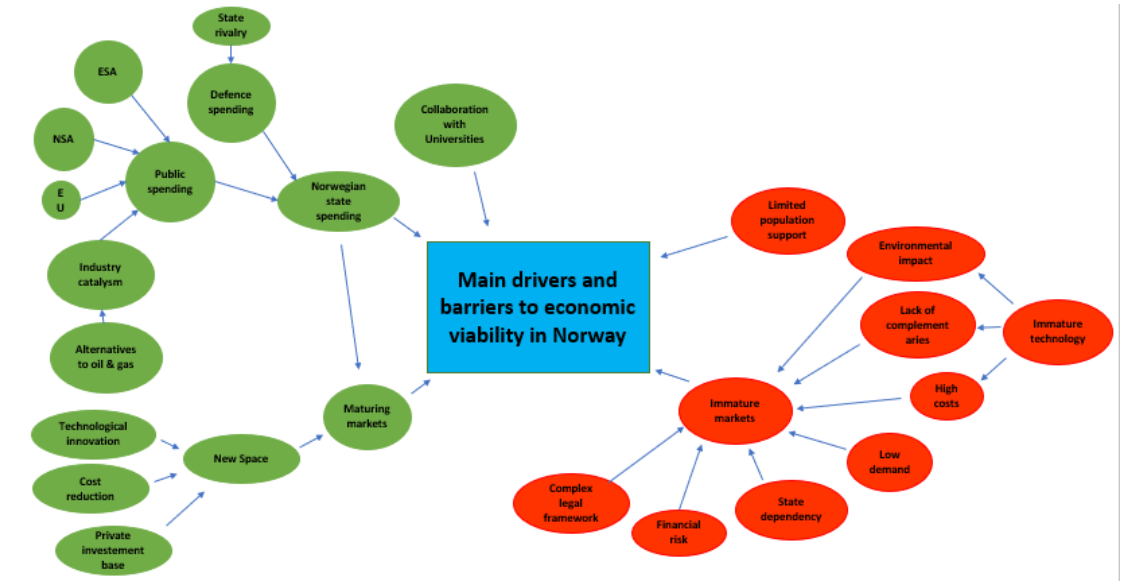
The figure below illustrates the main signs of a mature market in space. This is a generic illustration that is not valid only in the Norwegian market.

Figure 5.3: Maturity of markets in space across PESTEL categories



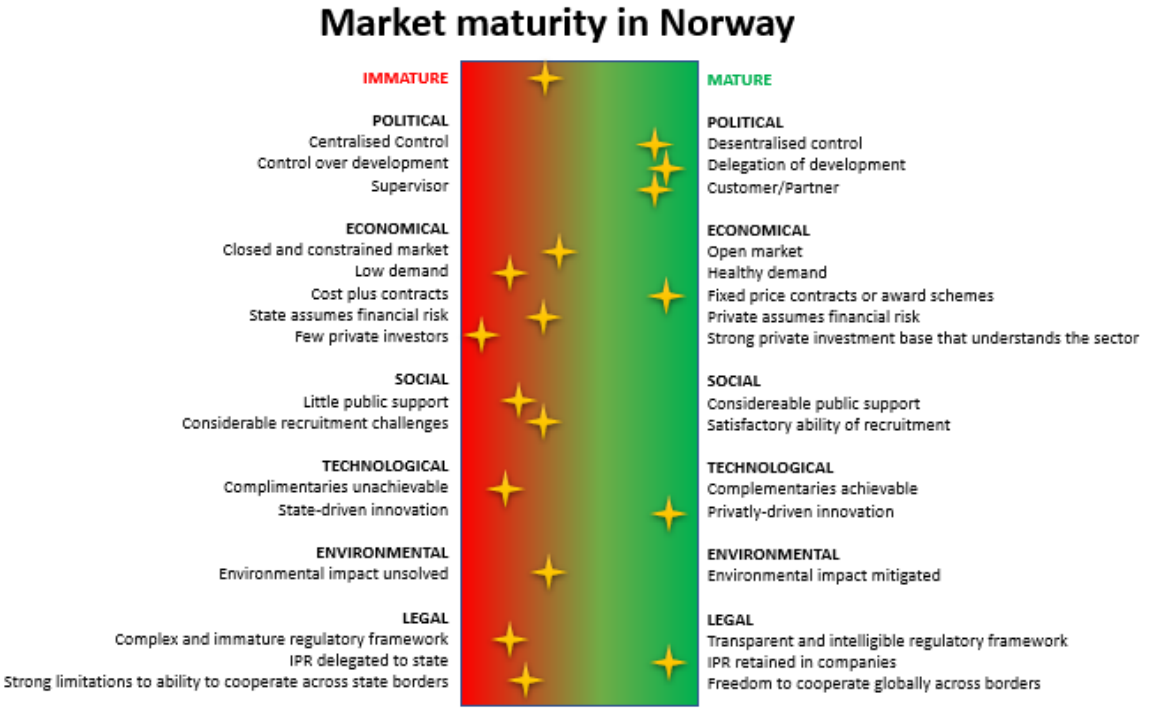
The figure below illustrates the main drivers and barriers that are assessed as to be the main forces in the Norwegian market (trends). It also illustrates the relationship between factors and how market state spending is forming a counterbalance against market immaturities on the other side.

Figure 5.4: Main factors impacting RQ1 and their relationship (drivers are green, barriers are red)



The following figure illustrates the author's assessment of the current degree of market maturity in the Norwegian commercial space sector based on literature review and interviews.

Figure 5.5: Author's assessment of market maturity of the Norwegian commercial space sector on a scale from immature (red) to mature (green)



5.11 RQ 2: Historical events

Research question 2 (RQ 2) is formulated: "What have been the historical events on the path toward a viable space economy?". There are many historical factors that have had an impact on the level of space activity, market demand and economic viability in the space sector, and these are too many to mention in this thesis. However there are some events that stand out in particular that must be mentioned in such a respect: The space race and the Apollo program, the Outer Space Treaty, the Space Shuttle through the Space Transport Services program, Commercial Space Launch Act of 1984, the loss of the Columbia shuttle in 2003, the US Space Exploration Policy of 2004, COTS, the termination of the Space Shuttle in 2011, and finally the New Space wave.

As discussed in chapter 5.3.1.3 the space race and Apollo program was a time period with high activity, attention, devotion and resources diverted towards space. Never again have the

public spending in space reached the levels that the world saw during those years. The result was years of innovation and advances in space and a growing commercial space sector growing to fulfil the needs of NASA.

In 1967 the Outer Space Treaty was formed and signed by multiple countries, including the US and the Soviet Union. Among other functions this treaty banned the placement of weapons of mass destruction in earth orbit, it directed the use of the moon and other celestial objects to be used exclusively for peaceful purposes, and that portions of space could not be subject to national claims of sovereignty. This treaty most likely contributed to making the world a safer place, and arguably put a stop to a possible continued race in space for sovereignty of celestial bodies and military use. In other words, this was perhaps a good for humankind, but perhaps not beneficial for increased activity in space.

Following the landing on the moon in 1969 the world's attention quickly went other places than NASA and the space programs. The Vietnam war was expensive and NASA was directed to revert their attention to earth orbit and creating a space station. The Space Shuttle was developed to provide an efficient and low-cost access to space. It would achieve this by utilising reusability of the shuttle itself. The Space Shuttle program encountered several difficulties and budget overruns and it ended up being rigid, comprehensive, dangerous, and expensive to the point that it would overshadow most other efforts on NASA's human space flight budgets. In total six space shuttles were built and two of the were lost: Challenger in 1986 and Columbia in 2003. The following year the US Space Exploration Policy of 2004 directed the Space Shuttle to be retired by 2010.

The failure of the Space Shuttle program provided a valuable lesson for NASA and US policymakers and in 2004 the President's Commission on Implementation of United States Space Exploration Policy stated that: "NASA's role must be limited to only those areas where there is irrefutable demonstration that only government can perform the proposed activity" (The President's Commission on Implementation of United States Space Exploration Policy, 2004, as cited by Weinzierl 2018, p 176). And with this statement captured the essence of the Commercial Space Launch Act of 1984 forwarded by the Reagan administration. As opposed to previous eras NASA did not plan to be in charge of the development of a vehicle replacing the Space Shuttle. Instead, NASA encouraged the commercial space sector to develop space vehicles through the COTS program.

The combination of the clear change of direction through the US Space Exploration Policy of 2004, the termination of the Space Shuttle and the initiation of the COTS program is most likely the main factors that contributed the advent of the New Space wave that is currently taking place. This is particularly true in the US, but it also has implications across the globe, Norway included (reference chapter 5.4.1.1).

5.12 RQ 4: SWOT

The last research question (RQ 4) was: "What are the strengths, weaknesses, opportunities and threats for a Norwegian company intending to perform commercial activities in space?" The intent of asking a question that is essentially shaped as a SWOT analysis is to tie the data gathered through RQ 1-3 and bring it closer to a Norwegian setting. As the data in RQ 1-3 is often generic in nature, the data in RQ 4 will be specific to the Norwegian environment. A SWOT analysis offers a look into a company's internal (SW) and external (OT) factors.

5.12.1.1 Strengths (S)

According to (source 1) the traditional strong Norwegian oil and gas sector is a factor that may play to the advantage of the Norwegian commercial space sector. The oil and gas sector is complex across all of the PESTEL categories, but especially the technological and environmental domains. This is transferable to the space sector to a high degree. The oil and gas found in Norway is situated offshore beneath a continental shelf where a depth of around 200m is the norm. On the surface, the North Sea is relentless with frequent storms, high precipitation, gusty winds and large waves. Successfully extracting resources in such environments requires mastering technological and environmental challenges. According to (source 1) the oil and gas industry is accustomed to operating in environments where pressures, temperatures and loads are demanding, which is also the case in space. Extracting knowledge and experience from the oil and gas sector may prove to be a source of strength for Norwegian space companies, both in respect to recruitment of for instance engineers and product developers. It may also enjoy the benefits from the fact that Norway already has an established method of recruiting and training the people that work in a highly comparable commercial sector.

Another source of strength for Norwegian space companies is that the commercial space sector is small in Norway. The advantages of this fact are that this increases the visibility of the companies that are already established in the sector, the sector is relatively transparent and

manageable and that cooperation and alignment with other Norwegian companies is relatively straightforward. According to (source 2) the small size of the sector along with his company's clear communication with respect to its goals and ambitions warranted NSA to approach his company and suggest attempting space projects.

Another strength of Norwegian space companies is the possibilities for a strong cooperation with research institutions. According to (source 2) the collaboration with a local university was paramount both for feasibility studies and R&D phases of his company's growth within the space sector. As discussed earlier in chapter 5.3.2.3 the collaboration with appropriate research institutions decreases costs by reducing the amount of personnel needed during product development and increases efficiency and total feasibility of Norwegian space projects.

A final strength is tied specifically to the company of (source 2). The CEO explained that due to the limited and immature commercial space market that currently exists in Norway, it became important to maximise market opportunities at the minimal costs to ensure economic viability of the space efforts. The company embedded this philosophy in their product development by basing their products on a generic technology that is modular and easy to adjust to new purposes. The company maximises the market opportunities by making products that is usable for a wide array of purposes in space, thus increasing the potential for recurring orders as much as possible. Further, by basing the core technology on a generic base there is little need for R&D and adjustment to fit new purposes. This reduces cost and the need for resource heavy R&D.

Finally, the company aims to unlock spin-off effects by basing their products for space on products that were originally designed for earth-based purposes. The company achieved spin-off effects by adjusting their earth-purpose product to the space environment. After technological innovation and product enhancement was achieved as a result of that process, the company would apply the improvements to the original product and thereby achieving positive synergetic effects for the company.

5.12.1.2 Weaknesses (W)

Even though the small size of the Norwegian commercial space sector is listed as a strength for Norwegian space companies, it is also listed as a weakness. It can be argued that the small size of the sector contributes to relatively little international attention as a whole, thereby

creating a need for and dependency of stimulus through state spending for the growth and sustainment of the sector. This is a crucial factor why the Norwegian commercial space sector must be considered to operate in an immature market.

According to (source 2) the relatively small size of his company prevents the company from rapid growth: Even though multiple market opportunities are identified, the company is unable to pursue them due to the constraints within the company. The main constrain is the lack of ability to recruit personnel with the right kind of qualifications and experience.

Securing the right kind of personnel with the right combination of qualification, experience and motivation seems to be a possible bottleneck for the further growth of Norwegian commercial space companies. And ironically, the oil and gas industry that was listed as a strength may be one of the main culprits to this fact: Since the oil and gas industry is clearly the largest sector in Norway, it also attracts vast amounts of intangible resources, especially in the form of engineers. It is reasonable to assume that the finite amount of talent leads to a struggle between multiple sectors to secure this important intangible resource in Norway. This struggle seems to be a clear source of weakness for the Norwegian space companies.

5.12.1.3 Opportunities (O)

As mentioned, both in the strengths and weaknesses chapters, the oil and gas sector is a dominating factor in the Norwegian economy. As a result of global warming and other environmental concerns this sector is facing a rising population opposition. There is a heated debate in Norway whether search for new oil and gas fields should be continued or not, and whether the oil and gas chapter in Norway should be stopped and when. There are strong forces in play that want Norway out of this polluting industry before the natural resources are depleted. In other words, it is now not a question of whether Norway will move away from oil or not, but it is a matter of when.

A sooner-rather-than-later approach to the conundrum of “peak-oil” in Norway signifies an opportunity for the Norwegian commercial space sector for multiple reasons: 1) environmental factors lead to considerable pressure to reduce and ultimately end Norway’s largest commercial sector (oil & gas), 2) political leaders have a responsibility to shape and secure Norwegian income after the oil & gas era, 3) the Norwegian oil & gas sector was developed through significant political and economic support and similar endeavours could be done for the commercial space sector, 4) the oil and gas industry possesses significant

intangible resources that is needed in the Norwegian space sector, 5) the relatively high salary of Norwegian employees makes the workforce little competitive for less complex jobs, but highly competitive for jobs that require a high technological understanding like engineers, 6) the flat structure and efficiency of the Norwegian work culture is a good fit for innovative companies.

Another sector that has strong traditions in Norway is the energy sector. Historically, hydropower was a significant factor in attracting industries to Norway that required access to vast amounts of energy such as aluminium and fertilizer production. According to (source 1) the strong Norwegian traditions within the energy sector could lead to opportunities in space. Oil and gas and the possibilities of migration of talent has already been covered, but some Norwegian companies also have a strong position within production of raw resources that is used for solar power panel production. Furthermore, Norway also houses companies and expertise within the fuel cell technology that could prove valuable for space applications.

As discussed in detail in earlier chapters, the efforts of the NSA with regards to allocating ESA contracts and the funds managed by the NSA for feasibility studies provide important possibilities for the Norwegian commercial space sector. According to (source 2) these efforts were paramount for the company's efforts within the space sectors. Future public funding of NSA and ESA will ensure future contracts and will allow the Norwegian commercial sector to grow and the market to mature. (Source 2) also perceived a heightened political interest in the space sector.

According to (source 2), the increased efficiency and reduced costs of space travel has resulted in an increasingly competitive "space-based solution" to problems in several new areas. The rationale being that as costs of space operations go down, many old problems can be solved better or more efficiently from space. An example is global navigation and communication where expensive ground-based equipment has been replaced with a more cost-efficient solution of GPS and satellite communications. Other examples can be search for wildfires and pollution or surveillance of fishing fleets that all can be solved by using satellite imagery instead of committing personnel and materiel to the mission. Or space-based internet, such as Starlink, that can compete with local internet service providers on many countries. It is reasonable to assume that the future will include an increasing number of space-based solutions to both old and new problems.

As stated in earlier chapters, NSA is a key factor to matching Norwegian industry to ESA contracts. NSA is proactive in the search for new companies that could potentially be awarded ESA contracts. Some of these companies do not yet know of these possibilities and the potential of expanding to new markets such as commercial space. Many of these companies could most likely enjoy synergetic effects as well as increasing the base of income if advancing to the space sector. According to (source 1), there is still unfulfilled potential within the collection of Norwegian companies to be matched with ESA needs for space activity and future contracts.

5.12.1.4 Threats (T)

The largest threat to Norwegian companies is most likely the high dependency upon state spending. As discussed in earlier chapters, the combination of a small market for space activities and a relatively immature market in general leads to state spending being a condition for activity in the Norwegian commercial sector. Should Norwegian state spending be reduced or ended in the space sectors there is little left for purely commercial markets, according to (source 2). It is reasonable to assume that most current companies with a footprint in space would soon leave the sector if this was the case.

Other threats to companies that are engaged for contracts is loss of cost control and lack of personnel. According to (source 2) an updated overview of the incurred and projected costs is essential to ensure mission success for a private company operating with a fixed price contract or an award scheme. The company must work continually toward meeting the specifications that are required, but not overshooting them as an overshoot is most likely a driver of costs.

As for the lack of personnel, there is a clear contest between companies and sectors to attract talent. Personnel with the right combination of knowledge, experience, motivation and talent is described as a scarce resource in Norway and a bottle neck for the company's ambition for growth, according to (source 2). Being a relatively small, the company of (source 2) is vulnerable to loss of personnel or illness. And this is particularly the case in the phases that involve product development or R&D. A lack of personnel in these phases could lead to problems with regards to cost, time or quality when attempting to meet a contracted specification.

5.13 Case study – Market entry of a Norwegian company

The commercial space sector is often claimed to have a high barrier for entry into the markets, and rightfully so. For this reason, it is particularly interesting to discover how this is done in a Norwegian setting. The interview with (source 2) provided such an opportunity. Since this chapter is based on one interview with only one source this is a case study and cannot be considered as something that is generic to the Norwegian space sector. It does however provide valuable insight into the decisive events that took place for a successful market entry.

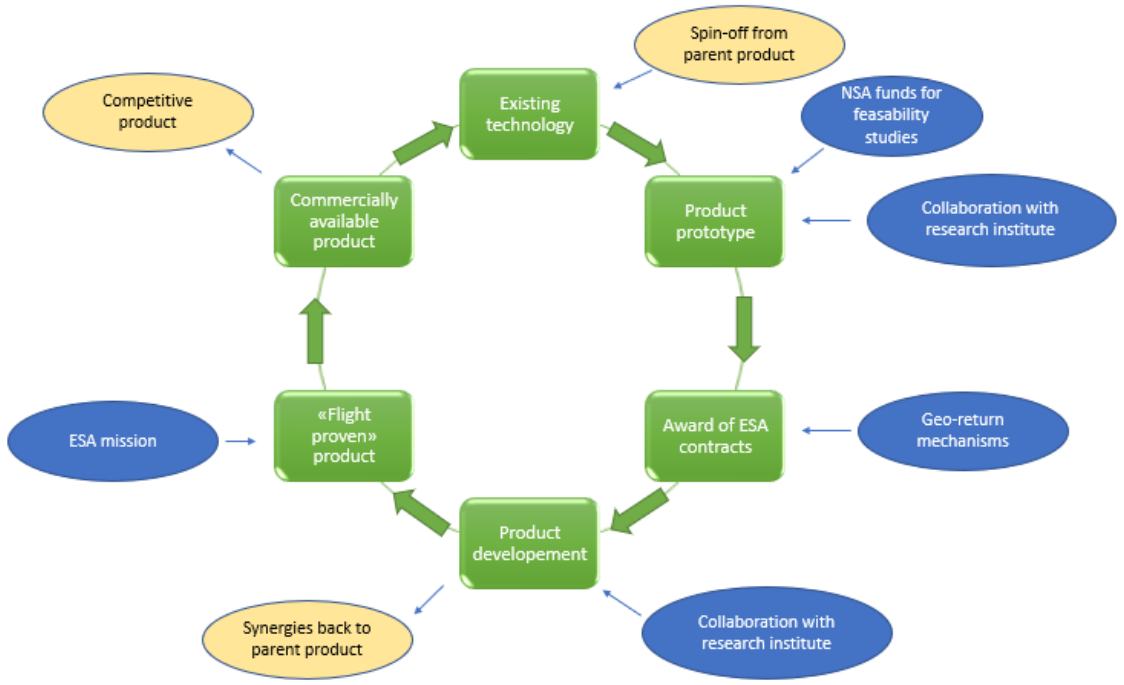
The company of (source 2) was a small size tech company before the entry into the space sector. NSA searched the Norwegian commercial landscape for companies that could potentially fulfil an ESA contract for equipment that would be used in space. The company of (source 2) was contacted by NSA regarding the ESA contract. The company had an existing portfolio and business model that served earth-based purposes that it considered possible to adjust to fulfil the ESA contract. The company assessed that little adjustments were necessary to adjust the existing technology thereby effectively lowering the entry barrier through spin-off effects.

NSA provided funds for feasibility studies for the company. The feasibility study was intended to uncover whether or not such an adaptation of existing technology could be done by producing a prototype. The feasibility study was conducted in close collaboration with a local university. Collaboration with the local university allowed a reduced R&D impact to the company itself, hence reducing the need for short term recruitment. The feasibility study produced a successful prototype and the company applied for the ESA contract. ESA is obligated to return the same number of contracts back to the Norwegian state as is attributed to ESA (geo-return mechanism). ESA selected the company as the contractor for the product for which it applied.

The company continued product development in a continued collaboration with the research institute and worked adjusted the project as necessary to meet economic viability through a thorough cost control during development. The product development had several results: 1) The contract was met and the company was award the fixed price of the contract, 2) the product was now “flight proven” essentially making the product available on a commercial market, 3) the product can now be sold as-is without the need for R&D, increasing the profit for the company, 4) the enhancements of the new product over the original product where

applied to earth-based applications through spin-in effects, 5) profit from future sales can be spent toward new product development cycles and thereby growing the company. The figure below illustrates the product development cycle of the company.

Figure 5.6: Case Study - Market entry of a Norwegian company



6.0 Conclusion

In this chapter I will present the conclusions of the research process and its practical and theoretical implications.

6.1 Conclusion

The critical issue of this master's thesis was: "What makes commercial space activities economically viable for a Norwegian company?" to answer this broad question four research questions were formulated. The first research question asked "what are the drivers and barriers that impact economic viability of commercial space activities?". Through the research process multiple factors were identified, and these were presented in chapter four in its entirety. Although the factors were too many to be listed here, the most crucial factors were found to belong to the political category and economic and market category. This underlines the strong dependency between economic viability of the commercial space sector and the

significant role of the host state. The state dependency of the Norwegian commercial space sector, among other factors, is the rationale behind why the Norwegian commercial space market can be characterised as an immature market. Further, the political category was found to be the strongest determinator when it comes to the maturing and evolving of immature markets, since it is political action that has the most impact when it comes to addressing market failures and ultimately allowing a market to achieve self-sustainability and economic viability.

The second research question was formulated as "what have been the historical events on the path toward a viable space economy?". The main historical event in such as respect was found to be the space race between the US and the Soviet Union in the 1950s and 1960s. This race was motivated by a rivalry between two different ideologies. This form of rivalry was found to be a strong motivator and source of public support across multiple domains. NASA was successful in delivering national prestige through the Gemini and Apollo programs through a centralised system where NASA was in charge of development and was supported by, and instrumental to multiple contractors in a growing commercial space sector. The second significant historical event was the failure of the Space Shuttle program. The failure signified a change of direction for NASA where it moved to a decentralised system incentivising commercial actors to fill the void after the termination of the costly and risky Space Shuttle. NASA largely adopted a philosophy of being a customer instead of a developer, allowing it to refocus on its primary goals of science and space exploration. For the commercial space sector this signified a changed dynamic with more responsibility, freedom and risk, but also higher potential for profits.

The third research question asked, "what are the current trends towards an economic viable commercial space economy?". The short answer is that the majority of market failures in Norway appear to be countered by efficient measures, however they are modest in force. A considerable increase in state spending over multiple years would be necessary to create a commercial space sector that would be robust and competitive enough to be an active part of a mature self-sustaining market. Of special note is the ESA contract award system which operates with a geo-return mechanism which has a profound positive impact on Norwegian commercial space sector. This means that almost every Euro the Norwegian government spends funding these programs, will be returned to the Norwegian economy. A second positive player in the Norwegian space sector is the NSA. It is proactively scanning the

Norwegian commercial landscapes for companies that might be eligible for ESA contracts. Further NSA also provides funding for initial feasibility studies. These two actions in combination successfully enable a lowering of the barrier of entry into commercial space.

Finally, the last question asked, "what are the strengths, weaknesses, opportunities and threats for a Norwegian company intending to perform commercial activities in space?". What differentiates Norway from many other comparable western countries is its level of dependency and investment in the oil and gas sector. The sector is the largest source of income for Norway and it is one of the largest employers. It also represents a large part of Norway's intellectual talent. The long Norwegian traditions for a strong oil and gas sector can be a source of strength since the oil and gas sector has many similarities to the space sector with respect to requirements to operate in challenging environments, high technological dependency and costly infrastructure. This fact also represents an opportunity since it is reasonable to assume that much of the talent employed by the oil and gas sector would also be quite efficient in the commercial space sector. However, the oil and gas sector also represents a weakness and a threat to the space sectors since oil and gas is highly competitive and is successfully securing the majority of Norway's intellectual talent, a scarce resource in a low population country such as Norway. The ambitions of reduced Norwegian dependency upon and ultimately a move away from the oil and gas sector is a significant opportunity: For the commercial space sector an opportunity to secure talent, and for the Norwegian economy an opportunity develop a footprint in a growing market with significant potential for profitability.

In summary, Norwegian commercial space companies can be economically viable. They do currently operate in what must be characterised as an immature market. The good news is that public agencies have efficient mechanism in place to counter the majority of the market failures, but these are dependent on increased state spending to be effective. The economic viability and growth of the Norwegian commercial space sector is currently highly dependent on state spending. It is reasonable to assume that an increase in the level of public spending on space programmes and a clear political investment on the commercial space sector would be beneficial for the Norwegian population, and this should be considered as a possible successor to the oil and gas adventure from which Norway owes much of its prosperity and social benefits.

6.2 Practical implications

The Norwegian commercial space sector is modest, but it is increasing in size. It is highly likely that more companies will be evaluating the option of expanding parts of their business into the space domain. As such, this thesis can provide an insight into the main factors that impact the economic viability of a company in the commercial space sectors in general and the Norwegian space markets specifically.

Further the thesis may provide useful insight for political players at various levels of the Norwegian government. Both by providing data from the perspective of the commercial company and by providing updated insight based on a scientific process. This is especially important for two reasons: As this thesis argues, the most crucial factor as to the economic growth and maturing of the commercial space market is political action. And second, Norway is deeply dependant and invested in the oil and gas sector. For multiple reasons that dependency will have to end in the long term. The commercial space sector represents an interesting and achievable opportunity for Norway's next economic venture.

6.3 Theoretical implications

This master's thesis covers a subject that has received little scientific attention in the past. The Norwegian commercial space sector represents an emerging market with a substantial potential. The scientific research process that forms the basis of this thesis has provided insight into an understudied field: The Norwegian commercial space sector. Data has been provided from multiple perspectives according to the PESTEL and SWOT model. Further a case study has provided a model of how market entry was performed by one particular company. It is likely that other companies will be able to follow the same model.

Future researchers are encouraged to utilise the data of this thesis. It would be interesting to see extended research into the level of maturity of the Norwegian commercial space market, perhaps it can be operationalised further to the point where it can be quantified and measured using quantitative methods.

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Appendices

Appendix 1 – Interview guide (Norwegian)

Intervjuguide

Introduksjon

Intervjuet inngår som en del av kildegrunnlaget for en masteroppgave ved Nord universitet. Masteroppgaven er planlagt fullført ila juni 2022. Temaet for masteroppgaven er privat næringsvirksomhet i verdensrommet, med spesiell fokus på teknologi og økonomi. Problemstillingen for masteroppgaven er *«What makes commercial space activities economically viable for a Norwegian company?»*. Gjennom oppgaven forsøker jeg altså å undersøke de teknologiske og økonomiske forutsetningene for næringsvirksomhet tilknyttet aktivitet i verdensrommet, sett fra en norsk bedrifts perspektiv. Videre ønsker jeg å undersøke om disse forutsetningene er i endring og hvilke styrker, svakheter og muligheter som finnes for norske bedrifter.

Intervjuteknisk

Intervjuet er såkalt semistrukturert som betyr at noen temaer og spørsmål ligger til grunn for å innrette samtalen, men intervjuer står fritt til å endre retningen av intervjuet basert på informasjon fra personene som intervjues. Du som intervjuobjekt oppfordres også til å komme med informasjon som kan være relevant i denne sammenheng dersom dette ikke dekkes i tilstrekkelig grad av intervjuer.

Spørsmålene og svarene kan med fordel innrettes etter følgende kategorier:

- Politiske faktorer
- Økonomiske faktorer
- Samfunnsmessige faktorer
- Teknologiske faktorer
- Miljømessige faktorer
- Juridiske faktorer

Temaer og spørsmål for intervjuet

For en norsk bedrift som ønsker å satse på næringsvirksomhet i eller i tilknytning til aktivitet i space:

- Hvilke faktorer øker økonomisk lønnsomhet?
- Hvilke faktorer hindrer økonomisk lønnsomhet?
- Hvilke forutsetninger må være på plass for at privat næringsvirksomhet i space skal være økonomisk lønnsomt idag?
- På hvilke områder er utviklingen størst (positiv og negativ) med tanke på økonomisk lønnsomhet for din bedrift?
- Hvilke tidligere hendelser har påvirket din bedrifts lønnsomhet mest (i positiv og negativ retning), tilknyttet aktiviteter i space?

- Hvilke styrker og svakheter representerer din bedrift sett i forhold til konkurrerende bedrifter?
- Hvilke muligheter og trusler står din bedrift ovenfor i konkurranse med andre bedrifter?
- Finnes det faktorer (positive og negative) som oppleves som særnorske som påvirker norske bedrifter i større grad enn utenlandske når det kommer til satsing på virksomhet tilknyttet aktivitet i verdensrommet?

Avslutning

Er det noen temaer som er sentrale som vi burde ha snakket om, men som ikke har blitt dekket så langt i intervjuet?

Er det ok å kontakte deg for eventuelle oppfølgingsspørsmål?

Appendix 2 – Declaration of consent (Norwegian)

Vil du delta i forskningsprosjektet

"Commercialization of space – The Search for Economic Viability for Norwegian Companies Conducting Space Activities»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å belyse faktorer som bidrar til å øke, og faktorer som bidrar til å hindre at privat næringsliv ønsker å satse på næringsvirksomhet i verdensrommet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Intervjuet inngår som en del av kildegrunnlaget for en masteroppgave ved Nord universitet. Masteroppgaven er planlagt fullført ila juni 2022. Temaet for masteroppgaven er privat næringsvirksomhet i verdensrommet, med spesiell fokus på teknologi og økonomi. Problemstillingen for masteroppgaven er *«To what degree are commercial space activities economically viable for a Norwegian company?»*. Gjennom oppgaven forsøker jeg altså å få frem drivere og barrierer for norske bedrifter som ønsker å satse på næringsvirksomhet tilknyttet virksomhet i verdensrommet. Opplysningene som innhentes i intervjuet vil kun bli benyttet i forbindelse med denne masteroppgaven. Opplysningene kan ikke benyttes til andre formål uten ditt samtykke.

Hvem er ansvarlig for forskningsprosjektet?
Nord universitet er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Intervjuobjektene som er forespurt om å bidra i forbindelse med denne oppgaven er utvalgt basert på deres ekspertise innenfor sitt respektive felt. Intervjuer fra flere organisasjoner og bedrifter vil inngå i kildegrunnlaget til oppgaven. Dette er organisasjoner og/eller bedrifter som har en direkte tilknytning til næringsvirksomhet i verdensrommet i en eller annen form.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du sier deg villig til å bli intervjuet. Intervjuet vil ta ca 45 minutter. Intervjuet vil inneholde spørsmål relatert til virksomhet i verdensrommet. Intervjuer vil ta notater underveis i intervjuet. Informasjon vil også samles fra andre informanter gjennom lignende intervjuer, samt skriftlige kilder slik som bøker, journaler og nyhetssaker.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine opplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Det er kun prosjektgruppen bestående av studenten og veilederen som vil få tilgang til opplysningene om deg (navn og e-post) samt notatene fra intervjuet.

Ditt navn vil bli avidentifisert i vårt datagrunnlag. Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data.
Ditt navn eller navnet på din bedrift eller organisasjon vil ikke bli publisert i endelig utgave av masteroppgaven.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er juni 2022.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Nord universitet har Personverntjenester vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Nord universitet ved Ove Jacobsen: ove.d.jacobsen@nord.no
- Vårt personvernombud: Toril Irene Kringen: toril.i.kringen@nord.no

Hvis du har spørsmål knyttet til Personverntjenester sin vurdering av prosjektet, kan du ta kontakt med:

- Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 53 21 15 00.

Med vennlig hilsen

Ove Jacobsen
(veileder)

Joakim A. Wesetrud
(student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *«Faktorer, trender og timing av vekst i privat næringsvirksomhet i verdensrommet?»*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)