Julius Haukkala

Financing Space Travel & Exploration:

An industry analysis

Helsinki Metropolia University of Applied Sciences
Bachelor of Business Administration
International Business and Logistics
Bachelor's Thesis
08.11.2017

Helsinki Metropolia University of Applied Sciences

Author Title Number of Pages, date	Julius Haukkala Financing Space Travel & Exploration: An industry analysis 28 pages + 1 appendix, 08.11.2017
Degree	Bachelor of Business Administration
Degree Programme	International Business and Logistics
Specialisation option	
Instructor	Marko Korkeakoski, Lecturer

The purpose of this thesis is to examine and analyse how the space race has changed from a cold-war era arms race between two superpowers, the United States and the Soviet Union into a more complex and developed industry with many players from both private and public sectors all around the world wishing to participate in the frontier of technological advancement and space exploration.

This thesis will analyse the topic of space travel and exploration and the space industry in general through the lens of politics, science, business and nations. Overall, the industry will also be contextualized from a historical perspective, highlighting the importance of discovery to the development of civilizations, examining some of the long-term effects of discovery that can be seen today as a result.

Keywords	Space Exploration, Space Industry, Technology

Contents

1. Introduction

I decided to choose financing space travel & exploration as my thesis topic due to several reasons. Firstly, the topic encapsulates a variety of subjects and areas of learning that I have undergone during my international bachelor level studies in Helsinki Metropolia University of Applied Sciences including logistics, international business, economics, marketing and finance.

Second, the space industry will most likely become more relevant in business and in our daily lives as technology advances – this thesis provides accurate insight into the state of research, businesses and technology currently involved in the space industry. As organizations such as the National Aeronautics and Space Administration (NASA) continue to make advances in technology and continue to make the technology available to the private sector through commercialization, barriers to entry will lower, prompting the industry for further growth, which will result in the space industry becoming increasingly relevant in a business context in the future.

The goal of this thesis is to give the reader the most accurate, up to date picture of the space industry by providing examples of contemporary cases reported and discussed by journalists, authors, scientists, politicians, businessmen & women and other entities involved in the industry. The purpose of the information gathered in this thesis is to enlighten the reader of the topic and help the reader form their own opinion of the topic, it's importance and the future outlook of the industry, supported by contextualized analysis of the cases. In other words, this thesis can be summarized as a collection cases related to the space industry, viewed from different perspectives relevant to the degree programme.

As opposed to traditional & saturated industries such as oil & metal, the space industry is at a stage where companies and governments alike are still trying to navigate what they want and what they are able to gain as tangible payoffs when investing into and supporting the space industry. Payoffs of space exploration can be wide spanning, since technologies originally developed by organizations in the industry may be used for entirely different purposes by military & commercial interests, for example. This

thesis intends to shed light onto the different usages of technologies developed in the space industry, while also looking at the different motives and agendas that have driven private and public entities in the past and what might drive these entities to pursue similar ventures in the future.

Lastly, this thesis was a great opportunity to combine personal interests with the academic knowhow gathered during my studies. I hope that this thesis will give you, the reader a better grasp of what the human race as accomplished in this frontier thus far and will leave you more knowledgeable and hopefully inspired about the future similar to how I have been inspired during the completion of this thesis.

2. Research Methods

2.1 The research question

The research conducted in this thesis ultimately seeks to answer the research question and provide reasoning to **why private and public entities finance space travel & exploration and why it is important**. The main research question, the catalyst of this paper, is followed by questions of how space travel & exploration is financed, what kinds of entities are involved in financing space travel & exploration, how the financing of space travel & exploration effects society and what are the implications on the industry in the future.

2.1 Research methodology

The information in this paper is collected mainly through qualitative & quantitative secondary data found in the internet in the form of articles, books and corporate publications. In order to answer the research question comprehensively, it is important to critically examine and analyze both the benefits and negative aspects of investing into the field of space travel & exploration.

The importance of historical data cannot be undermined, since history gives us valuable information regarding motives for investing into similar ventures and has shown the effects that these ventures have had on society. However, one challenge regarding the application of research methodology is the qualification of data in the context of determining the effects of more hidden and subtle causalities that investing into space ventures could have on society, such as scientific enlightment (more people aspiring to become astronauts or astrophysicists) or literature (Sci-fi boom, which could also affect movie and gaming industries, for example).

2.2 Analytical approach

The research conducted aims to objectively provide comprehensive content analysis regarding the subject matter of financing space travel & exploration. Presentation of implications and findings related to the research through reviewed literature is not designed to give final conclusions or answers regarding the research question, but rather to give multiple contextual viewpoints into different historical and present day activities and projects, refining the reader's understanding of the topic and helping the reader to understand the causal relations and motives that effect the topic and research question in different ways. The goal of this research paper is not in providing final answers to the questions at hand, but rather to inspire the reader to question more and to view the topic from a more critical and enlightened perspective, which can lead to different conclusions or further questions, depending on the reader.

2.3 Limitations

Progress, discoveries and technological advancements are made daily in the frontier of space exploration, which is why the reporting and analysis of all the key events that have led to the current space industry existing today would have been impossible and ineffective to combine for the purposes of this thesis. Therefore, the information documented and discussed in this thesis has been narrowed down to relevant subjects that have significance in relation to the development and current state of the industry, which also support in answering the research question for this thesis.

3. Space Travel & Exploration

3.1 Literature review

The literature reviewed in this chapter offers multiple viewpoints to the research question why private and public entities finance space travel & exploration from different perspectives such as cash flows, incentives, return on investment & opportunity cost. This chapter also focuses on the critical assessment of similarities and differences between governmental and private funding of different space travel & exploration ventures.

3.1.1 The current status of relevant literature

The National Aeronautics and Space Administration (NASA) is considered the most formidable and reliable source of scientific data related to space exploration due to the resources that the institution has at its disposal. Most authors that write about space exploration use the data collected and presented by NASA in their publications.

Some of the most notable authors in the area of space travel & exploration are astrophysicists such as Neil deGrasse Tyson & Carl Sagan, largely due to the scientific nature and the relevance of physics in relation to outer space regarding the topic. However, since 2011 and the closing of NASA's government funded Space Shuttle Program, there has been an increase in investment for different privately owned space programs due to the opening of the market, which has also resulted in an increase in the amount of literature that is published about the financing of space travel & exploration.

Most of the literature about the financing of space travel & exploration is published through trade journals and websites in the form of articles. The majority of the articles that are published about the topic contain speculation & debate about the necessity, opportunity cost & ROI of financing space travel & exploration. Many articles also include interviews with experts who give insight into not only the financial benefits of space exploration, but also the social, economic and technological benefits of space exploration, for example.

3.1.2 Critical appraisal of major references

Contemporary literature tackles the debate between private investment and public funding. In terms of space travel, entrepreneurs such as Sir Richard Branson and Jeff Bezos have founded privately owned companies called Virgin Galactic and Blue Origin to offer space tourism services in the future. On the contrary, very few private investors and companies have tackled the challenge of space exploration, possibly due to the higher and unknown risks that undiscovered space possesses, as well as being more expensive then conducting space travel on low-earth orbit (LEO), for example.

According to Neil deGrasse Tyson, government funded organizations such as NASA should be leading the frontier of space exploration in order to predetermine the risks involved for parties such as private investors in order to create a capital market valuation to determine the possible risks and costs that space exploration possesses.

According to John M. Logsdon, director of the Space Policy Institute and acting director of the Center for International Science and Technology Policy at George Washington University's Elliott School of International Affairs, "The high costs of sending humans into orbit and beyond are measured in dollars, rubles, or yuan. The benefits of human spaceflight are not so easily calculated, since they include both tangible and intangible payoffs" (Dubner, 2008).

Neil deGrasse Tyson, astrophysicist & the author of Space Chronicles: The Ultimate Frontier (2012) is along the same lines with Logsdon, stating that the issue of qualifying the merits of space exploration was the main focus of his book and also something that he found extremely difficult to answer.

In his book Tyson (2012: 6) also argues that even though NASA is an organization that exists for scientific purposes, it was actually founded on the basis of the fear factor possessed by the threat of the USSR Sputnik Space Program, which was originally designed to contain a nuclear warhead instead of satellite transmission. He argues, that this specific threat that the Russians posed to the national security of the United States was the exact thing that led to the foundation of NASA and the space race in general.

Tyson supports this claim by assessing the budget structure of NASA, of which throughout the years has had an average split of 25% for scientific research and the 65% budgeted for geopolitical purposes. Tyson also inspects this from a historical point of view, claiming that throughout human history, the parties that have emerged victorious in war are usually the ones with superior technology. In short, Tyson argues that despite the fact that NASA is a scientific organization, it is more so a political institution created in order to serve the national interests of the United States.

In terms of literature and debate related to the topic qualifying the merits & payoffs of space travel & exploration, the issues stated by both Logsdon & Tyson hold true. For example, NASA has been criticized for spending $2.5 billion on the Curiosity rover expedition that was designed to reach and investigate the possibility of life on Mars, with Curiosity reaching the surface of Mars on October 31st, 2012. The majority of the expedition if funded through taxpayer money, which raises the question weather the money invested into the expedition will benefit the average citizen living in the United States.

On the other hand, NASA and space exploration in general has brought many benefits to human civilization that many people take for granted, such as satellite networks that provide satellite television and weather forecasts that provide information about hurricanes and other storms that can save lives, for example. Moreover, the NASA budget for 2017 is about $19 billion, which amounts to 0, 5% of the Federal Budget of the United States. Consequently, the NASA budget is the smallest of all the Federal Government Agencies in The United States, which shows that the financing and operational costs of NASA are not necessarily as large as they seem in the context of the Federal budget of the United States, for example.

A recent example of the type of payoff that space exploration can bring can be seen from The German/American Gravity Recovery and Climate Experiment (GRACE), which is scheduled to end in 2017. The two satellites were launched in 2002 and have spent the last 15 years in orbit, giving valuable insight and data regarding how our planet has changed during that time. In other words, the experiment has lasted three times longer than expected and has given invaluable data regarding contemporary global issues such as climate change (Szondy, 2017).

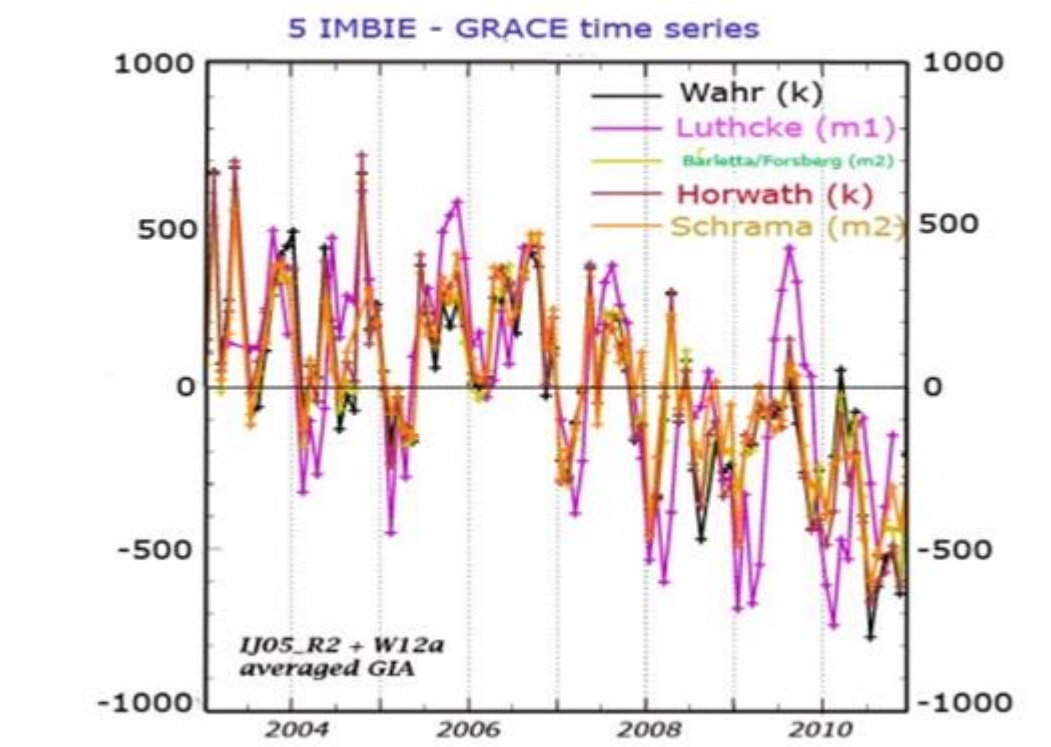


Figure 1. Monthly changes in Antarctic ice mass, in gigatons, as measured by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites from 2003 to 2011 (NASA-JPL/Caltech, 2013).

GRACE satellites have also provided data regarding Greenland ice loss between 2002 and 2017. According to the study, Greenland has lost approximately 280 gigatons of ice per year, causing sea levels to rise 0,8 millimeters per year (GRACE Tellus, 2017). GRACE satellites have also been valuable in predicting flooding around the world. Flooding is projected to become more frequent as warming temperatures amplify the atmosphere's water holding capacity and increase the occurrence of extreme precipitation events.

3.1.3 Identification of a specific research problem arising

One of the largest stepping stones regarding the research for this thesis was the relatively small amount of reliable academic literature that has been published related to the topic. Reasoning for this could be due to the fact that the topic of space travel & exploration mostly covers the science of physics rather than finance. Researching the topic from the financial perspective brought up multiple articles that mostly facilitated debate rather than offered data regarding the finances of space travel & exploration. Finding reliable fiscal information for privately held companies was also difficult due to the lack of transparency and data regarding the amount of money invested into and by privately owned companies as well as how companies involved in the space industry have decided to allocate funds for their respective projects and how these investments translate into their services or products.

3.2 Commercialization of space

The obscurity of illustrating the industry, market & companies involved in space travel & exploration also varies significantly amongst different authors of the topic. Some authors might see NASA as a monopolist, some see NASA as competition for privately owned companies and some authors see all the companies collaborating together towards a larger goal. For example, NASA, a United States government owned company has contracted and outsourced several of their operations to other companies, including low-earth orbit (LEO) related operations such as the transportation of supply and crew members to the International Space Station (ISS) to the Boeing Company for $4,2 billion and to the Space Exploration Technologies Corporation (SpaceX) for $2,6 billion (NASA, 2014).

Speaking at International Astronautical Congress in 2017, SpaceX CEO Elon Musk revealed an ambitious project in the company's quest to colonize Mars in the future. Called the Interplanetary Transport System, the company will focus on creating infrastructure for transportation between Earth and Mars. In a plan published in September 2016, The design includes fully reusable launch vehicles, human-rated spacecraft, in-orbit propellant tankers, launch pads supporting rapid turnover, and local production of rocket fuel on Mars via in site resource utilization (ISRU). In his speech, Musk revealed

the SpaceX plan of cannibalizing its previous products such as the Falcon, Dragon and Heavy, making them obsolete once the Big Falcon Rocket (BFR) is completed and ready for Mars. Along with utilizing the technology used in previous SpaceX rockets, the BFR will be 100% reusable, meaning that it will be able to travel back to Earth from Mars during the timespan of the mission.

As of 2017, SpaceX is arguably the most well-known NASA contractor and due to the steady yearly percentile decline of the annual NASA budget compared to the Federal Budget of the United States since 1967, NASA has become increasingly open to contracting and funding from the private sector in search of additional funding. The research paper "An Assessment of Cost Improvements in the NASA Commercial Orbital Transportation Services (COTS) and Commercial Resupply Services (CRS) Program and Implications for Future NASA Missions" published by Edgar Zapata in 2017 calculates the current improvements in cost efficiency related to several NASA missions that previously have been solely funded and operated by NASA. Parts of the missions have been contracted to private companies such SpaceX, Boening & Orbital ATK.

Eric Berger from Arstechnica provides an in-depth analysis of Zapata's research in his article "In-depth study: Commercial cargo program a bargain for NASA", published in August, 2017. According to Berger, Zapata uses life cycle cost analysis by using publicly available COTS data and depicts cost improvements in COTS/CRS figuratively by using a comparative scenario, where the NASA funded Space Shuttle would have fulfilled the ISS cargo requirement versus the COTS/CRS launchers and spacecraft. Zapata's findings and calculations based on future projections show that the supply services offered by SpaceX and Orbital ATK have cost NASA roughly three times less than if the space agency had continued to fly the space shuttle.

In his article, Berger highlights calculations undergone by Zapata which show that SpaceX has cost $89,000 per kg in delivering cargo to the ISS. Orbital ATK on the other hand has cost $135,000 per kg with somewhat similar logistical operations. Without the participation of SpaceX or Orbital ATK, NASA's Multi-Purpose Logistics Module would have cost $272,000 per kg. SpaceX's Dragon and Boening's Starliner will begin participating in NASA's commercial crew program with flights scheduled to begin in 2019 (Berger, 2017).

According to Berger, the study estimates that the cost of rotating a crew of four astronauts span from SpaceX projection of $405 million to Boening's projection of $654 million. In comparison, the two companies would be estimated to operate at 37 to 39 percent of the cost as opposed to NASA continuing the Space Shuttle Program (Berger, 2017). By opening the ISS to private companies and competition, NASA has effectively been able to diversify and become more redundant in the case of cargo supply failures, having multiple companies available for commissions in case of emergencies instead of relying on one set of supply equipment and technology.

Zapata's research paper, which was commissioned by NASA also examines other post-Shuttle contracting conducted by NASA such as the Commercial Crew Programme (CCP), which is the sister program of COTS cargo program. Overall, the research paper by Zapata shows that the contracting of these operations has already resulted in cost savings for NASA by opening low-earth orbit ventures for private business. However, Zapatas findings and estimates are widely based on future predictions related to current operations and missions. Due to the complex nature of the industry and difficulty of cost allocation, it remains to be seen how accurate Zapatas calculations remain in case of altering factors such as rapid technological advancement, competing contractors & a continuing trend of a relatively declining NASA annual budget, for example.

Different low-orbit resupply missions by companies such as SpaceX and Orbital ATK support different scientific research and expeditions undertaken at the ISS by NASA. According to Katherine Brown, NASA's Press Release Editor, the latest launch by Orbital ATK, Cygnus is scheduled to arrive at the ISS on November 14th, 2017 will deliver 7,200 pounds of cargo and equipment related to studies on antibiotic resistance, high-speed data transmission, plant growth and improved power and communication technologies (Brown, 2017).

According to Brown, ”The E. coli AntiMicrobial Satellite (EcAMSat) mission will investigate the effect of microgravity on the antibiotic resistance of E. coli, a bacterial pathogen responsible for urinary tract infection in humans and animals”. The mission could provide important information regarding antibiotic resistance in space, since microgravity has been shown to weaken human immune response. According to Brown, ”Results

from the investigation could help determine appropriate antibiotic dosages to protect astronaut health during long-duration missions and help us understand how antibiotic effectiveness may be increased in microgravity, as well as on Earth". The Optical Communications and Sensor Demonstration (OCSD) project will test laser-based communication by using CubeSats technology (Brown, 2017).

CubeSat, first developed in 1999 by California Polytechnic State University (Cal Poly) and Stanford University is a miniaturized satellite which can be built purely on commercial off-the-shelf (COTS) components. In other words, CubeSat provides some of the lowest barriers to entry for entities wishing to participate and finance space exploration. However, current launch systems and infrastructure raise barriers to entry, since all launched CubeSats must be hitched as secondary payload on large rockets launching much larger spacecraft, at prices starting around $100,000 (Dean, 2015).

CubeSats will also be delivered by Cygnus to the ISS to be used in The Integrated Solar Array and Reflectarray Antenna (ISARA) project on November 14th, 2017. According to NASA's Jet Propulsion Laboratory, "the ISARA mission will demonstrate a high bandwidth Ka-band CubeSat communications capability that is ready for immediate infusion into commercial, government and military systems" (see Appendix 1). Once applied, the project will increase downlink data rates 105 fold from a baseline 9.6 kbps to over 100 mbps, resulting in an increase in data capacity. The project, sponsored by NASA's Small Satellite Technology Program, will enable smaller satellites such as CubeSats to process data which would earlier have been possible by only much larger spacecraft, thus reducing long-term infrastructure costs for future missions related to commercial, government and military entities involved in space exploration (NASA/JPL, 2017).

3.3 NASA & the United States government

In order to understand why governments and individuals seek to finance space travel & exploration, it is important to discuss and examine the motives behind their behavior. Linda Weiss, Professor Emeritus of Comparative Politics at the University of Sydney & author of ”America Inc.?” (2014) argues in her book that all the major advanced industries of the past sixty years have been pioneered in the United States. Weiss argues that these technological advancements have been located in the United States for the benefit of the U.S. Government due to the strategy and role that the National Security State has over different industries in the United States. Consequently, Weiss argues that the main goal of the NSS is to ensure that technological advancements in industries that serve the interests of the U.S Government can be used and capitalized on for economical and geopolitical purposes by the U.S Government.

This imposes the question, what does the argument by Weiss have to do with financing space travel and exploration? Firstly, it provides a link between the U.S Government and NASA through the NSS, which NASA is a part of. Originally founded in 1947 by U.S. President Harry S. Truman through the National Security Act, the National Security State consists of three federal departments (Defense, Energy & Homeland Security) and four agencies (CIA, NASA, The National Science Foundation & the National Institutes of Health). In order to better understand the relationship between NASA and the U.S Government, it is important to understand the definition of NASA and how it is designed to serve the interests of the U.S. Government. The relationship between these two parties is relevant in the context of financing space travel & exploration due to the significant impact that both parties have in terms of economic, political and scientific development across the world.

”Spies and Shuttles: NASA's Secret Relationships with the DoD and CIA” (University Press of Florida, 2015) written by James E. David, a curator in NASA's division of space history is a book that discloses the degree of co-operation in which NASA has worked with the Department of Defense (DoD) and The Central Intelligence Agency (CIA), based on declassified documents posted April 10th, 2015 by the National Security Archive at The George Washington University.

According to David, The legislation establishing NASA in 1958 attempted to create separate and distinct civilian and military aeronautical and space programs. It directed NASA to conduct peaceful, scientific and open aeronautical and space research and operations. The Department of Defense (DoD) was made responsible of performing these activities related to military operations and defense.

This mandate was a guiding principle for NASA and the nation's political leaders concerning its spaceflight programs. These programs were promoted as demonstrations of America's use of space for peaceful and scientific purposes. However, NASA could not and did not always follow the mandate for several reasons. These included the need for NASA and the national security agencies to utilize each other's hardware and facilities to accomplish their missions, the reliance on one another for data and expertise concerning foreign aeronautical and space programs, and the requirement to monitor and restrict certain NASA programs to eliminate threats to classified programs or deny important scientific data to the nation's adversaries.

In his book, David suggests that communication and co-operation between these government funded institutions is in reality a lot closer and practically related than what meets the public eye. According to David, scientific information gathered by NASA for scientific purposes may actually serve or be utilized by the agenda of the DoD, for example. The statement by David imposes the ethical question of whether or not science should be used for military purposes. From perspective of national security, the trading of information could be seen as justifiable, but not necessarily from the perspective of financing space travel & exploration.

As government funded agencies, the majority of funding for these agencies comes from the U.S taxpayer. In a democracy, citizens express their support or objection for political entities and their decisions largely based on the proposed allocation of tax funds. The case of large government agencies forming undisclosed partnerships in different operations blurs the transparency related to the allocation of funds, resulting in the average citizen not knowing that he or she might unwillingly support U.S military campaigns by willingly supporting an increase in NASA funding and vice versa.

The close co-operation might not be beneficial from NASA's perspective both on the long-term and from the perspective of conducting scientific research & financing space travel & exploration as opposed to serving DoD and CIA interests. The weak position of NASA among U.S Government agencies can be demonstrated by comparing the budgets of the DoD and NASA. The annual military budget of the U.S for 2015 is $637 billion, whereas the budget of NASA for 2015 is $18 billion – which is less than 3% of to the military budget. This demonstrates the small amount of leverage that NASA has in the bigger scheme of things and truthfully shows the importance that the U.S Government sees in NASA currently (threat of government shutdown in 2013 jeopardized the entire funding of NASA). From the standpoint of NASA the disparity could actually result in them working *for* the DoD, which in turn could further endanger the initial purpose of why NASA was founded in the first place. At the moment, the 2015 budget of NASA holds a 50/50 split of about $7, 8 billion (~43% of NASA budget) for space operations ($3, 9 billion) and exploration ($3, 9 billion). By the fiscal year of 2019, NASA has projected to decrease its expenditures in the area of exploration, while projecting an increase in expenditure in space operations, giving some indication of the future whereabouts of NASA.

Since taking office, the Trump administration has been actively engaged in public discourse related to space exploration. According to Eric Berger from Arstechinca, Vice-President Mike Pence appeared bullish on space exploration during his speech on July 2017 at the Kennedy Space Center. According to Berger, Pence was quoted stating that the nation will return to the Moon, placing American boots on the face of Mars. In 2017, president Trump signed an executive order to establish the National Space Council led by Pence. (Berger, 2017).

The objective of the council is to explore military, civil and commercial interests and find ways to align them with the proposed space policies of the council and administration. According to Berger, Pence seems to be intent on pushing NASA towards a fixed-price model of contracting, in which the government buys a service-such as a launch-from the commercial sector.

On November 2017, a United States Senate Committee voted to approve President Donald Trump's nominee Rep. Jim Bridenstine as the administrator of NASA. Approved

with votes 14-13, Democrats strongly opposed to appointment of the Republican Bridenstine, underlying him as a candidate with little scientific or technical expertise. The Senate Committee result means that Bridenstine will be up for a vote by the whole Senate (Cama, 2017). The nomination of the republican Bridenstine could imply the alignment of partisan political agendas and goals within the realm of NASA's operations, which could further influence the integrity, nonpartisan public image and scientific reliability of the institution for the foreseeable future.

On July 17th 2013, NASA issued a statement about their future goals regarding the commercialization of space, stating: "New partnerships are intended to help companies accelerate their development efforts while enabling the nation to reap economic benefits from previous NASA work. NASA benefits by advancing the commercial space industry. This is a primary goal of the National Space Policy and NASA Strategic Plan, which enhance the U.S. aerospace industrial base and could lead to the availability of cost-effective commercial products and services to support human space exploration" (NASA, 2013).

A point worth noting from this statement is the manner in which it emphasizes on the national interests of the United States being the key beneficiary of this collaboration with the private space industry, whereas the collaboration **could** lead to the availability of cost-effective commercial products and services, with human space exploration being the secondary beneficiary after the United States. With that same note, all of NASA's major contractors are companies that are either founded or led by an American and companies that have their headquarters stationed in the United States. Therefore it is quite evident, that despite the narrative of scientific and technological advancement, there is still the factor of favorism towards national interests when it comes to NASA advancing their operations in the future.

One of NASA's long-term explorative goals are related to deep space activity and discovery. According to NASA administrator Charles Bolden, private enterprise is welcomed to low-earth orbit ventures, but deep space is the domain of NASA. NASA holds a key position in terms of controlling the space market, since it currently possesses far more know-how, infrastructure, equipment, technology and personnel than any other organization related to space exploration. NASA has been extremely vocal about its

ambitions to transfer logistical, low-orbit resupply service responsibilities to the private sector in the form of the Commercial Resupply Service contracts. This liquidates government NASA funding to be allocated into the principals that the organization was originally founded upon – space exploration. Therefore, it may benefit private investors as well by not having to invest into research & development through the private sector, when NASA is willing to be the spearhead of space exploration for mankind for both scientific and political reasons.

Due to the fact that NASA is such a major player in the industry, it also changes the barrier to entry of what companies are able to enter the commercial space travel & exploration industry. Apart from Virgin Galactic, all of the major privately financed companies seeking to conduct space travel in the future are companies located in the United States. This means that the incentive for companies in the United States is much higher to enter the market due to the fact that these companies are able to create jobs and tax revenue to the United States Government, which is a goal that is in accordance with the U.S. Government funding of NASA.

In 2014, Virgin Galactic had gathered an amount of $600 million dollars in investment, $380 million of which was provided by Aabar, Abu Dhabi's state investment company (Financial Times, 2014). The strategic & geopolitical implications of Aabar's investment in Virgin Galactic suggests that countries such as Abu Dhabi might look to acquire or gain access to the technology and knowledge in order to establish their own space program, or travel to space at the very least. Much like the colonization of the Americas, the country or company that is in space first will be the first one to get access to resources that it holds. In addition, the developing technologies under space programs such as NASA are patented, after which the patents are sent to the National Treasury of the United States, holding unknown future value in terms of future technological development. There is a possibility that investors have realized that commercial space programs are also tools for achieving technological supremacy in comparison to companies in addition to entering a new market in the form of space travel & exploration.

4. Implications on the industry in the future

4.1 History of discovery & exploration

Throughout the history of evolution, different species have had to explore in order evolve and further develop as a species. From the historical perspective of human evolution, as a species, humans would not be as developed and knowledgeable as we are today if it wasn't for the prehistoric man leaving the cave and learning to hunt and create fire, or if it wasn't for our ancestors who set sail to discover land across the Atlantic.

As of today, space is a frontier which remains largely unknown to the human species. In order for us to understand it further, humans must develop and implement new technologies that will enable us to further widen our understanding of the universe of which we are a part of. However, in reality, space exploration is not the only challenge that we face as a species – there are many problems that occur and have to be dealt with, which often take priority over our aspirations to explore.

Historically, exploration by humans has never been solely propelled by the will to discover – things such as financial gain (conquest of the Americas & African slave trade), political power (Spanish inquisition & religious conversion of the indigenous people in the Americas) & the survival instinct of humans (hunting → fear of starvation) are some examples of motives that have spurred exploration in the past. This thesis seeks to uncover some of these motives that are relevant to discovering and learning more about space, encountering and investigating these motives from the perspective of financing space travel & exploration.

It is important to elaborate on the importance further in a historical context in order to form a comprehensive picture of not only the importance of financing space travel & exploration, but on the importance of discovery in general.

4.2 China's increasing role

According to historian Stephen J. Pyne ”Exploration is a specific invention of specific civilizations conducted at specific historical times. It is not a universal property of all human societies. Not all cultures have explored or even traveled widely. Some have been content to exist in xenophobic isolation.”

Steven J. Dick, chief historian of NASA, in his article ”The Importance of Exploration” (NASA, 2007), argues that the ”xenophobic isolation” that Pyne refers to in his definition of exploration is something that applied to the Ming dynasty in China after the 1430s. According to Dick, by building the Great Wall of China in order to protect itself from hostile raiders, the nation ”Fully equipped with the technology, the intelligence, and the national resources to become discoverers, the Chinese doomed themselves to be discovered." In the article, Dick implies that by limiting the capabilities and importance of discovery, China's technological and intellectual development stagnated, deeming the decision "catastrophic ... with consequences we still see today."

China's economic surge throughout the last decade has enabled the Chinese government to further develop their own space programme. According to the Science and Technology Department of Tibet, the world's highest planetarium will be built in Tibet by 2019. The planetarium, which is Chinas first, will have the region's largest optical astronomical telescope, with a 1- meter-diameter lens, with plans of becoming a major regional base for astronomical research and public science education. The planetarium will be located 4,000 meters above sea level and will be unaffected by large-scale pollution occurring at lower altitudes in China.

The economic growth of China has enabled the country to compete in various space-related endeavours with other countries, such as the United States. In 2000, China began to operate its homegrown global navigation and positioning network in mainland China by launching Beidou-3 satellites into orbit, reducing reliance on the U.S.-based Global Positioning System. By 2012, the network had expanded thoroughout the Asia-Pacific region, with plans of having a worldwide network providiong real-time geospatial information completed by 2020. The network would eventually provide monitoring

and safety information along the nation's multinational infrastructure megaproject, the Belt and Road Initiative, designed to link China with Central Asia, Europe, Africa and beyond. On completion, Beidou, will join GPS, Russia's GLONASS and the European Union's Galileo as satellite navigation systems with global coverage. India, France and Japan are also developing regional systems. (Associated Press, 2017).

The article ”What Happens if China Makes First Contact?” published in The Atlantic by Ross Andersen in 2017 examines the course of China's scientific development from a historical perspective, highlighting the geopolitical and economic losses that the country has endured in the past due to its protectionist policies. The First Opium War (1839-1842) resulted in British Victory and the Treaty of Nanking, in which Hong Kong Island was ceded to Britain. Coined by Chinese nationalists as the ”Century of Humiliation”, desipte possessing far more manpower than the British, the Qing dynasty suffered heavy causalties of 18,000-20,000 men and was forced to agree to unequal treaties due to its loss, ceding ports and allowing opium trade to take place in China, which had hampered public health especially in southern China. One of the major reasons for China's heavy defeat in battle is argued to have been related to the nation's lack of scientific and naval innovation during the time, having little to no military presence over its own waters and ports.

China's neighbouring country, Japan responded to western aggression by modernizing its fleet, which is one of the reasons why Japan was able to destroy the entire Chinese navy in a single battle during the First Sino-Japanese War in 1894. Japanese aggression and expansionism in China contiued up until the Second World War, when the United States was able to force Japan into surrender by introducing their own scientific and technological superiority in the form of the atom bomb.

According to Andersen, China began to regain its geopolitical might in the 1980's during Deng Xiaoping's reign. China is on pace to outspend the United States in R&D during this decade. However, quality of research especially in the domain of space exploration might not be as effective compared to the United States due to the country having an advantage in scientific infrastructure in the form of world-class higher education institutions, private and public space enterprise in the form of SpaceX, Boening, Blue Origin, Lockheed Martin, NASA, etc.

Even though scientists in China no longer have to endure persecution similar to what happened during Mao Zedong's cultural revolution, scientists are largely handicapped by political acts such as The Great Firewall of China, which is designed to prevent western influence through the internet over the Chinese populous. The firewall is designed to block websites operated by large American companies and creating alternative services to the public that are created by Chinese companies.

However, once scientists are denied the use of popular and more sophisticated search engines such as Google Scholar, it is evident that the Chinese public and scientific community does not possess similar access to information as opposed to their western counterparts. There are ways to gain access into websites operated by western companies in China through VPN services or the Tor network, however both are relatively slow or require monthly fees in order to be used in China, causing another disadvantage regarding access to information.

4.3 Future outlook of the Indian Space Research Organisation

China's neighbouring country India has also decided to further develop their national space program. According to the article "India is Building Reusable Launch Vehicles to Explore Mars and Search for Alien Life: ISRO Chief" by Yogesh K. from Doonwire, the Indian Space Research Organisation (ISRO) Chairman Kiran Kumar revealed in an inaugural talk at Physical Research Laboratory (PRL) during a three-day brainstorming session titled "Vision and Explorations for Planetary Sciences in Decades 2020-2060" that the organisation will focus on developing reusable launch vehicles (RLV's) to cut costs incurred during the launch of spacecraft.

According to Kumar, the main objective of ISRO is to create and develop RLV's that can support launches of various different spacecraft, with full reusability for future launches. Optimally, ISRO's implementation of a functioning RLV system would be a significant mark in the development of Indian space travel and exploration. A multiple launch system would reduce cost of access and alleviate contingency and risk involved in single launches. A multiple launch platform compatible with different spacecraft would also allow ISRO to allocate research funds into spacecraft development and mis-

sion based activities, without having to use resources for launch pad development for each mission.

In addition to RLV development and manufacturing, Kumar outlined ISRO's objective of investigating signs of life and resources for human habitation in space. Kumar emphasised interest in developing ISRO capabilities related to deep space problems, an area of space in which NASA intends to be the frontrunner for scientific advancement. Kumar also identifies the growing trend of private entrepreneurs entering the segment, focusing on the competitiveness and changing dynamic of the current space race. Kumar's ambitious statements signal India's and ISRO's willingness to claim a larger role in space exploration, setting sights on developing India's national space program to compete with both private and public entities. (Yogesh K, Doonwire, 2017).

4.4 Maslow's Hierarchy of Needs

In the context of today, without analyzing the history of discovery and exploration, financing space travel & exploration might seem unethical or irrelevant to some people: There are multiple issues that have to be dealt with or solved within our planet such as terrorism & climate change that should be prioritized, for example. However, sacrificing long-term goals in the face of short-term problems and needs might not in reality result in solving the fundamental issues related to the short-term problems at hand.

The theoretical framework called The Hierarchy of Needs created by Abraham Maslow, applied into the context of this topic suggests that humans have an *inherent* set of priorities that have to be met before they can pursue other goals in their life. According to Maslow, physical and safety needs are needs that have to be met before an individual is able to pursue any other needs that they might possess.

Maslow's theory indicates that it is only natural for humans to behave in the manner of China in the 1430s or the United States Government after 9/11 – humans simply cannot genuinely pursue the need for discovery if they feel that they are not fed or safe, which are both two foundations of Maslow's pyramid model. However, the benefits of discovery is something very abstract from the perspective of an individual – on the long-term, it can be very beneficial but it does not seem grant much benefit to the

individual on the short-term. Therefore it is difficult to allocate it into a certain category in Maslow's Hierarchy of Needs, since different people perceive the topic and its importance differently.

The presumption of long-term goals discarding relevant short-term matters might not apply in all cases. On the long-term, the technological advancements made by investing into improving future technologies in the form of space travel & exploration could provide results that could be used in order to solve or help other issues within our planet. Innovation in this field has the possibility of creating new jobs and markets. The influence of the satellite on broadcasting & the potential of future excavation of resources from space are examples of what innovation in this field has brought and what it can bring in the future. Investing in long-term goals related to space travel & exploration does not necessarily mean that the beneficiaries of the returns on the investment are solely entities that are somehow affiliated with space travel and exploration, when in reality the potential technological advancements and new information gained by the investment could be used as tools to benefit in other areas and matters as well.

5. Conclusion

Based on the research conducted for this thesis, there are several connections that consistently appear in the context of financing space travel & exploration. Firstly, due to the industry being in a relatively early stage of development, R&D and operational costs are very high with long lead times being a persistent issue in terms of costs. In other words, financing space travel & exploration is very capital intensive, which increases the barrier to entry for numerous parties seeking to become involved in the industry.

The most prominent public and private entities affiliated with the topic are located in The United States, largely due to the incentives and competitive advantage that the U.S Government and NASA both offer to private U.S based investors and businesses seeking to enter the market.

Traditionally, the industry has been divided into private businesses mostly offering solutions regarding space travel, whereas government funded institutions such as NASA are more affiliated with the prospects of exploration. According to William D. Eggers, leader of public sector research at Deloitte, after 2011 and the closing of the NASA Space Shuttle Program, the industry has become more commingled, resulting in NASA reaching out to private businesses more actively through contracting both space travel & exploration services for companies located in The United States due to the ever decreasing funding from the U.S Government, forcing NASA to turn to private investors and partnerships for funding.

Motives for entering the industry remain diverse, with different parties seeing different opportunities in moving into space. Most businesses seeking to enter the space travel industry see it as a transportation method of the future, competing with the traditional transportation methods available today. The biggest issue is that at the moment, no company has been able to either conduct flights on a regular basis and with sufficient safety assurance, nor has any company been able to offer services on a sustainable and profitable basis. Most companies in this area have encountered several backlashes

in terms of R&D, with companies such as Virgin Galactic and SpaceX both having experienced failed launches and consequently destroyed spacecraft thus far.

From the perspective of public funding, several conclusions can be made regarding the involvement of governments in financing space travel & exploration. Historically, governments become involved in the space race through the threat that the newly introduced satellite technology initially posed to the national security of governments. Satellite technology became a tool for governments which provided intelligence about other countries for the respective governments. Satellite technology as an innovation has enabled and opened several new markets and industries around the world, which is a testament to the widespread economic and technological potential that the industry possesses.

6. References

Andersen, Ross (2017). *What if China makes first contact?* The Atlantic. https://www.theatlantic.com/magazine/archive/2017/12/what-happens-if-china-makes-first-contact/544131/?single_page=true

Babcock, Jonathan. (2015). *Encouraging private investment in space: Does the current space law regime have to be changed?* The Space Review. http://www.thespacereview.com/article/2669/1

Berger, Brian. (2011). *U.S. Budget Compromise Includes $18.5 Billion for NASA.* Space News. http://www.space.com/11374-nasa-budget-2011-congress-compromise.html

Berger, Eric. (2017). *In-depth study: Commercial cargo program a bargain for NASA. Arstechnica.* https://arstechnica.com/science/2017/11/in-depth-study-commercial-cargo-program-a-bargain-for-nasa/

Berger, Eric. (2017). *Mike Pence appears bullish on efforts by SpaceX and others. Arstechnica.* https://arstechnica.com/science/2017/07/mike-pence-gives-a-shout-out-to-commercial-space-companies/

Berger, Eric. (2017). *Trump to sign executive order creating a national space council. Arstechnica.* https://arstechnica.com/science/2017/06/trump-to-sign-executive-order-creating-a-national-space-council/

Brown, Katherine. (2017). *NASA Space Station Cargo Launches Aboard Orbital ATK Mission.* NASA. https://www.nasa.gov/press-release/nasa-space-station-cargo-launches-aboard-orbital-atk-mission

Byerly, Josh. Perrotto, Trent J. (2013). *NASA Announces Effort to Form New Collaborative Partnerships with Private Space Industry.* NASA. http://www.nasa.gov/press/2013/july/nasa-announces-effort-to-form-new-collaborative-partnerships-with-private-space/#VjtuE7crLZ4

Cama, Timothy. (2017). *Senate panel advances Trump's controversial NASA nominee.* The Hill. http://thehill.com/policy/energy-environment/359356-senate-panel-advances-trumps-controversial-nasa-nominee

David, James E. (2015). *Spies and Shuttles: NASA's Secret Relationships with the DoD and CIA.* University Press of Florida.

Dean, James. (2015). *NASA seeks launchers for smallest satellites.* Florida Today. http://www.floridatoday.com/story/tech/science/space/2015/05/16/nasa-seeks-launchers-smallest-satellites/27392049/

deGrasse Tyson, Neil. (2012). *Space Chronicles: Facing the Ultimate Frontier,* edited by Avis Lang. W.W. Norton

Dick, Steven J. (2007). *The Importance of Exploration.* NASA. http://www.nasa.gov/missions/solarsystem/Why_We_01pt1.html

Dubner, Stephen J. (2008). *Is Space Exploration Worth the Cost?* Freakonomics. http://freakonomics.com/2008/01/11/is-space-exploration-worth-the-cost-a-freakonomics-quorum/

Eggers, William D. *Analysis: NASA's New Role As Partner.* Nextgov. http://www.nextgov.com/emerging-tech/2013/09/analysis-nasas-new-role-partner/70468/

Foust, Jeff. (2014). *Exploration and the private sector.* The Space Review. http://www.thespacereview.com/article/2567/1

Gordon, Sarah. (2014). *Virgin group: Brand it like Branson.* Financial Times. http://www.ft.com/intl/cms/s/2/4d4fb05e-64cd-11e4-bb43-00144feabdc0.html#axzz3PzxuyP2I

Hambleton, Kathryn. (2017). *NASA Affirms Plan for First Mission of SLS, Orion.* NASA. https://www.nasa.gov/feature/nasa-affirms-plan-for-first-mission-of-sls-orion

Jet Propulsion Laboratory, NASA. (2017). Integrated Solar Array & Reflectarray Antenna (ISARA) Mission Information. NASA/JPL. https://www.jpl.nasa.gov/cubesat/isara.php

Kaku, Michio. (2009). *The Cost of Space Exploration.* Forbes. http://www.forbes.com/2009/07/16/apollo-moon-landing-anniversary-opinions-contributors-cost-money.html

Varma, KJM. (2017). *China to build worlds highest planetarium in Tibet next year.* http://indiatoday.intoday.in/story/china-to-build-worlds-highest-planetarium-in-tibet-next-year/1/1082633.html

Leahy, Bart. (2006). *Space Access: The Private Investment vs. Public Funding Debate.* National Space Society. http://www.space.com/2401-space-access-private-investment-public-funding-debate.html

Loff, Sarah. (2017). *NASA Completes Review of First SLS, Orion Deep Space Exploration Mission.* NASA. https://www.nasa.gov/feature/nasa-completes-review-of-first-sls-orion-deep-space-exploration-mission

Normille, Dennis. (2017). *Science suffers as China's internet censors plug holes in Great Firewall.* Science Magazine. https://www.sciencemag.org/news/2017/08/science-suffers-china-s-internet-censors-plug-holes-great-firewall

Pyne, Stephen J. (1994). *The Third Great Age of Discovery.* Space: Discovery and Exploration.

Szondy, David. (2017). *GRACE gravity mapping mission comes to an end.* New Atlas. https://newatlas.com/grace-gravity-mapping-end/51953/

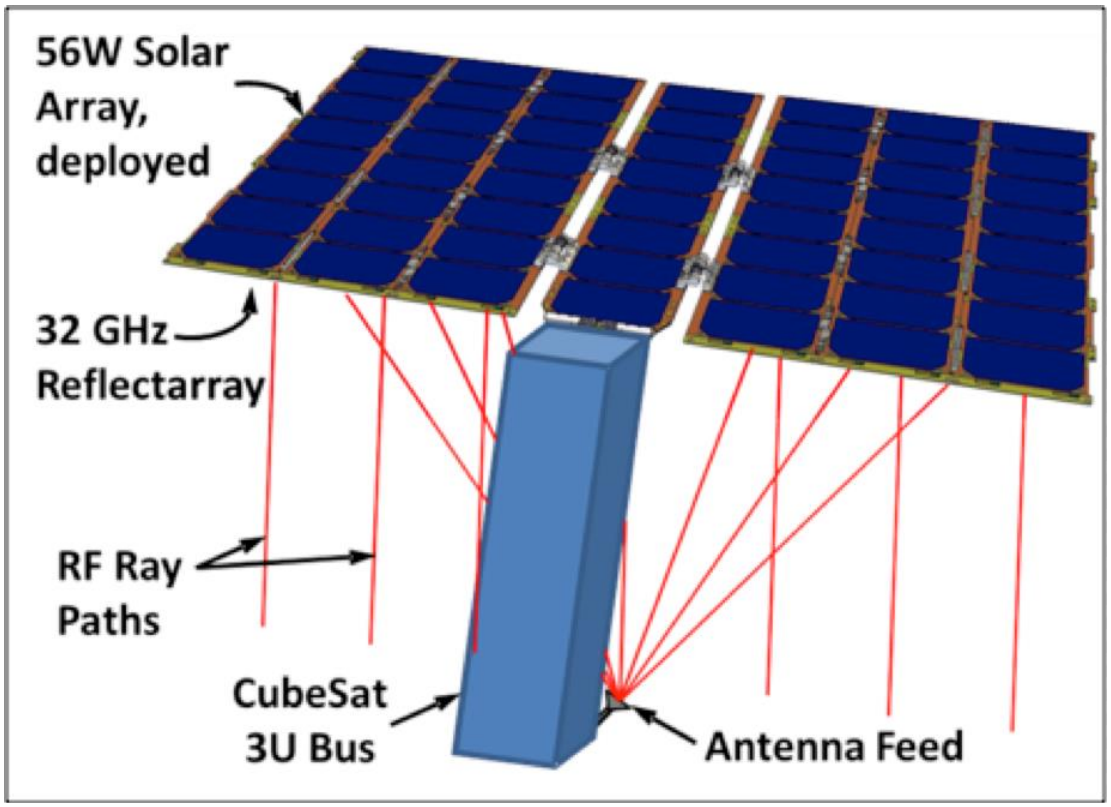
Weiss, Linda. (2014). *America Inc.?* Cornell University Press.

Yogesh, K. (2017). *India is Building Reusable Launch Vehicles to Explore Mars and Search for Alien Life: ISRO Chief.* Doonwire. http://www.doonwire.com/category/news/india-is-building-reusable-launch-vehicles-to-explore-mars-and-search-for-alien-life-isro-chief-17110901

Zapata, Edgar. (2017). *An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions.* NASA. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf

Figure 1 Image credit: NASA-JPL/Caltech; NASA GSFC; CU-Boulder; Technical University of Munich; Technical University of Denmark; Delft University of Technology, Aerospace Engineering, Netherlands; Durham University, UK; Leeds University, UK https://www.nasa.gov/mission_pages/Grace/multimedia/chart20121129.html#.WgolgGi0OUl

7. Appendix 1



Appendix 1: Integrated Solar Array & Reflectarray Antenna (ISARA) combined with CubeSat technology.