[QUALITATIVE EVALUATION OF LONG-TERM SPACE PROJECTS ON THE EXAMPLE OF THE LOP-G MISSION]

[HENDRIK-JOACHIM PEETZ]

[S1702887]

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This dissertation is my original work and has not been submitted elsewhere in fulfilment of the requirements of this or any other award. In accordance with academic referencing conventions, due acknowledgement has been given to the work of others.

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ABSTRACT

In public and governmentally funded space agencies such as NASA, some projects and missions are cancelled due to various reasons. These cancellations have a negative effect on both workforce and the agency itself (Cappels, 2004). It appears that some of these cancellations can be related to political decisions (Forbes, 2017; Wall, 2018; Malik, 2010) and others to financial reasons (ESA, 2019; Wade, 2019). NASA in partnership with other space agencies proposed a follow-up to the International Space Station called "Lunar-Orbital Platform-Gateway" (LOP-G), a space station orbiting the Moon (Ching, et al., 2017). This mission has estimated costs of $135 billion (Falk, 2018) and will include partnerships with private industry (Webb, 2019). Due to the complexity and financial volume of this mission, the causes that resulted in a cancellation of former projects are analysed, enabling a more precise risk assessment of exceptionally long-term space projects. It is shown that the main risks that cause cancellations to happen can be quantified and categorised into political risks, financial risks and partner risks. About 78% of cancellations are related to political influences and about 22% are related to financial issues. As the LOP-G mission includes contribution of partners, qualitative and quantitative data to express a risk rate for partner risks are analysed with the result of a 0% risk ratio. These results demonstrate that the main qualitative risk of the analysed agencies (NASA, CNES and ESA) is related to political decisions and that the risk assessment process of space agencies should further analyse these risks to minimise the probability of a cancellation to happen or at least reduce the impact of a cancellation. This research study can be used as basis for future risk and project assessment processes of space agencies by providing a quantitative risk framework that can be aligned to existing assessment processes of these agencies. In addition, recommendations about lowering the negative impact of cancellations are provided and advice on how to further analyse the findings of this work to generate a more precise analysis of the identified risks is given.

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Abbreviations

ASAP	Aerospace Safety Advisory Panel
CNES	Centre National d´Etudes Spatiales
CSA	Canadian Space Agency
DLR	German Aerospace Centre
DSG	Deep-Space Gateway
e.g.	for example
ESA	European Space Agency
i.e.	that is
JAXA	Japan Aerospace Exploration Agency
LEO	Low-Earth Orbit
LOP-G	Lunar Orbital Platform-Gateway
NASA	National Aeronautic Space Administration
PPP	Public-Private Partnership
RM	Risk Management
SU	Soviet Union

1. Introduction

This chapter will provide a background to, and an overview of the research problem, the rationale behind the research and the structure of this dissertation.

The US government, in cooperation with NASA, agreed on financing a follow up project to the currently operating International Space Station (ISS). To realise the proposed project called “Lunar Orbital Platform-Gateway” (LOP-G), NASA will cooperate with international partners, both agencies and industry (Webb, 2019). Taking a look at similar, past long-term projects with comparable costs, it can be seen that projects have been cancelled. The reasons for that vary. Some of them are governmental and political decisions which will be shown later in this work.

The negative impact of such program terminations affects multiple parts of an organisation like NASA. Although such cancellations often result from events not anticipated in the project´s planning process, these qualitative risks should be included in a framework that supports project and risk management in the risk assessment and analysis processes.

The following work will analyse project cancellations from both industry and space agencies, as well as the reasons for the terminations in order to establish a framework for currently uncalculated qualitative risks. The focus is on risks of political decisions affecting these projects. As a basis for this work, the currently proposed and critically viewed LOP-G project of NASA will be analysed and assessed to recommend whether the risk of a possible cancellation is higher than estimated by the project planning. Due to the project’s high costs and completion time, there is a need for a more precise evaluation of risks.

1.1. Research Background

This chapter will provide information about the background of the research study and the LOP-G project itself. The aim and objectives of this work will be shown at the end of this chapter.

During the history of NASA and other space agencies, cancellations of space projects have always been a part of project administration and management. The impact of a cancellation affects stakeholders of the agency like the public, politics and economy, but mostly damages the administration itself in terms of significant losses of productivity and prestige (Hurley & Jimmerson, 2009). Especially cancellations of long-term projects, such as the “Constellation” program or the Space Shuttle program, have a huge negative impact. President Barack Obama cancelled “Constellation” in 2011 due to the project being behind schedule and lacking innovation, although NASA had already spent $9bn on it (Amos, 2010).

The Space Shuttle program, which operated successfully from 1981-2011 with 135 completed missions (Broad, 2011), was also cancelled due to political change, leading to a downsize of workforce, frustrated employees, fears of decline throughout the agency and astronauts leaving the agency. After these program abortions, the Aerospace Safety Advisory Panel (ASAP) concluded that a negatively affected workforce can be caused by the lack of a defined mission, and that future projects might also suffer because of a lack of visionary goals (Broad, 2011).

These are only two recent examples that show that a mission has to be defined precisely to reduce the risk of a cancellation, and that a change in politics can have a major impact on the continuation of a long-term space mission.

On the contrary, the “James Webb Telescope” mission further underlines the necessity of establishing a framework to use for future risk assessments of long-term space projects in order to evaluate qualitative and quantitative data more precisely for political and programmatic decisions (Harwood, 2010; Grush, 2018). Like “Constellation” this project is behind schedule and overdrawing the budget multiple times, but the administration and government are still financing the project (Koren, 2018). This raises the question: Does the decision-making process of government and administration include a saturation which considers prestige and financial damages being too high if the project would be cancelled?

The conclusion that comes up is that there are still unknown variables in the current assessment process of project and risk management in space agencies which should at least be defined to be included in future evaluations.

1.2. ISS program ending

One of the major reasons to build the LOP-G is the ending of the International Space Station (ISS) program. Without the ISS orbiting Earth, NASA and other space agencies would have no place for long-term experiments in zero gravity, forcing astronauts to be grounded on Earth (Grush, 2018). Although President Barack Obama released a National Space Policy for the US in June 2010 stating that the ISS is headed for an extended operation time, this was soon changed with the release of the “ISS End-of-Life Disposal Plan” (David, 2010).

Due to a political shift, and the USA´s current president Donald Trump, who aims to send humans back to the Moon instead of to Mars, the funding of the ISS will stop in 2025 (Foust, 2018). The free budget would then be spent on the development of the Space Launch System and the Orion capsule to achieve the aims of Mr. Trump. The problem of cancelling the ISS too early is that there is no alternative of having human activities in Low-Earth Orbit (LEO), which could cause similar problems as with the cancellation of Constellation program by the Obama administration, leaving NASA with no destination to get astronauts into space (Grush, 2018).

It can be seen that changes of government, especially in the US, have a great impact on running space programs (Forbes, 2017; Wall, 2018; Malik, 2010) and can cause major issues for institutes to handle, which again emphasises the need for the inclusion and assessment of such political risks in future projects.

1.3. The LOP-G project

The International Space Exploration Coordination Group (ISECG) Global Exploration Roadmap published in 2018 showed that the future goal of NASA and other space agencies is to have sustainable human missions to the Mars system (ISECG, 2018). The Lunar Orbital Platform-Gateway, formerly Deep-Space Gateway project, is an initial short-duration habitat on lunar orbit proposed by NASA in their "NextSTEP" program as near-term need to achieve the long-term goal of the Global Exploration Roadmap (Ching, et al., 2017).

The reasons for building this structure, besides the fact that experiments in zero gravity and on moon surface can be exercised, are that the station can serve as a docking and refuelling point for space vehicles that aim to reach farer places in deep space (Mintz & Testa, 2018). This would support future space missions that aim to reach for example Mars in terms of allowing spacecrafts to transport heavier and thus more complex payloads into deep space, needing less propellant and less fuel at launch. The first module is slated to launch in 2022 (Mintz & Testa, 2018).

The overall cost of the LOP-G project is expected to exceed that of the estimated $125 billion needed for building and operating the comparable ISS project, which makes it important to have a precise risk-analysis that not only focuses on technical possibilities and impossibilities, but also evaluates the qualitative impacts such a long-term project can face such as political decisions (Falk, 2018).

1.4. Science Funding, project partners and budgeting

To understand why it is important to be able to determine the qualitative risk of project cancellations due to political or governmental decisions more precisely, there must be an understanding of how such science is funded. Excluding the more specific privately funded research corporations, the vast majority of research is funded by private companies, non-profit organisations and most importantly by government grants (Understanding Science, 2019). In the case of the world´s biggest space science organisation NASA, the $19.5 billion budget for 2019 is funded using federal revenue from income, corporate, and other taxes (Amadeo, 2019). The other partners besides NASA that are leading the development of the LOP-G, i.e. the European Space Agency

(ESA), Roscosmos, the Japan Aerospace Exploration Agency (JAXA) and the Canadian Space Agency (CSA), are also research organisations financed by public and governmental funds (Boucher, 2018; Onuki, 2013; Orwig, 2015; ESA, 2019). The contributions of every space agency partner to LOP-G are shown in Figure 1.

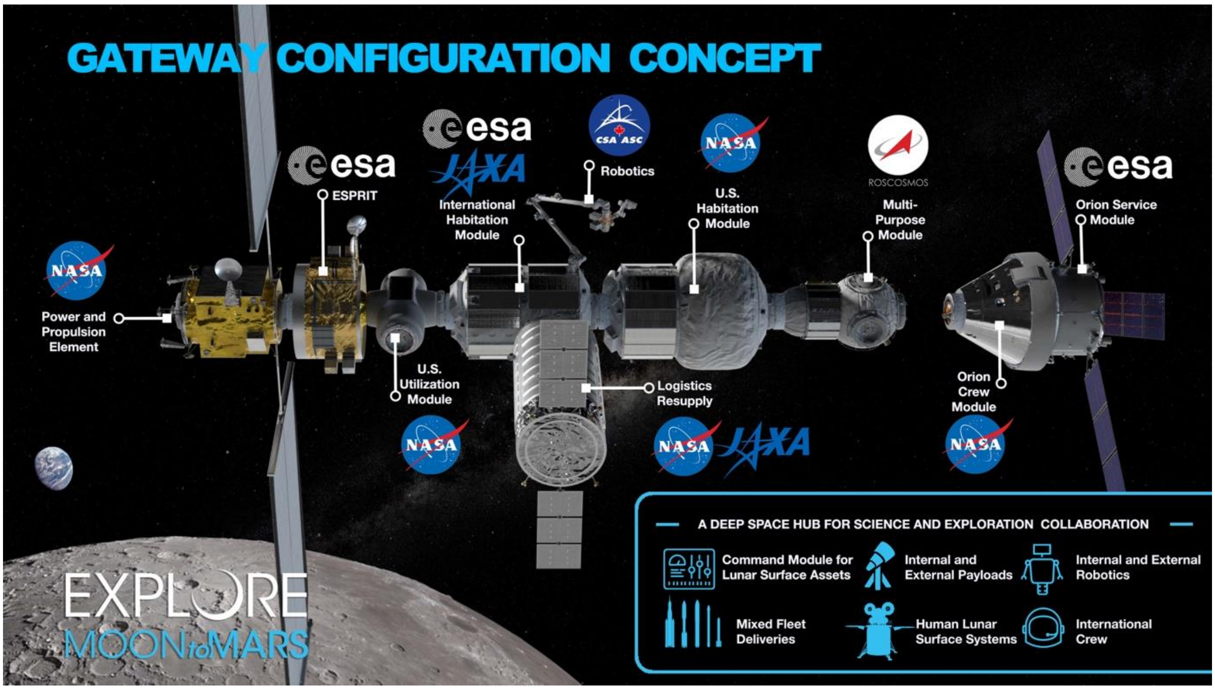

Figure 1: Gateway Configuration Concept (Webb, 2019)

Taking a look at the budget plans for LOP-G, the administration requested “US $504.2 million in FY 2019, along with a projected “out-year” funding profile of $662.2 million in FY 2020, $540 million in FY 2021, $558.9 million in FY 2022, and $459.1 million in FY 2023”, which needs to be approved by the President and Congress (Sloss, 2018, para. 5).

Due to the high estimated costs to develop, build and operate the space station, NASA and their partners are planning to involve industry partners as well, which currently are Boeing, Airbus and Energia (Bychkoc, et al., 2017; Airbus, 2018). In addition to these partners, NASA plans to award contracts to commercial bidders during 2019 to develop an electric propulsion spacecraft the fits LOP-G requirements and would then exercise a contract option to take over control of the spacecraft after one year of testing and demonstrating (Sloss, 2018).

1.5. Aim & Objectives

The aim of this dissertation is to establish a framework for a qualitative risk-based assessment of long-term space projects in consideration of quantitative data as basis for political and programmatic decision-making processes.

This aim will be achieved by considering the following objectives:

- To analyse the impacts and risks of political change influencing the decision-making processes of especially long-term projects;
- To determine the factors that might cause the budget to be financially overdrawn by analysing possible cost explosions;
- To create a scenario analysis about the partnership with industry partners that are related to the LOP-G project;
- To establish a quantitative risk analysis by considering factors like programmatic fit, political change, public prestige, runtime and economic impact of LOP-G.

1.6. Dissertation Structure

The structure and the content of the chapters in this research study is shown in Figure 2. Each chapter will have a short introduction about its content, which is labelled in the same colour as shown in Figure 2.

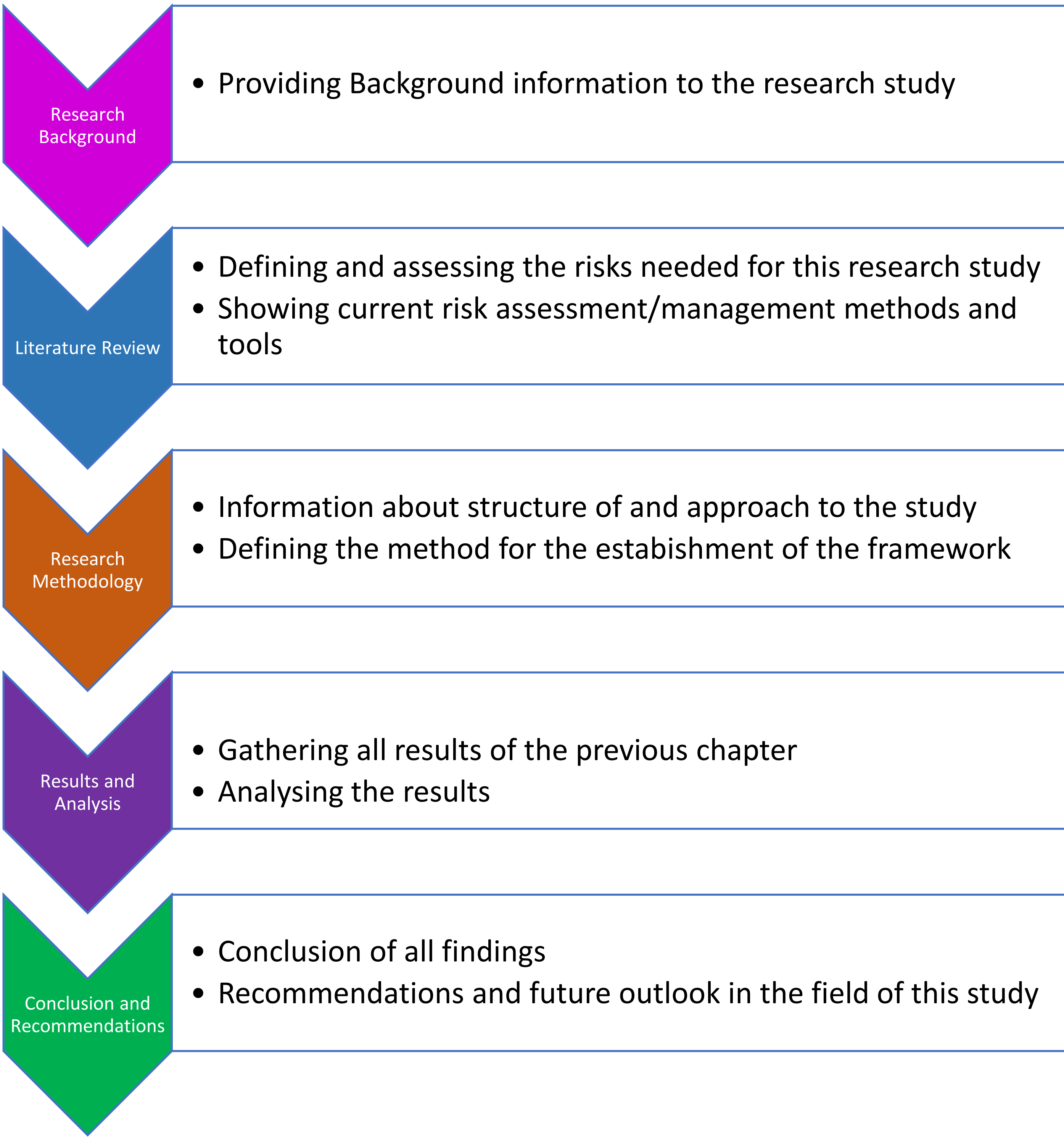

Figure 2: Structure and content of the chapters in this research study

2. Literature Review

In this section, the risks that are needed to achieve the aim of this work will be assessed and analysed. In addition, current risk assessment and management methods used by space agencies and private industry will be shown.

The process of project risk analysis and management is aimed at minimising potential risks that could prevent achieving project objectives, which in project management terms are to achieve the required completion date, the required performance objective and to keep within budget (Norris, et al., 2000). Risk management within a project supports the organisation by giving more control over the project via five factors: time, money, organisation, information and quality (Lindenaar, et al., 2004).

Setbacks that might occur during the lifetime of a project, like new political agendas, lack of skills among project employees and other future deviations (Lindenaar, et al., 2004) can only be anticipated by conducting a risk analysis with continuous risk management.

2.1. The term "Political Risk"

"Political Risk" in this work is defined as the risk of being forced to cancel a project due to a political decision. In case of a public organisation like NASA the "Political Risk" has been described earlier in this work on the examples of project cancellations like the "Constellation"-program. In case of a private company, "Political Risk" is the risk of the company of being forced to cancel a project due to decisions made by top management like the board of directors. This can be defined as a political risk because organisations set a stage for the exercise of power and operate by distributing authority, giving them political structures (Zaleznik, 1970).

NASA´s organisational structure can be compared to this political structure of a private company, because the Agency management department is the primary level of management and responsible for NASA policy and standards, defining Strategic Enterprise, developing NASA´s strategy and many other organisational regulations (NASA, 2019). Organisational structures of the other cooperating space agencies are also similar to NASA´s structure, therefore similar to an industry company structure (Howell, 2018; CNES, 2003; JAXA, 2019). This also partially applies on ESA, which has the Council and the Director General as their two organs that run the space agency and make programmatic decisions (ESA, 2019).

It can be seen that these political organisational structures do not differ a lot between public space agencies and private sector companies. Because of this and the fact that the risk of being forced to cancel a project due to a top management decision affects both types of companies, this risk is defined in this work as "Political Risk", which either applies for the risk of a governmentally ordered project cancellation.

2.2. Project and risk assessment

The following subchapters show various methods and tools used by public and private organisations to assess projects and risks.

2.2.1. Space agencies

The first step in every space mission lifetime cycle is the mission analysis and identification, where mission requirements are evaluated to outline the available trajectory options (ESA, 2009).

Although the various phases of a mission are self-defined by every space agency, NASA and ESA both start a mission by having Design Reference Mission (DRM) analysis, feasibility studies, engineering systems assessments, technology needs analyses and analyses of alternatives that need to be performed (NASA, 2014).

To be more precise, the information that is used to analyse a mission are the timeline of major events, delta-V budget, power and thermal aspects, launcher injection, coverage of science targets, and a qualitative assessment of complexity and operational risk (ESA, 2009). What is important to add is that the results from this analysis are not aimed to be accurate and optimal, but should provide the mission analyst with a good understanding of the feasibility of the mission (ESA, 2009).

The ESA approach to safety risk assessment and management is comparable to the Risk Management (RM) tools and techniques used by NASA. The four steps of ESA are defined as (Preyssl, 1995):

- Step 1 – Identification of hazardous conditions and accident scenarios;
    - Tools are: hazard matrix, hazard tree and consequence tree method
- Step 2 – Determination of event probabilities;
    - Tools are: statistical method, extrapolation method, expert judgement method, structured data collection, calibration-entropy method.
- Step 3 – Calculation and interpretation of risk values;
    - Risk value is indicated as "potentiality" or "probability interval";
    - Risk contribution measures risk reduction potential;
    - Uncertainty contribution measures decrease in uncertainty;
    - Precedencies of ranking of main risk contributors:
        - Consequence severity;
        - Probability of risk or uncertainty reduction potential.
- Step 4 – Use of risk values within risk management;
    - Risk values that were identified are used and interpreted as a support to the decision-making process in risk management.

The Centre National d´Etudes Spatiales (CNES) on the other hand uses a 5-step approach to the RM process during every project phase, which can be seen in Figure 3.

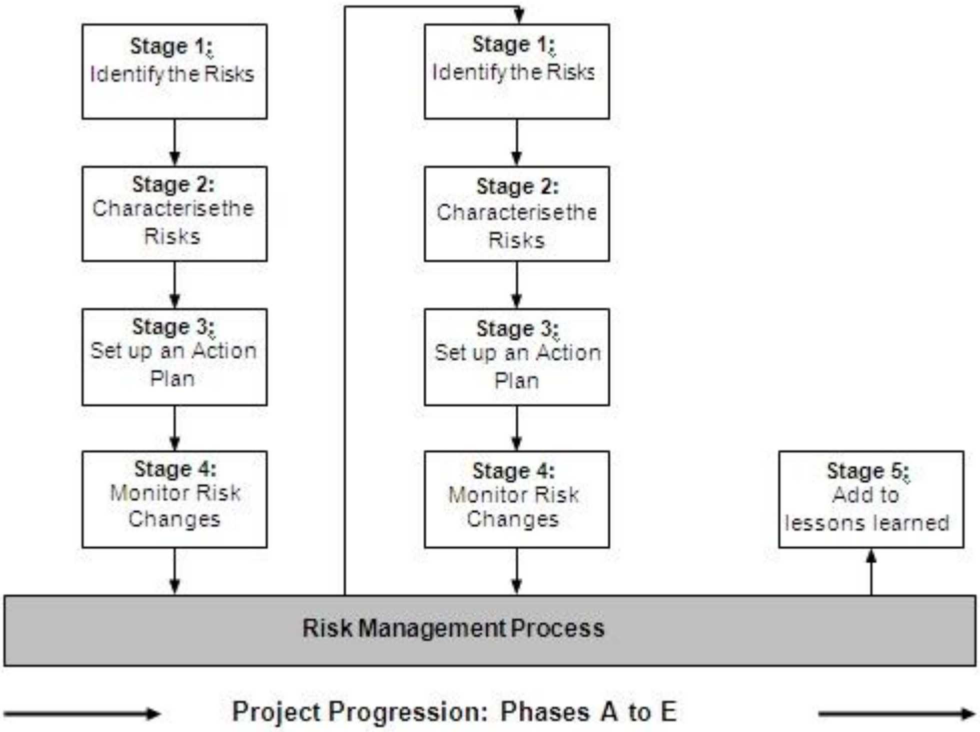

Figure 3: Definition of the Project Risk Policy (CNES, 2012)

For assessing the various quantitative and qualitative risks a project or mission can face, NASA and other space related agencies are using the following RM tools and techniques (Perera, 2011):

Quantitative

- Stochastic and Deterministic Modelling
    - Probabilistic Risk Assessments (PRA)
- Cause & Effect Analysis
    - Failure Modes & Effects Analyses (FMEA) & Failure Modes, Effects & Criticality Analysis (FMECA)
    - Fault Tree Analysis (FTA)
- Systems Engineering Analysis and Risk Assessments

Qualitative

- Root Cause Analysis
- Hazard Analysis
- Brainstorming
- Process Mapping and Analysis (Human Factors)
- Taxonomy-Based Questionnaires
- Pareto Method
- Affinity Grouping

Due to the fact that the various segments of the LOP-G need to be taken to lunar orbit, the effects of meteoroid environment, as well as of the space debris on spacecraft in Earth orbit need to be analysed. This is currently done with use of ESABASE2 and NASA´s Bumper software, which both are able to provide the full lunar mission analyses capability (Bunte, et al., 2013).

All key element data for the risk assessment process is taken from publicly available information and if some of these information show a non-compliance the element must be assessed as “not acceptable”, except for the fact that if an appropriate risk analysis shows that a certain component is allowed to be used for a specific application and the key element cannot be assessed it will be assessed as “acceptable” (Tetzlaff, et al., 2008).

2.2.2. Industry

Due to the fact that industry partners are involved in the LOP-G project, the project risk assessment and management process of industry projects is examined and then compared to the processes of space agencies. The industry approach towards a new project is comparable to the approach of publicly funded space agencies (Loureiro & Curran, 2007).

First, sources of risks are identified and the most serious effects of risks are defined as overdrawing estimated costs, missing the required completion date and failing to achieve the required quality and operational requirements (Perry & Thompson, 1992). It is important to identify the sources of risks that are directly associated with each activity of the project, which in the case of LOP-G is the political risk that affects both public and industry organisations, and analyse these using the same qualitative and quantitative methods that have been described earlier, because these methods are universally usable risk analysis tools (Badiru & Osisanya, 2016; Perry & Thompson, 1992).

Uncertain events that are too difficult or even impossible to predict, especially in long-term projects, must also be part of a mitigation strategy and can only be effectively managed if they are incorporated in the risk management process throughout the projects´ life cycle (Badiru & Osisanya, 2016). Therefore, it is necessary to define the yet still unknown uncertainty of a cancellation of the LOP-G program to enable a more effective risk management of the project. An approach towards a possible solution to this will be proposed and analysed in the following parts of this work.

2.3. Project Cancellations

The reasons for a project cancellation whether an industry or a publicly funded project can vary a lot, but the impact is the same. The reputation of the firm, the value of the firm´s stock, as well as employee productivity is affected by a cancellation (Cappels, 2004). It is important to add that there is little research on the correlation between employee productivity and a project cancellation, but the existing research suggests that the productivity of a project team is negatively influenced by the perception of the cancellation for the next several years (Cappels, 2004).

In general, terminating a project in case of a success or a failure needs a skilled project manager who ensures that no obligations or activities are unfulfilled (Nicholas, 2004). Whatever the reason for cancelling the project was, it could have been avoided if project management had acted in a more ethical manner, or would have exercised better project planning and control (Nicholas, 2004). Therefore, both project and risk management seem to fail to anticipate and manage the risk of a project cancellation, leading to the previously named consequences within the organisation. In the following, a more detailed look into some of the more recent project cancellations of NASA, CNES and ESA is taken to show the reasons of the cancellations, as well as their approach towards managing them.

The “NetLander” mission was a $350 million project of the French space agency CNES, which was planned to be send on an international mission with NASA to Mars in 2007 to study the red planet´s weather and subsurface geology (Bova, 2009). Due to several years of falling governmental funding, CNES had to cut or freeze 10 of its 44 running missions in 2003 including the “NetLander” mission, which was then officially cancelled after contributor NASA also retreated from the program in the same year (Butler, 2003; Bova, 2009). The cancellation of this mission is a good example of how political-decisions in terms of science funding affect running space projects and the space agency itself.

Spaceplane “Hermes” was an ESA mission planned for launch by 1998 on an Ariane 5 rocket and first proposed by the French CNES in the early 1980s to provide independent European human spaceflight (ESA, 2019). Due to overdrawn budgets and flight rescheduling from launching in 1998 to a first test in 2002, the project was cancelled in 1992 after a total of $2 billion had been invested and no Hermes was built (Wade, 2019).

Another example of an ESA project cancellation due to budget constraints is the “Eddington” space telescope mission in 2003. Although over 400 astronomers had written to ESA to keep the “Eddington” mission alive, the European Space Agency´s Science Programme Committee (Spc) decided to cancel the mission and also to reduce the running “BepiColombo” project to Mercury because of budgetary problems that occurred due to several sudden demands on ESA finances after the Ariane 5 rocket was grounded in January 2003 (Whitehouse, 2003). "Eddington" is seen as the first ESA mission that has been cancelled ("Hermes" counts as a CNES mission developed under the auspices of the ESA) and David Southwood who was the head of ESA´s science programme stated that the reason for the budget problem is not only caused by the grounding of the Ariane 5 rocket, but more general because of tighter financial controls on space projects (Whitehouse, 2003) and cost overruns in missions like "Rosetta" (Cain, 2003). This example shows that risks that occur in projects can also negatively affect other current missions of an agency, even up to a cancellation.

Based on the fact that ESA´s financial budget is contributed by all member states on a scale based on their Gross Domestic Product (GDP) and that decisions are made on a democratic basis by the ESA council with each member state having one single vote, a decision on whether continuing or cancelling a mission can be seen as an act of a political-decision (ESA, 2019).

2.3.1. Political change

Some of the project cancellations described in this work had been cancelled after a governmental change. When taking a deeper look at two of the most popular long-term space projects that were affected by this, there are a few conclusions to make.

Starting with the Constellation program which was a part of the 2004 released moon plan of President George W. Bush and aimed at returning astronauts to the moon by 2020, the program ended after President Obama released the 2011 budget request for NASA (Malik, 2010). The reasons for the cancellation, which had been analysed by an independent committee and submitted to the US president where underfunding of the project, technical difficulties and delays that would allow NASA to get back on the moon 8 years later than proposed (Whittington, 2017; Malik, 2010). The two alternatives proposed by the same committee where too expensive for the Obama administration, so the Constellation program was cancelled without having a decent follow-up program, resulting in huge criticism by former astronauts and US congress which has not been consulted for this decision-making (Whittington, 2017). In addition, Obama wasted the last 8 years spend on NASA to get Americans beyond LEO but announced that America would go to Mars within the next 30 years, where critics state that this announcement was made to distract from Obama´s lack of interest in space exploration and his vacuous space policy nature (Whittington, 2017).

The other popular program that ended after a governmental change is the Space Shuttle program. In 2004, former President George W. Bush announced the cancellation of the Space Shuttle after completion of the ISS as part of his vision for space exploration which was the Constellation program (Pascual, 2017). Although there were financial reasons behind this cancellation, the main reason was that the limited pool of people at NASA having experience in space flight could not be taken away from the still running ISS program, so the other space flight program (Space Shuttle) had to be phased out in order to fund and realise the Constellation program (Forbes, 2017).

The current US president Donald Trump released a budget proposal that announced the intention to cancel the ISS funding by 2024, although the official end of the ISS lifetime is set to 2028, because Trump´s main focus in space exploration is on returning astronauts back to the Moon (Grush, 2018). The end of the ISS program would free billions that are needed to realise the technology needed for achieving Trump´s goal, but as seen on the cancellation of the Constellation program by the Obama administration, the ISS ending could lead to a gap in LEO activities and no opportunity for NASA to get astronauts into space (Grush, 2018).

Last year, a congressional candidate in the Texas district launched an anti-space campaign that attacked the investments into space exploration with arguments about having problems on earth (Autry, 2018). This campaign and its arguments can lead to politicians criticising space science and although these candidates that fell for this campaign reveal their ignorance about science and economics, they can misinform and confuse the public about the scientific efforts of space agencies like NASA (Autry, 2018).

The impact of a governmental change can be seen especially on the example of US presidents affecting NASA missions. During the legislative periods of the current and the last two US presidents, the aim of the US space exploration programme changed from targeting the Moon to reaching Mars and back to sending astronauts to the Moon. In all three cases, budget requests of the reigning administration made a huge impact on running programs, even forcing them to be cancelled.

Therefore, the risk of LOP-G being cancelled or at least strongly influenced by US administration after a governmental change is immanent and should be part of future risk assessments.

2.3.2. Overdrawn Budget

Generally speaking, projects can fail due to numerous reasons, but as it can be seen on the examples of project cancellations shown in this work, most of space projects failed by reasons of overdrawn budgets, project delays, political decisions and lack of scientific or technological gain. Taking a deeper look at the causes for a project to be over budget, there are common factors that should be monitored to prevent this from happening (Angus, et al., 2015):

- Inflation during long-term projects
- Unfavourable changes in currency exchange rates
- Failing to get firm prices from suppliers and contractors
- Unplanned personnel costs, including overtime, incurred in keeping the project on schedule
- Unanticipated training costs and consulting fees

Especially in an organisation where funds are limited and projects have to compete for these limited funds organisations can suffer from financial downturns (Marchewka, 2014). The reasons for this arise from changing requirements in terms of laws, changing priorities of the organisation, self-made problems by management due to a lack of oversight or a bureaucracy of overly complex and unwavering rules and policies and/or a missing organisational plan to prepare stakeholders for planned changes which can lead to missing the proposed project deadlines (Marchewka, 2014).

2.3.3. Public Prestige

The benefits from space exploration reach from new knowledge and innovation to culture and inspiration and other direct, as well as indirect benefits as seen in figure 4. Besides these benefits, space exploration is also meant to advance the interests of the policymakers constituency and the nation, but more importantly it is a tool for international prestige, cooperation and leadership (Knipfer, 2017). China is the most up-to-date example of the positive impact of space exploration on the public prestige of a country. Although the Chinese space program isn´t operating scientific missions in the same depth as NASA does, they make visible advances in especially governmentally valuable moon missions much quicker than in other, less prestigious realms (Noack, 2019). The country made its most important missions like the currently successful moon landing public on its own, which is seen by external scientists as medium for China to gain prestige (Noack, 2019).

NASA´s Mars rover „Opportunity", which operated on Mars from 2004, felt silent in 2018 and as the reaction to its demise has shown, the real geopolitics of space exploration remain linked to prestige and national pride (Juul, 2019). Even further it can be said that since the beginning of the space age, nations were demonstrating their technological knowledge, skill and economic strength through venturous human and robotic spaceflight missions, and even more importantly these missions were seen as a matter of international standing and national prestige by great powers such as the US (Juul, 2019).

The most famous example of how a space project can have a positive impact on national prestige is the Apollo 11 mission, best known as the Moon-landing. By winning the space race between the America and the Soviet Union (SU) on sending humans on the Moon, the successful Apollo 11 mission had given a worldwide boost to America´s prestige and, especially for Americans heightened a sense of national pride (Chaikin, n.d.). This mission was intentionally aimed towards recapturing the prestige that the US lost due to the successes of the SU in space exploration and the failures of the US, therefore used by the US government as one major political act during the Cold War to symbolize the strength of America in the global head-to-head competition with Russia at that time (NASA, n.d.).

The downsides of the impacts of space exploration on public prestige can best be seen on the failure of a Russian Proton rocket in 2012 and other botched space projects of the Russian space agency. Besides a multimillion-dollar loss caused by the failed space projects, Russia´s then Prime Minister Medvedev stated that the government is losing authority and that they´re struggling to restore confidence in its space industry (Reuters, 2012). In addition, these failures undermined the standing of Russia´s space rockets in the market and strengthened competitors like Europe´s Ariane rocket (Reuters, 2012). Such reputational damages, as also seen on the Space Shuttle disaster in 1986, can plunge a governmental space program into a huge crisis, which also affects subcontractors in terms of falling stock prices and loss of credibility in the public eye (Rickard, 2015). NASA underlines the negative reputational impacts of a failed space project by officially commenting on the Space Shuttle Program that "[NASA´s] reputation was kind of sullied there, because we never finished what we started out to do" (Stone & Ross-Nazzal, n.d., p. 37).

The fact that space projects have an impact on the public prestige of the government, the agency itself and also on involved project partners in different ways is an important reason to include a possible loss of prestige in the risk assessment of the LOP-G project. In addition to the relation between large science projects and national leadership and prestige, the desire to maintain scientific leadership is embedded in the culture of US science and reinforced by the system of intellectual and financial incentives that govern the activities of research institutions and scientists (U.S. Congress, Office of Technology Assessment, 1995). This in return could lead to challenges in the collaboration between LOP-G project partners if a governmental change in the US leads to a scientific power struggle between the collaborating nations.

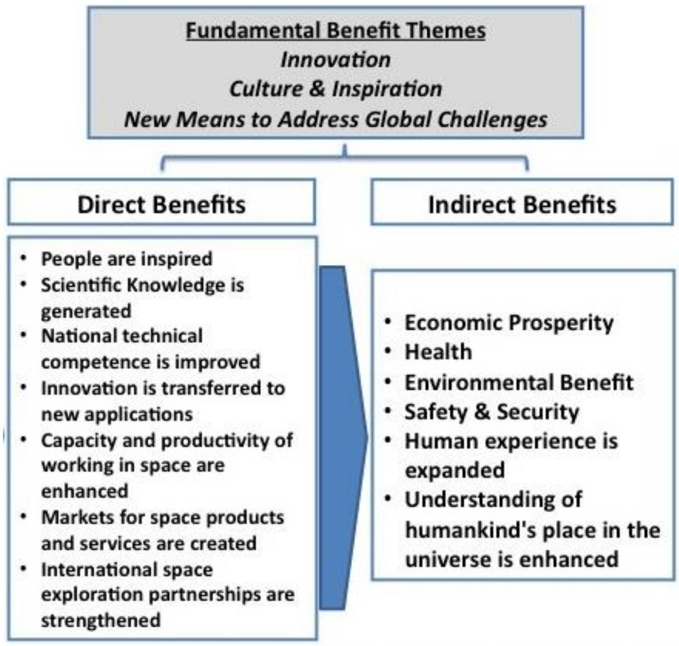

Figure 4: Fundamental Benefits of Space Exploration (ISECG, 2013)

2.4. Chapter summary

The findings of this chapter show that the existing risk assessment processes of industry and space agencies are similar and do include an analysis of political and financial risks. Although these risks are included, the literature review has revealed that projects and missions were cancelled because of financial issues defined in this chapter as overdrawn budgets, as well as political influences defined as political change and public prestige. As a result of the findings in this chapter, the focus will lie on analysing past project cancellations to find out to which extent these risks affect space projects by subdividing past cancellations into political and financial reasons, and quantifying these data to achieve the aim of this research study of establishing a risk framework for assessing future projects such as the proposed LOP-G mission. In addition, the risk that emanates from partnerships with other agencies and private industry will be analysed as this is part of the LOP-G mission.

3. Research Methodology

3.1. Introduction

In this chapter, the general structure, ethical considerations and limitations of this work will be defined to show the approach towards achieving the aim of this research study.

The next part of this chapter is the data collection in which it is described how the presented data was gathered and how it was used for further analysis. Project related risk rates are calculated, data sets about private-partners and public-partners are analysed and, risks that will later be used for the framework are measured.

3.2. Research Structure

The model that is used for structuring this work is the "Research Onion" model. It consists of the following six parts: Philosophical stances, Approaches, Strategies, Methodological Choices, Time Horizons, Techniques and Procedures, and helps to understand and choose a research philosophy (University of Derby, 2017).

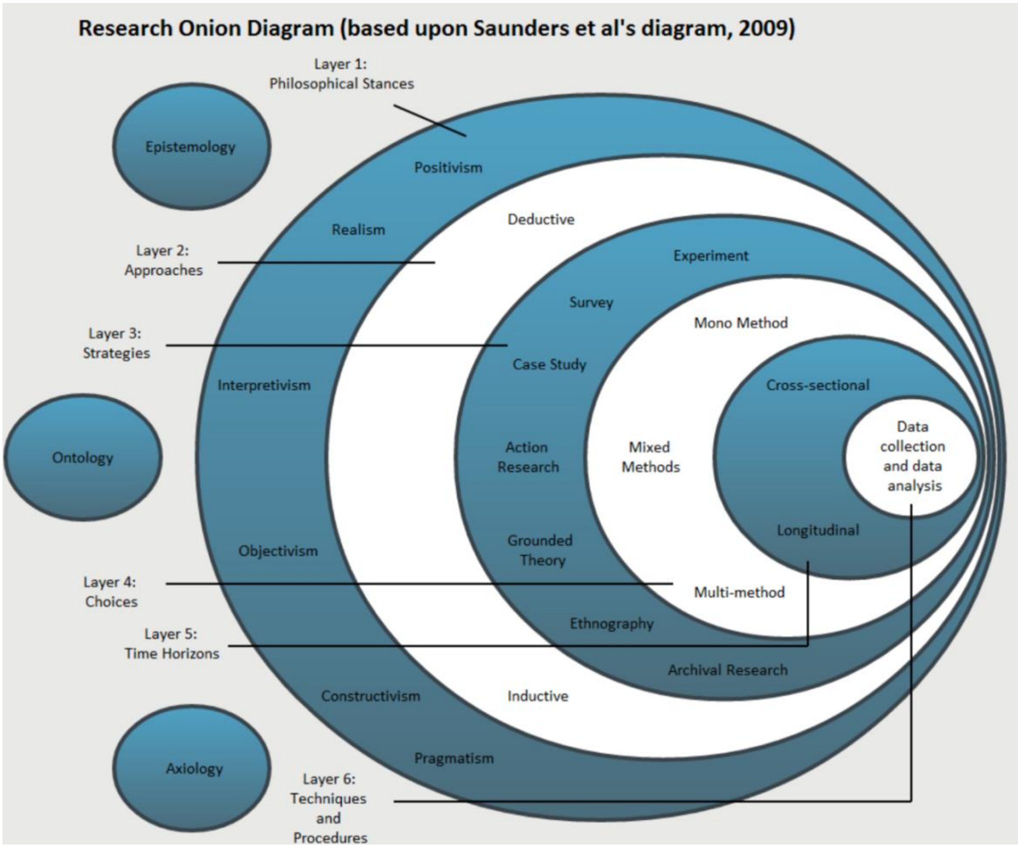

Figure 5: Research Onion Diagram (University of Derby, 2019)

3.3. Research Philosophy

Critical Realism is the philosophy of this work, because this philosophical position on the one hand encourages the gathering and understanding of data by assuming a scientific approach to the development of knowledge, and on the other hand recognises the need for multi-level study required for the research on this topic (Lewis, et al., 2009). Due to the fact that the research for this topic needs to be objective, the scientific approach is chosen to be deductive as it helps to explain causal relationships between variables, operationalises research needs and generalises research to ensure this work can be used for studying on similar projects in the future (Collins, 2010).

Most of the data that will be collected and used for this work is taken from existing data sets or archive documents which allow an explanatory, exploratory or descriptive analysis of changes, therefore the primary strategy used for data collection is the archival research (University of Derby, 2017).

Both qualitative and quantitative data will be gathered from past events, impacts on projects, or missions that belong to space science to see what could affect this research study and how.

The methodological approach towards this work is a mixed method of quantitative and qualitative research methods later described in the "Philosophical Approach". This approach will be further supported by the use of a scenario analysis generated from both sets of data.

The Time Horizon of this work is chosen to be a longitudinal study as it allows to detect changes or developments in the characteristics of the studied subject, as well as it allows to look beyond a single moment in time ensuring a deeper look into recent and past space projects needed to build up an overall picture about the possible impacts and their correlating variables on a long-term project like LOP-G (IWH, 2015).

Last, Data Collection and Analysis need to be defined as suitable decisions have to be made regarding primary and secondary research. All data will be taken from secondary research, because historical and present qualitative and quantitative data that can be related to the research study needs to be analysed by using suitable tools in order to achieve the aim of this work (University of Derby, 2017).

After all necessary data has been gathered through secondary research, this data will be analysed by combining and aligning the data to create a rating framework that can be used for assessing future long-term space projects in terms of especially qualitative risks.

3.4. Philosophical Approach

For achieving the aims and objectives of the research project, quantitative data will primarily be used and analysed which is supported and amended by the use of qualitative data. Quantitative research is used to capture relevant facts and explaining these with empirical-analytical methods by using numeric, statistic and analytic data taken from all types of statistics, timescales, surveys, etc. (Ernst, 2003). Additional qualitative research is needed for this work, because only using quantitative research methods will not allow showing the full scope of possible problems. Complete control and objectivity will not be achieved with just quantitative research, and the data gathering instruments cannot solve all open questions that occur in the behavioural sciences, which is an important part of this work to be analysed due to factors like political change or public prestige (Taylor, 2005).

The benefits of using additional qualitative research are: the researcher can include both descriptive and interpretive data analysis, and that these methods are theoretical frameworks as basis of a process of the phenomena being studied (Trumbull, 2005). Combining both research methods often has a complementary effect on their strengths and weaknesses, and in addition allows opportunities for feedback to help interpreting the findings, conducting an analysis on different levels and obtaining more perspectives in order to get a broader view on the research subject (Bamberger, 2000; Stirn, 2018).

3.5. Data Collection

In the following chapters, all data that has been analysed earlier in this work, as well as data generated from information taken from official publications of space agencies and their partners is collected and summarised.

Although CNES is not a partner of the LOP-G project it has been analysed due to the unavailability of information from other LOP-G partners (see Chapter 3.6. Limitations) and its comparability in terms of organisational structure, governmental affiliation and space missions to those project partners (CNES, 2019; JAXA, 2019; Roscosmos, 2019).

3.5.1. Project Terminations

To be able to determine the various ratios of project completions, project cancellations and project terminations, the total amount of missions and projects of space agencies (NASA, ESA, CNES) will be summed up by using data taken from the space agencies´ websites and Wikipedia, which is then double-checked using academic research combined with online searching tools such as Google, DuckDuckGo and follow-up websites. Missions or projects that occur in data sets of multiple agencies such as "Hermes", "BepiColombo" and "Cassini-Huygens" will appear in every of the dedicated agencies´ list of missions compiled in this research study.

After these data were collected, the total amount of project completions and cancellations, as well as their associated ratios will be determined. A combined ratio will also be determined that is defined as termination ratio, due to the fact that the effects of a project termination, whether the mission was cancelled or completed, are similar as it has been earlier proven in this work. Future missions have been included in the total number of missions, but missions that are proposed but not officially confirmed have been excluded.

The used data sheets can be found in the Appendix (Appendix 1-3). All calculations used the SUM function determining the total amounts of: missions, terminations and cancellations for each space agency. The ratio of each variable is then calculated by dividing it by the total amount of missions, then multiplied by 100 to express the ratio in percentage, e.g.:

$$\frac{Total\ amount\ of\ project\ cancellations}{Total\ amount\ of\ missions} \times 100 = Cancellation\ ratio\ in\ \%$$

The "Termination Ratio" is defined in this work as the ratio of all missions that have been ended by the space agency, whether completed successfully or cancelled. This ratio is created by summing up both completed and cancelled missions, divided by the total amount of missions and multiplied with 100 to express the ratio in percentage:

$$\frac{Total\ cancellations + Total\ completions}{Total\ missions} \times\ 100 = Termination\ ratio\ in\ \%$$

Due to the fact that the LOP-G project is a mission that will be operated by various space agencies, the average of each ratio to determine a combined and project specific completion ratio (CoR), cancellation ratio (CaR) and termination ratio (TeR) is calculated by using the following formula:

$$\frac{(comp.NASA\ missions + comp.CNES\ missions + comp.ESA\ missions) \times 100}{tot.NASA\ missions + tot.CNES\ missions + tot.ESA\ missions} = Average\ CoR\ in\ \%$$

These three average ratios are used as the approximate value of project cancellation ratios to establish the proposed framework. Although the LOP-G mission is mainly operated by NASA, the average approximate value of the three ratios will be used in the risk assessment process, because projects that involve operating partners are riskier, especially in terms of intersection points (Brohman & Cross, 2014). The greater the value of a project and the more suppliers or project partners a project has, the greater the risk of failing to execute the project (Brohman & Cross, 2014) , which is why it is important to include both the ratios of each space agency and the combined ratio of all partners in the risk assessment process.

3.5.2. Private-Partner Ratings

It is also important to calculate the potential risk of one or more industry partner cancelling the contribution to the LOP-G project, because industry partners are operating on constructing station modules and propulsion modules which are essential parts of the space station and therefore bear a certain risk towards the mission if not completed according to the project plan or cancelled at all (Hedman, 2019). There is no data available to precisely calculate such ratios, therefore a qualitative approach towards the risk assessment of private partners is chosen. The assessment and risk analysis of project partners is important in terms of public-private partnerships (PPP), because PPP projects include different risks that can be categorised into these five main risk categories (Alier, et al., 2006):

- Construction risk: results from project delays, overdrawing building costs or design problems;
- Demand risk: results from the ongoing need for service;
- Availability risk: related to the quality and continuity of service provision;
- Residual value risk: related to the future market price of an asset; and
- Financial risk: results from the variability in exchange rates, interest rates, and other factors that affect financing costs.

A PPP in case of a science project, or more generally spoken in a research & development (R&D) case, is defined as "any formal relationship or arrangement over fixed-term/indefinite period of time, between public and private actors, where both sides interact in the decision-making process, and co-invest scarce resources such as money, personnel, facility, and information in order to achieve specific objectives in the area of science, technology, and innovation" (Organisation for Economic Co-operation and Development, 2014, pp. 9-10). Based on this definition, the "Residual value risk" and some of the financial risks like variability in exchange rates and interest rates can be excluded.

Due to the complexity of assessing and calculating each factor of an industry firm that may or may not pose any risk of a project cancellation, this work will use data provided by rating companies such as “Standard & Poors” and “Moodys” which will then be transferred into the framework later in this work. The remaining risks are summarised and then categorised into “Experience”, “Funding/Budget” and “Company Performance”.

The term “Experience” is defined in this work as the experience of the private sector company in working together with public companies, as well as in working on space projects. By having a high rating in “Experience”, the risk of project delays, design problems, overdrawing building costs and both demand and availability risk is reduced (Gransberg & Riemer, 2009; Baker, 2010).

“Funding/Budget” is defined in this work as how secure and stable the financial situation of the company is to endure such a long-term project. This variable is analysed and rated by looking at financial analysis of external rating agencies mentioned before. The higher the rating, the more stable the company is and the less the risk of being forced to cancel the project due to financial problems, therefore reducing the overall financial risk (Shemetev, 2010).

The third and last term “company performance” is defined in this work as the overall performance of the organisation measured by analysing past and present stock market performance, revenue and the future outlook of the organisation evaluated by rating agencies. A high rating in this category reduces the Availability and Demand risk, because a stable looking company is more likely to last for the duration of a long-term project and therefore able to provide ongoing service for the project (Welpe & Wollersheim, 2015; Ferrell, et al., 2015).

Starting with current ratings and historical rating data from Airbus, the organisation received a stable outlook for short term and long term operations from three different rating agencies (Standard & Poor´s, Moody´s and Fitch Ratings), which the company also received in the past 4 years (Airbus, 2019). The Boeing Company has recently been rated by Moody´s and also received a stable outlook with two positive ratings for short term and long term operations as well (Moody´s, 2019).

Lockheed Martin, another partner of NASA on the LOP-G project, has been rated with a stable outlook and positive ratings for both short term and long term operations (Moody´s, 2019).

The last industry partner that has officially been stated by NASA is the Russian S.P. Korolev Rocket and Space Corporation "Energia" (Zak, 2019). There are no official ratings published to this time, therefore data provided by various stock analytic companies, as well as data provided by other sources will be used and aligned to rate the company.

3.5.3. Agency-Partner Ratings

For further assessment of the feasibility of the LOP-G project, the overall country risk of the operating space agency partners will be analysed. The analysis has its main focus on the overall country risk, the credit rating and the political stability. Data is taken from the currently published country risk analysis and risk map of the AON company, because this organisation is a leading global professional risk and insurance services firm (AON, 2019) that also includes ratings of different rating agencies in their analysis. Additional information about the country´s credit rating is taken from Trading Economics, who also combine ratings of various rating agencies (Trading Economics, 2019) and from information provided by the Coface Group, which is a global working credit insurance and risk management agency that publishes economic studies about every country (Coface, 2019). Some information about the economic and political outline of a country are taken from the Santander market trend analysis as Santander is one of the world´s best banks in 2019 according to Forbes (2019). For the evaluation of the credit rating of the European Union (EU), the officially published credit ratings from the European Commission (European Commission, 2019) are used. All the information gathered from AON, Trading Economics, Coface, Santander and the European Commission will be put into a chart and rated individually, where A is the best possible rating and E the worst possible rating.

The rating in this work is focused on risks and ratings that can have a direct or indirect impact on public space agencies and therefore the LOP-G project. For agency partners, the following criteria have been taken into account for generating the partner rating:

- Country risk: Data from up-to-date country risk assessments from AON and Coface. The higher their rating the higher the rating in this work.
- Credit rating: Information from economic studies and credit ratings published by rating agencies such as Coface, Trading Economics, etc.
- Political Stability: A combination of information taken from country risk assessments, as well as economic and political outlines provided by e.g. Santander.

For private industry partners the following criteria are used:

- Experience: Is defined as the partner´s experience in working on space related projects. For this, all information related to space missions and projects is taken from the company´s database. A high amount of space related projects and the longer a company is involved in working in this field, the higher the rating in this work.
- Funding/Budget: Is aligned to the financial rating of the industry partner. The information is mainly taken from stock ratings and/or finance agencies that rated the financial status of the organisation.
- Company performance: This criteria is assessed by combining the information about the organisations stock market development taken from the "Funding/Budget" assessment, combined with the information taken from the organisations current company report (except for Energia: there was no company report available, so external evaluations from financial rating agencies also used for the "Funding/Budget" assessment are taken into consideration).

After each of the three attributes has been individually rated, an overall rating will be concluded by summing up every individual rating (A=1, B=2, … E=5), dividing it by the total amount of ratings which in this case is 3 and commercially rounding it to two decimal places. The following is a mathematical example of the Japan rating in this work:

$$\frac{B+A+B}{3} = \frac{2+1+2}{3} = \frac{5}{3} = 1{,}666667 = 2 = B\ Overall\ Rating$$

The overall ratings are then used for the assessment of the "Partner Risk" and therefore needed for the establishment of the framework.

France and the EU for example received an average country risk rating in this work due to the fact that according to AONs Risk Maps 2019 populist parties have gained ground and are continuing to spread, which is dangerous for "traditional" politics going forward and also for the Europe in general, because populist parties have an anti-EU slant (AON, 2019) (see "Partner Scenario Analysis" – Appendix 5 for examples).

According to the findings in this work about each country in which one of the LOP-G space agency partners is inhabited, the concluded rating can be taken from the information in Appendix 6 "Partner Analysis".

3.5.4. Risks

To be able to establish a risk framework, all risks that have been shown in this work need to be captured and summarised. In the following, a list of the identified risks is generated and categorised afterwards to simplify the framework:

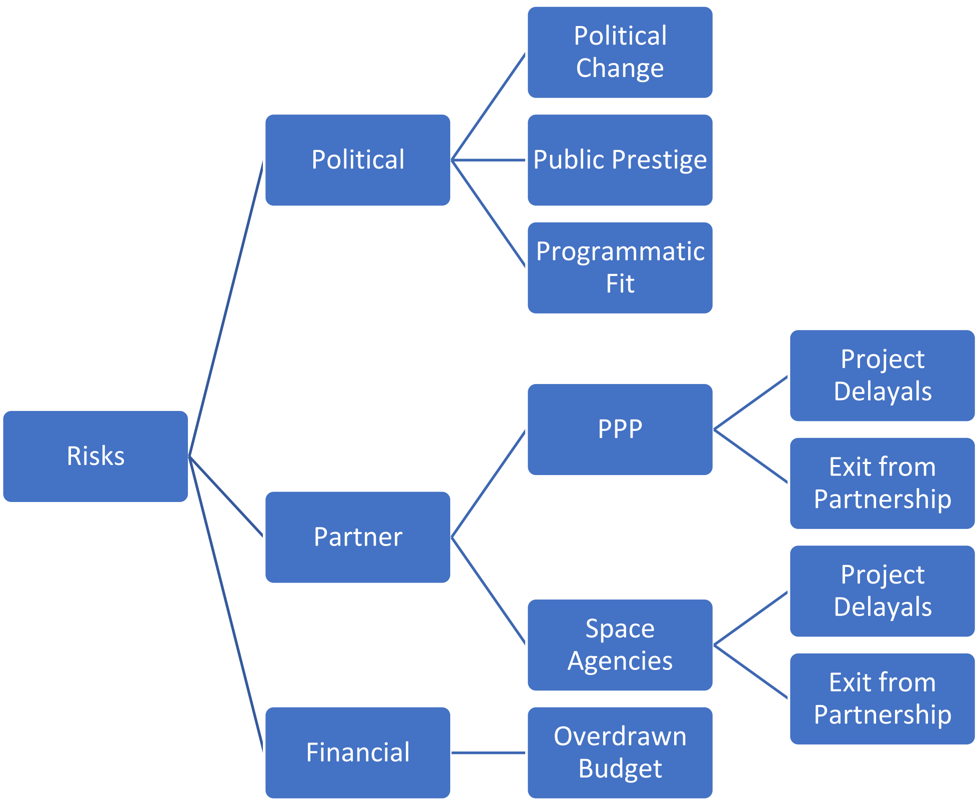

Figure 6: Risks and subcategories

As it can be seen in the analysis and rating of the confirmed project partners, all private partners have a rather stable overall rating and therefore, the focus will not lie on further analysing the risks that can emanate from these partnerships. In addition, this research could not reveal evidence of a cancelled space project caused by a private company. Even though, it is important for the directing project management company, which in this case is NASA, to constantly monitor project partners and to further update the partner scenario analysis to ensure that a possible project cancellation is unlikely to happen or at least early identified.

All risks are summarised to the three main categories "Political", "Partners" and "Financial". All cancelled missions brought together in the Excel sheets (Appendix 1-3) are divided into the three categories according to their reason for a cancellation taken from the associated sources. It is important to mention that during the research it appeared that most of the projects were cancelled due to budget constraints. Although it seems that this is a financial reason or risk, this reason for a cancellation is declared as political risk due to the fact that budget cuts of a project or a stop of funding are related to programmatic fit, which can best be seen on the current example of the WFIRST mission (Foust, 2018). Hence, project cancellations that result from overdrawn budgets are declared as financial risk, and project delays or cancelled partnerships are declared as partner risk.

The formulas used to calculate the various ratios that determine the share of a specific risk to the total amount of cancellations a space agency had are the following:

$$\frac{Cancellations\ by\ risk\ type\ of\ the\ agency}{Total\ amount\ of\ missions\ of\ the\ agency} \times 100 = Specific\ risk\ ratio\ in\ \%$$

and

$$\frac{Total\ cancellations\ by\ risk\ type}{Total\ amount\ of\ cancellations} \times 100 = Overall\ risk\ ratio\ in\ \%$$

3.5.5. Aligning qualitative and quantitative risks

The evaluation of the contribution of industrial partners to the LOP-G project and the PPP shows that all industrial partners have a stable future outlook and former experiences in the field of space related projects.

Just as in the assessment of public partners, there is no information about space project cancellations that were caused by a PPP, resulting in a qualitative assessment of the risk.

The Triangulation method will be used in order to on the one hand be able to link both the qualitative and quantitative risk assessment of this research study to generate the risk framework (Salkind, 2010), and on the other hand to ensure that the qualitative assessment is performed with the minimum level of bias (Rossi, 2007).

3.6. Limitations

One major limitation that occurred during this study was the unavailability, or limited access of data about space projects of JAXA and Roscosmos. Although both space agencies are governmental and public companies, there are almost no data sets publicly available that could be used for meaningful analysis. After multiple attempts to get further information from both agencies about past and recent space projects via e-mail, no answer or data that could be used for this work has been received. Therefore, these two agencies could not be analysed in terms of cancellation rates or similar examinations and have only been included in the partner analysis.

All data gathered in this work concerning space missions of NASA, CNES and ESA might include missing data about missions due to the fact that many information about especially cancelled space projects were found in sources that are not directly linked to the information taken from the agencies´ official websites, like e.g. in newspapers, journals and scientific books. For a more significant and precise analysis of the research study, it is suggested to request all data directly from the space agencies and to analyse the data provided, which was not given for this work to this date.

Information regarding the political decision-making process in both governmental and space agency decisions could only be addressed on a meta-level, therefore all results and conclusions drawn from these information are simplified.

The data needed for this research study was not intended to be used for such research which is why some sources and data collected can be less accurate.

3.7. Ethical Considerations

The ethical focus of this work is to develop an objective and fact based evaluation of current, past and future space projects by providing a neutral research study that is based on neutral resources used in the data collection process of this work. It is important to state that although the DLR was partly involved during the research of this study, no views or opinions of the institute have been incorporated in this work to make sure that the results of this work do not include any political, professional or personal bias. This is because the involved DLR institute is part of the Research & Development branch and not part of the agency branch. Therefore, a neutral and objective analysis is ensured and the secondary data chosen for this study will exclusively represent a risk of researcher bias.

4. Results and Analysis

In this section, the findings of this research study are summed up followed by an analysis of the results.

4.1. Results

The LOP-G project is a long-term follow-up mission to the ISS which was proposed by NASA and accepted by US government to be realised. Besides various critics about the necessity and scientific benefits of having a space station orbiting the moon, no access to human spaceflight missions in LEO and possible costs explosions due to a much higher delta-V, there are various risks that can have huge negative impacts on the whole mission which should be considered.

The negative effects of a mission being cancelled after years of work on both workers and the agency itself are huge, but nearly the same when a mission is successfully completed. These effects range from frustrated employees over fears of decline and generally a downsize of workforce. In addition, a cancelled project can also cause other projects related to that to be cancelled as well. Even unforeseen events in other running projects like overdrawn budgets or project delays can cause project cancellations. It is therefore very important to reduce the risk of a cancellation, for example by using the findings of this work and including these in the risk assessment or project assessment process, or at least to reduce the negative effects of a cancellation.

One of these major risks leading to a project cancellation and causing such effects is the influence of political and governmental decisions on public space agencies such as NASA, CNES, or even ESA. This is because programmatic decisions and budget decisions, as well as decisions over the mission funding and the agencies themselves can be made by the heads of government.

The reasons for these cancellations primarily result from budget constraints or changes in programmatic fit, both again result from decisions made by the government. In this research study, the main factors that led to such decisions being made are political change, public prestige and financial instabilities, whereat the last only applies on CNES and ESA according to the information collected. Therefore, an analysis of the impacts and risks of political change influencing the decision-making processes of projects could successfully be realised as stated in the objectives.

The analysis of the financial risks of space projects revealed that the main factors that cause overdrawn budgets or lead to cost explosions are: Inflation during long-term projects, failing to get firm process from contractors and suppliers, unanticipated consulting fees and training costs, unplanned personnel costs and unfavourable changes in currency rates (Angus, et al., 2015). Although these factors could have been determined as stated in the objectives, it is suggested to further analyse the determined factors to be able to optimise the monitoring and controlling of these factors.

By calculating the rates of project cancellations of the three space agencies and the ratios of cancellations by type (political, financial, partners), the following results were produced:

- NASA: 7,53% overall cancellation Rate - 72,22% of these due to “Political Risk”
- CNES: 2,41% overall cancellation rate - 75,00% of these due to “Political Risk”
- ESA: 5,69% overall cancellation rate - 85,71% of these due to “Political Risk”

More than 70% of projects have been cancelled due to political decision in each of the agencies. The average cancellation ratio of CNES, NASA and ESA in terms of political cancellations is 75,86%; political risk is the major risk.

The amounts of cancellations resulting from financial risks like overdrawing budgets have been calculated in this work with the following results:

- NASA: 27,78% “Financial” Risk rate
- CNES: 25% “Financial” Risk rate
- ESA: 14,29% “Financial” Risk rate

These results can also be seen in Figure 7, showing the shares in each of the three risk types to the cancellations of the space agencies, as well as an overall average breakdown of the risk types and their ratios.

The statistical risk of a partner causing a project cancellation is according to historical data 0%, because there has been no evidence about projects cancelled due to a partner leaving the project, causing project delays or overdrawing the budget.

Industrial partners and their possible impact on the LOP-G project have been analysed in this work with the help of ratings of external rating agencies and a scenario analysis that also includes risks and ratings of external agencies. In a PPP, the main risks that have been identified are demand risk, availability risk and financial risk. These risks have been categorised into experience, funding/budget and company performance. All partners rated in consideration of these categories received an excellent and stable overall rating except for Energia. Although the company has worrying balance sheets with weak fundamentals (Simply Wall Street Pty Ltd, 2019; Marketwatch, 2019; Bloomberg, 2019), the company can still be seen as a stable project partner due to Energia being the largest space industry company in Russia with experience in developing and constructing space stations, but also due to the fact that the company´s umbrella organisation is the state corporation Roscosmos (Henry, 2015).
Nevertheless, the scenario analysis (see Appendix 5) revealed that there are various possible scenarios to happen that could disrupt the LOP-G project.

The space agency partners have also been analysed using the same methods as for the industrial partners. The main risks of space agencies have been aligned to the risk types defined in this work, except for the partner risk. These are categorised into country risk, credit rating and political stability. The results are that except for Roscosmos which received an average rating, the overall stability of the space agencies is good.

The calculation of the mean ratios offers the following results:

- “Political” risk mean ratio ≅ 78%
- “Financial” risk mean ratio ≅ 22%

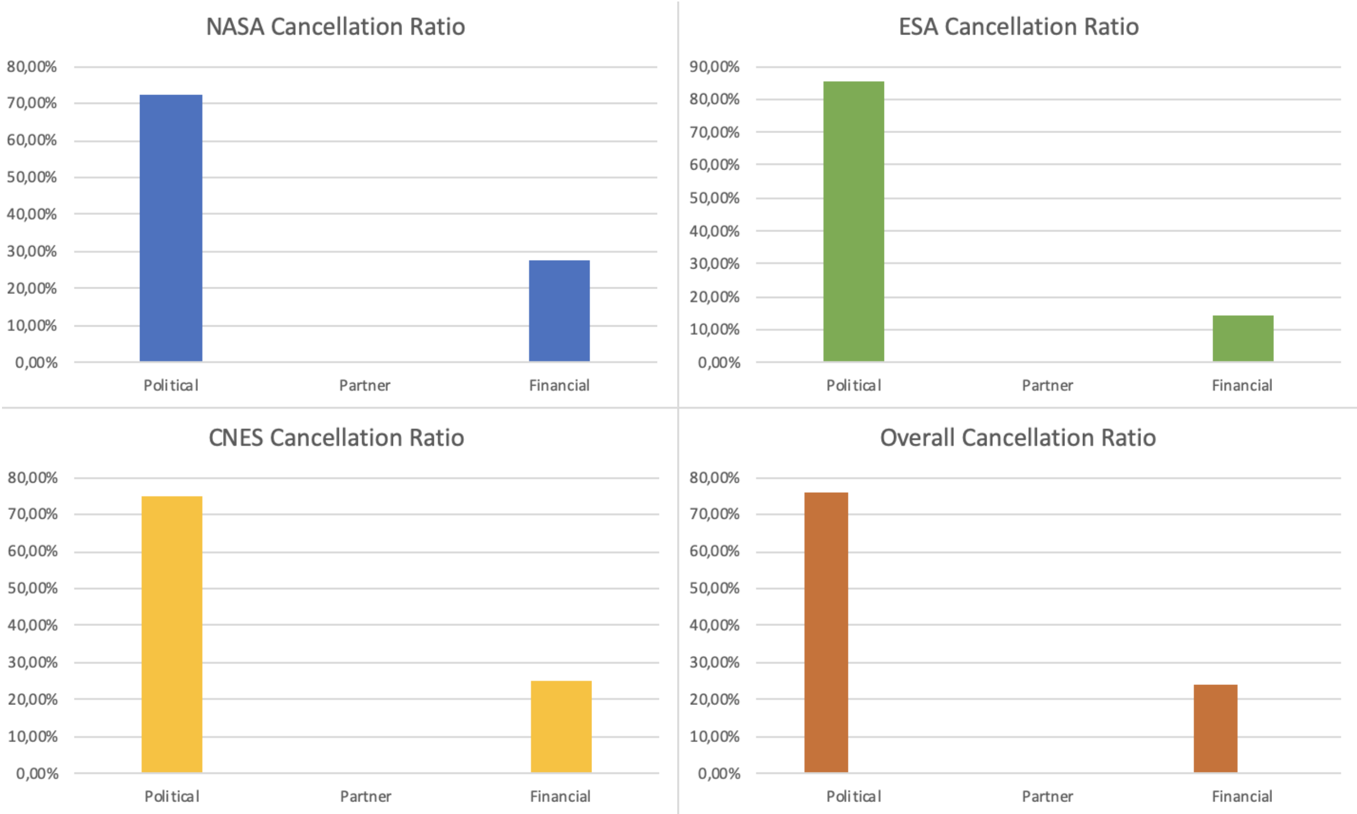

Figure 7: Cancellation Ratios

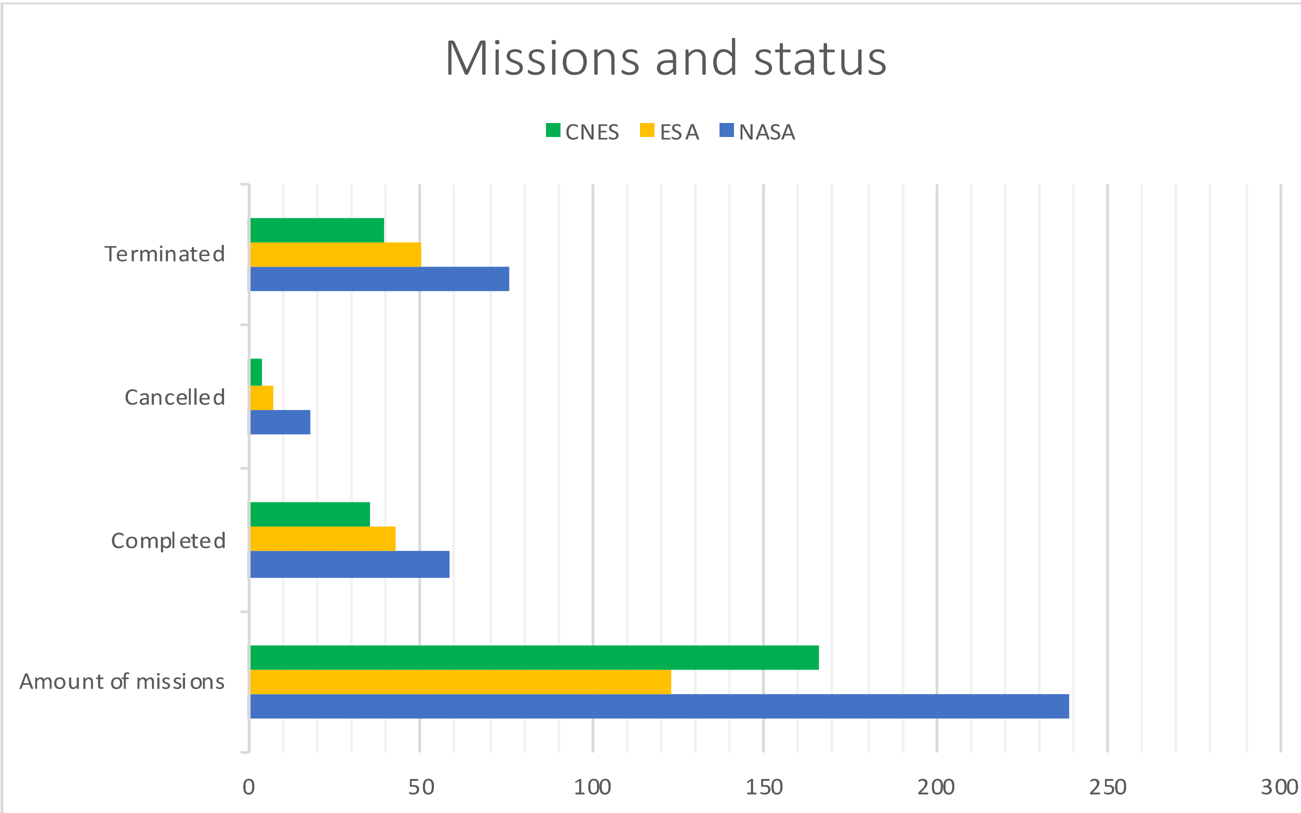

Figure 8: Missions and status by agency

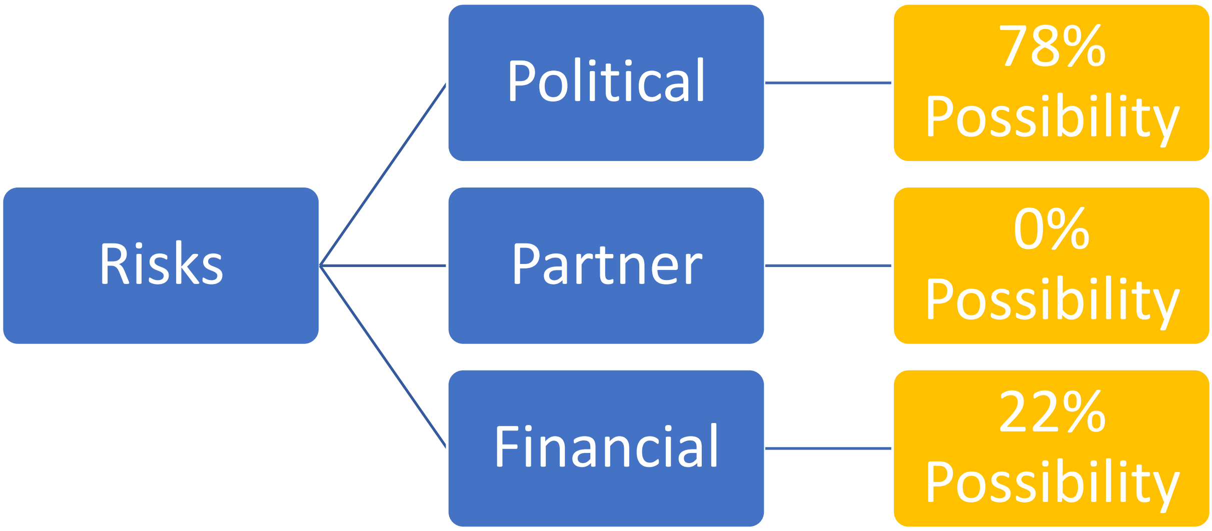

Figure 9: Risk weighting

4.2. Analysis

By analysing the cancelled projects of all three space agencies it has been identified that political decisions have a major effect on projects and missions directed by space agencies. In addition, although space agencies include political risk in their risk management and project assessment processes, the main reasons for a project to be cancelled is due to political reasons.

The projects that were cancelled range from rather small satellite missions to huge long-term projects such as the "Constellation" program, which leads to the conclusion that these risks apply on all kinds of projects equally.

These reasons are expressed as budget cuts, budget constraints, programmatic fit and scientific use. This research study also identified that additional reasons were public prestige and personal interest of the head of government, especially in the US government as seen most recently on the cancellation of the "Constellation" program.

The current US president Trump changed his space exploration plans in June 2019 and published a statement in which he said that NASA should not focus on going to the Moon, but instead focus on Mars and Defence and Science (McGraw, 2019). This now in return signalised a shift in the governmental support for NASA´s Artemis mission (Kooser, 2019), which underlines the impact of governmental interests on a scientific mission. This is therefore possible to happen to the LOP-G mission as well, not only because of this, but also due to the fact that the US government will have at least two more elections with two possible governmental shifts before LOP-G will successfully be completed. The likeliness of President Trump, or following US presidents to shift NASA´s aims or to reallocate budgets of existing projects is therefore given. Consequential, the risk of the LOP-G mission suffering budget constraints, budget cuts or other formerly stated risks is eminent and should be assessed and monitored throughout the missions lifetime.

In Chapter 2.3. and its subchapters, reasons for project cancellations were pointed out and categorised into political change, public prestige and overdrawn budget. The analysis of the data collected throughout this research study shows that especially the two political risks correlate with project cancellations. The fact that about ¾ of all cancelled projects throughout all three analysed agencies have a political reason as cause for that proofs the influence of political decisions on running space projects. That science in general and space research is under political influence has already been verified (Lopatto, 2017; O´Raifeartaigh, 2018; Dawson, 2016), but impacts and risks emanating from these influences have not been analysed. Using the information from the calculations and the data gathered during this research, the negative impacts of politics affecting space projects can be defined as worst-case scenarios according to the definition of Dennis Lock and Lindsay Scott (2016, pp. 37-38), because of the fact that the projects were cancelled and due to the resulting negative effects on the agency and its workforce. The calculations also revealed that in all analysed space agencies the majority of cancellations is linked to political influences (Figure 9), and that this risk can be numerically expressed.

In Figure 8 it can be seen that the amount of missions cancelled is marginal compared to the total amount of missions. When expressing the total numbers in percentages rounded to one decimal place, only about 8% of NASA, 2% of CNES and 6% of ESA missions are cancelled. These findings suggest that the calculated cancellation ratios are low and may be considered as “acceptable” risks, but because of the negative effects caused by these minor risks these ratios have to be included in the assessment processes of missions and projects. The importance of managing minor risks is vital to an organisation and should not be ignored (Banks, 2003).

These results are surprising as the author expected the cancellation rates to be higher. This can be linked to whether good planning of the missions and projects, or to a rather stubborn approach towards the completion of projects. To get a more precise evaluation of the reasons for these low cancellation ratios, further analysis of the completed missions by taking a look at the related success rates is recommended. One possible way of doing so is the assessment of target achievement rates of completed missions. If e.g. one third of all completed missions only managed to achieve about half of their scientific goals, this would indicate that the analysed space agency has a stubborn approach towards the completion of missions, which in return could be linked to public prestige.

Comparing the three risk ratios it is interesting to see that ESA has an about 10% higher political risk ratio than CNES and NASA. The reason for this could be the structure of ESA (as described in Chapter 2.3.). As ESA is an association of multiple European countries that can vote on projects on a democratic basis, this could lead to a higher political influence on projects than in CNES and NASA, resulting in a higher political risk ratio.

Another reason for these low ratios could be the restricted accessibility of cancelled projects and missions. During the data collection and research phase of this work, it appears that although the analysed space agencies have signed an agreement about the transparency in space activities (Singer, 2019) the availability of official information about cancelled space projects is limited, especially in case of NASA. Some of the information about cancelled projects could not even be accessed via official space agency websites and needed to be accessed using information taken from journals or (online-) newspapers.

According to the partner ratings of the public partners, the overall stability of partners is good, except for the Russian agency Roscosmos which received an average rating. Since there still exists a wish for scientific leadership, especially in the US government, and since there currently is a political discrepancy between US and Russian government (Russell, 2018), it is suggested to draw this into account when assessing the risks of the LOP-G project. Both JAXA and Roscosmos could not be assessed as precisely as NASA´s other partners CNES and ESA due to lacking information about missions and cancellations, but because both agencies contributed various missions to the ISS (Zak, 2017; JAXA, 2016) and because the partner analysis ratings expressed an average to good overall rating, the risk of project disruptions coming from these agency partners can be assessed as improbable. This is also supported by the calculation of mission cancellations by type which revealed a 0% cancellation caused by project partners. This can be linked to the fact that space agencies offer contracts that include milestone payments to their partners (NASA, 2017; Eurostat, 2016). Although payments to agency partners are secured and the possibility of a cancellation of a paid partnership is unlikely to happen, the qualitative results combined with the scenario analysis on the contrary lead to the conclusion that there is a minor risk which needs to be controlled.

After the triangulation method was applied to align the qualitative and quantitative "Partner" risk results, the implications of the findings are to include a hypothetic risk ratio to ensure that the minor "Partner" risk can effectively be implemented in the risk framework. This also ensures that the risk is not ignored and therefore monitored throughout the lifetime of the project or mission. The triangulation method was chosen as it helps especially when divergent results appear and can lead to a better explanation of the analysed problem (Jick, 1979), as well as this method minimises biases that may be inherent when using a single research approach (Salkind, 2010). In the case of this research study the method helped to link all results of the partner analysis to the results of the analysis of historical data about space missions. The triangulation and analysis of the "Partner" risk still results in a 0% risk ratio, but leads to the awareness of including this risk in every space agency´s risk management process due to the fact that private actors are becoming more important in future space activities (Bockel, 2018), and due to the analysed risks emanating from partnerships (see Chapter 3.5.2.).

As was seen by Alier, et al. (2006), there are five major risks of a PPP that can lead to the project being negatively affected up to a project cancellation. According to the findings of this work, none of these risks occurred during a PPP yet. Nevertheless, the scenario analysis revealed some possible risk scenarios that can affect the LOP-G project (Appendix 5). This was an essential objective needed for achieving the aim of this work, because the LOP-G project is reliant on the contribution of private partners (Hedman, 2018; Sloss, 2018) and the analysis of historic space project data has not shown any evidence about an existing correlation between project cancellations and PPP´s.

Although an objective assessment of the risks expresses a minor threat for the LOP-G project to be cancelled, the current political situation of mainly the US, but also Russia and Europe should be considered. Due to the fact that LOP-G is a NASA operated mission and most of the budget is given by the US government, and the fact that according to the findings of this work the current political situation of the US can be seen as inconstant, especially in terms of the US space exploration plans, the political risk of the project should be uprated. This resulting subjective and qualitative assessment of the political risk should be included in the risk management plan of the mission to ensure that a stable financing of the project is secured and that all partners cooperate throughout the mission´s lifetime.

Such risk of the US president changing the plans of the public US space industry by reducing budgets and/or changing the aims and goals of NASA cannot be managed yet. A resulting scenario could be that the LOP-G mission loses its programmatic fit which in return can cause the project to be cancelled or delayed. One possible way of mitigating the impact of such a political decision and to deal with budget constraints or cuts is shown in the recommendation section of this work.

Aligning the findings of this work to the project and risk assessment processes of space agencies as described in Chapter 2, it can be seen that the method towards finding the results of this research study follow the almost identical steps used by NASA, CNES and ESA: identifying the risks, determining the probabilities, calculating and interpreting the risk values and lastly using these results within risk management.

The resulting risk framework as seen in Figure 10 can be implemented in the project and risk assessment process of a space agency, in this example NASA.

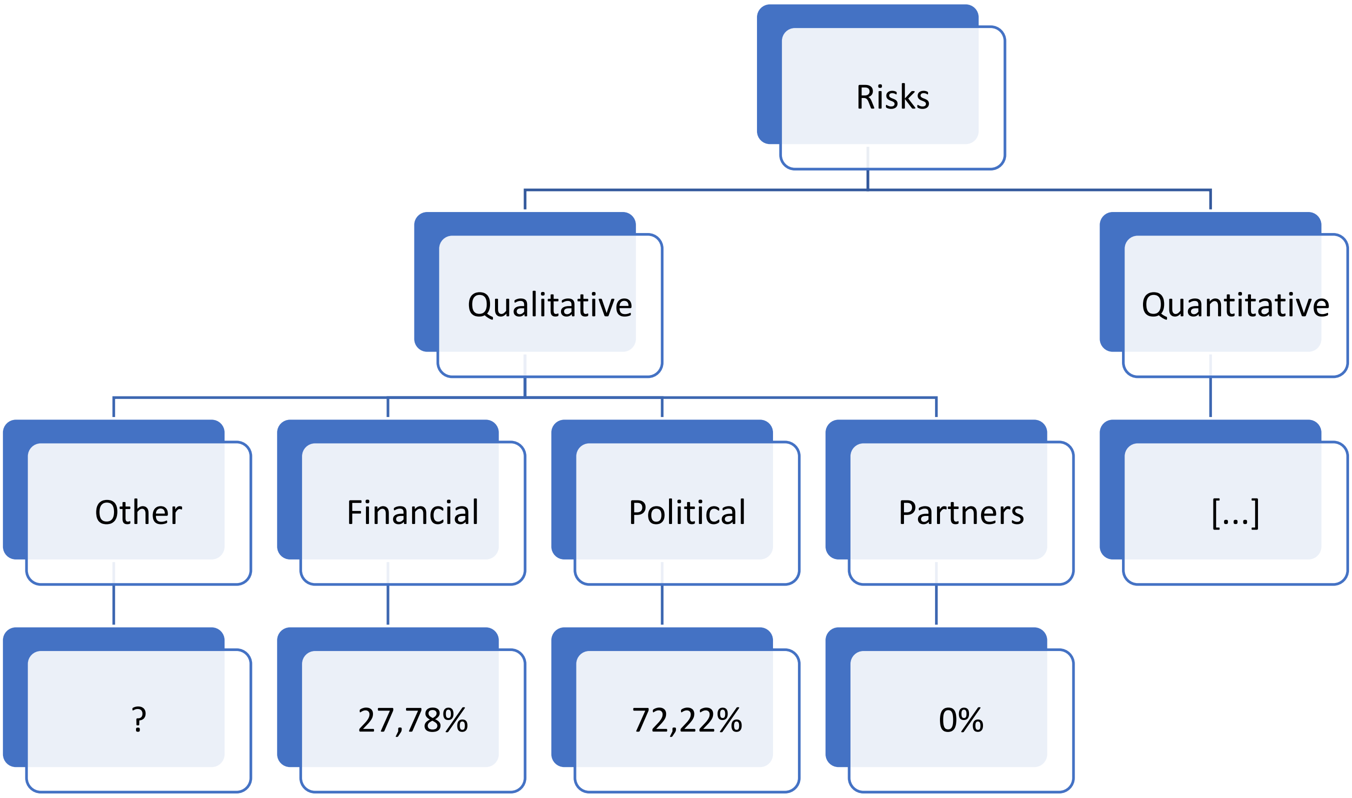

Figure 10: Risk Framework on the example of NASA

5. Summary & Conclusion

The research study revealed that the possibility of a project being cancelled ranges from 2% to 8% depending on the space agency. All project cancellations analysed in this work had been cancelled due to qualitative risks. More precisely, about 78% of these cancellations were caused by political impacts and 22% were caused by financial impacts. Therefore, political risk is the major risk. Last, although there is no statistical evidence or other information to be found that shows which missions were strongly influenced by a project partner that in the end forced the project to be cancelled, the risk of this to happen exists for as long as the project involves partners and should therefore not be ignored.

More generally, it has been found out that governmental and political change, as well as public prestige can negatively affect a project. The longer the runtime of a project is, the more political change it can encounter and therefore the higher the risk that budget constraints, budget cuts or even a cancellation can occur. Especially US presidents have had and still have major influences on running projects and can determine whether to change the programmatic aims of NASA or the budget. This can result in NASA being forced to adapt to these decisions, leading to changes within projects or whole missions. Transferring these findings and critics (see Appendix 7) on the LOP-G project, it can be concluded that this long-term space project can encounter many difficulties and should therefore be reassessed under the inclusion of both the findings of this work and the critics. It is important to add that these results are very superficial and should be further analysed for more precise evaluations of the risks.

A recent article about the US Vice President Pence announcing that the US plans to send astronauts back on the Moon within the next five years by reason of being in a 21st century space race (Wall, 2019) underlines the analysed influence of public prestige on space missions. Such a moon landing could raise the question of the LOP-G project being obsolete, which in return could increase the risk of a governmental decision to the disadvantage of the project.

The implications of these findings are that the subjective, qualitative risk of the LOP-G project encountering a cancellation is higher than the results of the quantitative calculation.

The generated risk framework (Figure 10) can be implemented in every project or risk assessment process of a space agency using the methods of this research study with the indication that it has to be updated on a regular basis. Such is necessary due to ever-changing economics and politics (Cerna, 2013), e.g. when there are governmental changes or when the project is shifted to a new project phase. This should then provide an informative and roughly calculable outlook on how feasible and stable a project is in regard of political, financial and project partner risks.

In addition, this framework, or more precisely the calculations of the cancellations rates can be used by other space agencies to assess the partner risk of the leading organisation of a project or mission. If e.g. NASA launches a mission and seeks for contribution of other space agency partners, these partners can use the framework and calculations to assess the risk of NASA cancelling the project due to one of the risks (Financial, Political or Partner).

On the basis of all analysed information it is proposed that NASA should find a comparable alternative to the LOP-G project. This would ensure that when one or more of the assessed risks has a growing probability, or occurs and disrupts the project, most of the work on the LOP-G project could be transferred to the alternative project, which could mitigate at least the impact of a worst-case scenario cancellation.

5.1. Open Issues

During this work, the subject-matter of a possible saturation within long-term space projects has been touched as seen on the example of the James Webb Telescope. There are projects that are behind schedule and overdrawing their budgets that are being or were kept alive, whereas on the contrary there are projects that have been cancelled especially due to these reasons. It is suggested to make this a subject for future research to determine the factors on which decisions whether to keep a project financed and running, or to cancel it are made.

As earlier mentioned in the "Limitations" section of this work, all data gathered to establish the framework and to draw conclusions about the cancellations are on a meta-level and do only show a scope on how the risks in this work impact on projects. On the basis of this it is proposed to go deeper into detail and to further analyse the exact reasons for the cancellations of the affected projects. This would lead to a more detailed risk register that could be part of future project and risk assessments of space projects, which in return could maintain and simplify the risk management process of space agencies comparable to the structure of NASA (like e.g. CNES and JAXA).

During the analysis of overdrawn budgets in chapter 2.3.2., two aspects that should be taken into further investigation have been identified. First, project delays are described as one major factor that causes a project to be financially overdrawn (Angus, et al., 2015), which is still happening in space projects and was a huge problem especially at NASA (Thompson, 2008). Secondly and in relation to project delays and cost overruns, one other main reasons of budget overruns are unplanned personnel costs, including overtime (Angus, et al., 2015). The implications of these findings are that space agencies should analyse the average amount of overtime an employee has to make during a project by generating statistics. These data sets should be investigated to find possible causes for that and in return be able to reduce the risk of such issues to occur.

As mentioned in the "Analysis" chapter, the reasons for the low risk rates should be further analysed to answer the question if space agencies have a stubborn approach towards projects, or if they have a good project planning. In addition, the reasons for the difficulties in finding some of the information about cancelled projects should also be analysed.

5.2. Recommendation

Due to the fact that there are still risks that are difficult to calculate, mitigate and manage like the change of governmental space exploration plans as seen on the formerly mentioned example of President Donald Trump, it is recommended to implement a system that helps to lower the impact of a project cancellation.

The idea is to establish a captive insurance company within the space agency, which functions as a life insurance for projects. Taking NASA as an example, the agency could establish a subsidiary company to "insure the risks of the controlling entity and/or its affiliates or its individual owners [being] subject to the same corporate governance matters […]" (PwC, 2019, p. para. 1&2).

This insurance company works like other insurance companies and would gather funds of all members, in this case projects or missions, which are later paid in case one of the projects is cancelled (Reavis III, 2012). The author suggests to set the premiums according to the average cancellation ratio of the space agency. Taking NASA as an example with an average cancellation ratio of 7,53%, every project that receives budget for realising the project (after Phase B is completed; see figure 11) should receive an additional 7,53% of funds that are directly paid into NASA´s captive insurance company.

If one of the insured projects is now being cancelled, the funds of the life insurance could be taken to finance the workforce that could be dismissed after losing the project. These employees could in return propose new projects with the information from the cancelled project or could help to complete other running projects. This might lower the negative impact of frustrated employees after a project is cancelled, won´t reduce the workforce and lower the fears of decline.

Mission lifetime cycle

Phase 0	Mission analysis and identification
Phase A	Feasibility
Phase B	Preliminary Definition
Phase C	Detailed Definition
Phase D	Qualification and Production
Phase E	Utilisation
Phase F	Disposal

Figure 11: Mission and project lifetime cycle (ESA, 2013)

Appendix

Appendix 1 – List of NASA missions

List of NASA missions			
Name	**Completed**	**Cancelled**	**Source**
ACE			(1)
Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT)	x		(2)
Advanced Earth Observing Satellite (ADEOS)	x		(2)
AIM			(1)
Analog Missions			(1)
Apollo			(1)
Apollo-Soyuz			(1)
Applications Technology Satellite (ATS)	x		(2)
Aqua			(1)
Aquarius	x		(1)
ARCTAS			(1)
ARTEMIS			(1)

ASTRO-1			(1)
ASTRO-2			(1)
Astro-E2 (Suzaku)			(3)
Atmospheric Laboratory of Applications and Science (ATLAS-1)	x		(2)
ATTREX			(1)
Aura			(1)
BARREL			(1)
CALIPSO			(1)
Cassini-Huygens	x		(1)
CHAMP	x		(1)
Champollion (Deep Space 4)		x	(4)
Chandra X-Ray Observatory			(1)
CINDI			(1)
Clementine			(1)

Cloud-Aerosol Transport System (CATS)	x		(1)
Cloudsat			(1)
Cluster ESA/NASA Mission			(1)
Combined Release and Radiation Effects Satellite (CRRES)	x		(2)
Comet Rendezvous Asteroid Flyby (CRAF)		x	(5)
Commercial Crew			(1)
Commercial Resupply Services			(1)
Compton Gamma-Ray Observatory			(1)
Constellation		x	(6)
Cosmic Background Explorer (COBE)			(1)
Cosmic Hot Interstellar Plasma Spectrometer (CHIPS)			(1)
CubeSats			(1)
Curiosity			(1)
CYGNSS (Cyclone Global Navigation Satellite System)			(1)

DART (Double Asteroid Redirection Test)			(1)
Dawn			(1)
Deep Impact	x		(1)
DISCOVER-AQ			(1)
Dynamics Explorer 1 (DE 1)	x		(2)
Dynamics Explorer 2 (DE 2)	x		(2)
Earth Observing-1	x		(1)
Earth Probe Total Ozone Mapping Spectrometer (EP-TOMS)			(1)
Earth Radiation Budget Satellite	x		(1)
ECOSTRESS			(1)
Environmental Science Services Administration (ESSA)	x		(2)
EPOXI			(1)
Euclid			(1)
Europa Clipper			(1)

European Remote Sensing (ERS-1)	x		(2)
Exploration Mission-1 (EM-1) (SLS/Orion)			(1)
Exploration Mission-2 (EM-2) (SLS/Orion)			(1)
Explorer			(1)
Extreme Ultraviolet Explorer			(1)
FAST	x		(1)
Fermi Gamma-ray Space Telescope			(1)
Fire and Smoke			(1)
FUSE			(1)
GALEX			(1)
Galileo			(1)
Gemini			(1)
GEMS		x	(7)
Genesis			(1)

GEOdetic SATellite (GEOSAT)	x		(2)
Geotail			(1)
GLAST			(1)
Global Precipitation Measurement (GPM)			(1)
Glory			(1)
GOES	x		(1)
GOLD (Global-scale Observations of the Limb and Disk)			(1)
GRAIL	x		(1)
Gravity Probe-B			(1)
Gravity Recovery and Climate Experiment (GRACE)	x		(1)
Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)			(1)
Heliophysics			(1)
Herschel			(1)
HETE-2			(1)

Hinode (Solar-b)			(1)
Hitomi (ASTRO-H)			(1)
HL-20 Personnel Launch System		x	(8)
Hubble			(1)
Hurricanes			(1)
IBEX (Interstellar Boundary Explorer)			(1)
IceBridge			(9)
ICESat	x		(1)
ICESat-2			(1)
IMAGE			(1)
InSight			(1)
International Gamma-Ray Astrophysics Laboratory (INTEGRAL)			(1)
International Space Station			(1)
Ionospheric Connection Explorer (ICON)			(10)

IRIS (Interface Region Imaging Spectrograph)			(1)
ISS-Rapid Scatterometer (ISS-RapidScat)	x		(2)
IXO (International X-Ray Observatory)		x	(11)
IXPE (Imaging X-ray Polarimetry Explorer)			(1)
James Webb Space Telescope			(1)
Jason	x		(1)
JUICE (JUpiter ICy Moons Explorer)			(1)
Juno			(1)
Jupiter Icy Moons Orbiter (JIMO)		x	(12)
Kepler and K2			(1)
LADEE: Lunar Atmosphere Dust Environment Explorer	x		(1)
LAGEOS 1 and 2			(1)
Landsat			(1)
Landsat Data Continuity Mission			(1)

Laser Interferometer Space Antenna (LISA)		x	(13)
LCROSS			(1)
Lockheed Martin X-33		x	(14)
Low-Boom Flight Demonstration			(1)
LRO (Lunar Reconnaissance Orbiter)			(1)
Lucy (Trojan Asteroid Mission)			(1)
Lunar Outpost			(1)
Lunar Quest Program			(1)
Magellan			(1)
Magnetospheric Multiscale (MMS)			(1)
Marine Observation Satellite (MOS-1)	x		(2)
Mariner			(1)
Mars 2020 Rover			(1)
Mars Astrobiology Explorer-Cacher (MAX-C)		x	(15)

Mars Exploration Rovers (Spirit and Opportunity)			(1)
Mars Express			(1)
Mars Global Surveyor	x		(1)
Mars InSight Lander			(1)
Mars Odyssey			(1)
Mars Pathfinder			(1)
Mars Reconnaissance Orbiter			(1)
Mars Science Laboratory (Curiosity)			(1)
Mars Scout Program			(16)
Mars Telecommunications Orbiter (MTO)		x	(17)
MAVEN: Mars Atmosphere and Volatile EvolutioN			(1)
Mercury (Human Spaceflight Program)			(1)
MESSENGER: Mercury, Surface, Space Environment, Geochemistry and Ranging	x		(1)
Mini-RF			(1)

Modular Optoelectronic Multispectral Scanner (MOMS)	x		(2)
Moon Mineralogy Mapper			(1)
Near Earth Asteroid Rendezvous (NEAR)			(1)
NEEMO (NASA Extreme Environment Mission Operations)			(1)
NEOWISE			(1)
Neutron star Interior Composition Explorer (NICER)			(1)
New Horizons			(18)
New Millennium Program		x	(19)
Nimbus 1	x		(2)
Nimbus 2	x		(2)
Nimbus 3	x		(2)
Nimbus 4	x		(2)
Nimbus 5	x		(2)
Nimbus 7	x		(2)

NISAR (NASA-ISRO Synthetic Aperture Radar)			(20)
Nmbus 6	x		(2)
NMP EO-1			(1)
NOAA-N			(1)
NOAA-N Prime			(1)
NOAA-POES (NOAA-POES)	x		(2)
NPP			(1)
NuSTAR			(1)
Ocean Surface Topography Mission/Jason 2			(1)
Operation IceBridge			(1)
Orbiting Carbon Observatory-2			(1)
Orbiting Carbon Observatory-3			(1)
Orion Spacecraft			(1)
OSIRIS-REx			(1)

PACE			(1)
PARASOL	x		(2)
Parker Solar Probe			(1)
Phoenix	x		(1)
Pioneer			(1)
Pioneer Venus			(1)
Planck			(1)
Pluto Kuiper Express		x	(21)
POES			(1)
Polar			(1)
Project Prometheus		x	(22)
Psyche			(1)
QuikSCAT			(1)
Radar Satellite (RADARSAT)	x		(2)

Radiation Belt Storm Probes/Van Allen Probes			(1)
Ranger			(1)
RapidScat			(1)
RHESSI			(1)
Roentgen Satellite (ROSAT)			(1)
Rosetta			(1)
RXTE	x		(1)
Scientific Balloons			(1)
SDO (Solar Dynamics Observatory)			(1)
Sea-viewing Wide Field-of-view Sensor (SeaWiFS)	x		(2)
SEAC4RS			(1)
Seasat 1	x		(2)
SeaWinds	x		(2)
SERVIR			(1)

Shuttle Radar Topography Mission (SRTM)	x		(1)
Shuttle-Mir			(1)
Skylab			(1)
Small Satellites			(1)
SMAP (Soil Moisture Active Passive)			(1)
SOFIA			(1)
SOHO			(1)
Solar Anomalous and Magnetospherice Particle Explorer (SAMPEX)			(1)
Solar Orbiter Collaboration			(1)
Solar Radiation and Climate Experiment (SORCE)			(1)
Sounding Rockets			(1)
Space Interferometry Mission (SIM)		x	(23)
Space Launch System (SLS)			(1)
Space Shuttle		x	(1)

Space Station			(1)
Spaceborne Imaging Radar-C (SIR-C)	x		(2)
SPHEREx			(1)
Spirit	x		(24)
Spitzer			(1)
Stardust-NExT	x		(1)
STEREO			(1)
Stratospheric Aerosol and Gas Experiment-III Meteor-3M (SAGE-III)	x		(2)
Submillimeter Wave Astronomy Satellite (SWAS)			(1)
Suomi NPP			(1)
Surveyor			(1)
Suzaku			(1)
Swift			(1)
Synchronous Meterological Satellite (SMS)	x		(2)

TDRS (Tracking and Data Relay Satellites)			(1)
Terra			(1)
Terrestrial Planet Finder (TPF)		x	(25)
TERRIERS	x		(2)
TESS (Transiting Exoplanet Survey Satellite)			(1)
THEMIS			(1)
TIMED			(1)
TIROS	x		(2)
TOMS-EP	x		(1)
TOPEX/Poseidon	x		(1)
TRACE	x		(1)
Tropical Rainfall Measuring Mission (TRMM)	x		(1)
TWINS			(1)
Ulysses	x		(1)

Upper Atmosphere Radiation Satellite (UARS)	x		(1)
Van Allen Probes			(1)
Viking			(1)
Voyager			(1)
Wide-Field Infrared Explorer (WIRE)			(1)
Wide-Field Infrared Survey Explorer (WISE)			(1)
Wide-Field Infrared Survey Telescope (WFIRST)			(1)
Wilkinson Microwave Anisotropy Probe (WMAP)	x		(1)
WIND			(1)
X-38		x	(26)
XMM Newton			(1)

(1) = (NASA, 2019)
(2) = (NASA´s Earth Observing System, 2019)
(3) = (NASA, 2019)
(4) = (NASA, 2019)
(5) = (NASA, 2019)
(6) = (NASA, 2019)
(7) = (NASA, 2019)
(8) = (Astronautix, 2019)
(9) = (NASA, 2019)
(10) = (NASA, 2019)

(11) = (NASA, 2019)
(12) = (NASA, 2019)
(13) = (NASA, 2017)
(14) = (NASA, 2017)
(15) = (Amos, 2011)
(16) = (NASA, 2007)
(17) = (Spacetoday, 2005)
(18) = (NASA, 2019)
(19) = (NASA, 2019)
(20) = (NASA, 2019)
(21) = (NASA, 2019)
(22) = (Space, 2005)
(23) = (NASA, 2019)
(24) = (NASA, 2019)
(25) = (NASA, 2014)
(26) = (NASA, 2014)

Appendix 2 – List of ESA missions

List of ESA missions			
Name	**Completed**	**Cancelled**	**Sources**
Aeolus			(1)
alphasat			(1)
ANS	x		(2)
ard			(1)
ariane			(1)
artemis			(1)
athena			(1)
atu			(1)
ATV Johannes Kepler	x		(3)
ATV Jules Verne	x		(3)
BepiColombo			(1)
biomass			(1)
cheops			(1)
cluster			(1)
Cluster-II			(2)
columbus			(1)
COS-B	x		(1)
CryoSat			(1)
darwin		x	(2)
don quijote		x	(2)
earthcare			(1)
echo		x	(2)
ECS-1	x		(1)
ECS-2	x		(1)
ECS-4	x		(1)
ECS-5	x		(1)
eddington		x	(2)
edrs			(1)
electra			(1)
Envisat	x		(3)
ERS-1	x		(1)
ERS-2	x		(3)
ESRO-1A	x		(1)
ESRO-1B	x		(1)
ESRO-2B	x		(1)
ESRO-4	x		(1)

euclid			(1)
eureca	x		(1)
european robotic arm			(1)
exomars			(1)
ExoMars/TGO			**(2)**
Exosat	x		(1)
expert		x	(2)
flex			(1)
Gaia			(1)
galileo			(1)
Galileo FOC G13 & G14			(1)
Galileo FOC G5 & G6			(1)
Galileo FOC G9 & G10			(1)
GEOS-1	x		(1)
GEOS-2	x		(1)
Giotto	x		(1)
giove-a			(1)
giove-b			(1)
GOCE	x		(3)
heos-1	x		(1)
heos-2			(1)
HEOS-A1	x		(1)
HEOS-A2	x		(1)
hermes		x	(2)
Herschel	x		(3)
Hipparcos	x		(1)
hopper		x	(2)
hubble space telescope			(1)
huygens	x		(3)
hylas-1			(1)
Integral			(1)
ISEE-2	x		(1)
ISO			(1)
Italsat F1			(2)
Italsat F2			(2)
IUE	x		(1)
ixu			(1)
james webb space telescope			(1)
juice			(1)

LISA Pathfinder	x		(3)
Marecs-A	x		(1)
Marecs-B2	x		(1)
Mars Express			(1)
Meteosat-1	x		(1)
Meteosat-2	x		(1)
Meteosat-3 (P2)	x		(1)
Meteosat-4 (MOP-1)	x		(1)
Meteosat-5 (MOP-2)	x		(1)
Meteosat-6 (MOP-3)			(1)
Meteosat-7 (MTP)			(1)
MetOp-A			(1)
Metop-B			(1)
MetOp-C			(1)
metop-sg series			(1)
MSG-1			(1)
MSG-2			(1)
MSG-3			(1)
MSG-4			(1)
mtg series			(1)
neosat			(1)
Olympus			(1)
ots-1			(1)
ots-2	x		(1)
Planck	x		(3)
plato			(1)
proba series			(1)
quantum			(1)
Rosetta	x		(3)
sat-ais			(1)
Sentinel-1A			(1)
Sentinel-1B			(1)
Sentinel-2A			(1)
Sentinel-2B			(1)
Sentinel-3A			(1)
Sentinel-3B			(1)
Sentinel-5P			(1)
smallgeo			(1)
SMART-1	x		(3)

smos			(1)
soho			(1)
solar orbiter			(1)
spacelab			(1)
SWARM			(1)
TD-1A	x		(1)
Teamsat	x		(2)
Ulysses	x		(3)
vega			(1)
Venus Express	x		(3)
xmm-newton			(1)

(1) = (ESA, 2019)
(2) = (ESOC, 2019)
(3) = (ESA, 2019)

Appendix 3 – List of CNES missions

List of CNES missions			
Name	**Completed**	**Cancelled**	**Sources**
ADEOS	x		(1)
ADEOS-2	x		(1)
Aeolus			(2)
Aeris			(2)
Alphabus			(2)
Argos			(2)
Ariane 5			(2)
Ariane 6			(2)
Ariane series			(2)
Athena			(2)
Athena-Fidus			(2)
Atv	x		(2)
BepiColombo			(2)
Biomass			(2)
Cadmos			(2)
Calipso			(2)
Callisto			(2)
Cardiolab			(2)
Cardiomed			(2)
Cardiospace			(2)
Carmen			(2)
Cassini-Huygens	x		(2)
Cdpp			(2)
Cds			(2)
Ceres			(2)
Cesars			(2)
CfoSat			(2)
CHAMP	x		(1)
Cheops			(2)
Cluster			(2)
Comet			(2)
Copernicus			(2)
CoRot	x		(2)
Cospas-Sarsat			(2)
Cryosat			(2)
Cso/Musis			(2)

Data and services hubs			(2)
Declic			(2)
Demeter	x		(1)
Doris			(2)
Double Star	x		(2)
Earthcare			(2)
Egnos			(2)
Electric satellites			(2)
Elisa			(2)
ERS-1	x		(1)
ERS-2	x		(1)
Euclid			(2)
Euso Balloon			(2)
ExoMars			(2)
Expose	x		(2)
EyeSat			(2)
Fast			(2)
Fermi			(2)
Fireball			(2)
Flip			(2)
Form@ter			(2)
Gaia			(2)
Galileo			(2)
Games		x	(3)
Geico			(2)
Geipan			(2)
Goce	x		(2)
Grace	x		(2)
Gradio			(3)
Hayabusa2/Mascot			(2)
Helios			(2)
Hermes		x	(4)
Herschel	x		(2)
Horizon 2020			(2)
Hy-2a			(2)
Iasi			(2)
Iasi-ng			(2)
Insight			(2)
Integral			(2)

International Charter "Space and Major Disasters"			(2)
International Space Station			(2)
Isis			(2)
Janus			(2)
Jason-1	x		(1)
Jason-2			(2)
Jason-3			(2)
Jason-cs/Sentinel-6			(2)
Juice			(2)
Juno			(2)
Jwst/Miri			(2)
Lisa Pathfinder	x		(2)
Mars 2020/SuperCam			(2)
Mars Express			(2)
Maven			(2)
Medoc			(2)
Megha-Tropiques			(2)
Merlin			(2)
Meteor-3			(2)
MetOp			(2)
Microcarb			(2)
Microscope	x		(1)
Msl-Curiosity			(2)
Mtb	x		(2)
Myriade			(2)
Myriade-Evolutions			(2)
Neosat			(2)
Netlander		x	(5)
New Horizons			(2)
Nustar			(2)
Odatis			(2)
Odin			(2)
Oersted			(2)
Orsted			(2)
Osiris-Rex			(2)
Otos			(2)
Parabolic flights			(2)
Parasol	x		(1)
Parker Solar Probe			(2)

Peps			(2)
Perseus			(2)
Pharao			(2)
Phobos-Grunt	x		(2)
Picard	x		(2)
Pilot	x		(2)
Planck	x		(2)
Plato			(2)
Pleiades			(2)
Polder	x		(2)
Premier-07		x	(6)
Prisma	x		(2)
PROBA-V			(2)
Prometheus			(2)
Proteus			(2)
Resurs-01	x		(1)
Robusta	x		(2)
Rosetta/Philae	x		(2)
SAC-C			(2)
SAC-D			(2)
Saral/Altika			(2)
ScaRaB	x		(2)
Sentinel-2			(2)
Sentinel-3			(2)
Smos			(2)
Soho			(2)
Solar Orbiter			(2)
Soyuz in Guiana			(2)
Spot			(2)
Spot-4	x		(1)
Spot-5			(2)
SST (Space Surveillance and Tracking)			(2)
Starlette			(2)
Stereo			(2)
Strateole-2			(2)
Svom			(2)
Swarm			(2)
Swot			(2)
Syracuse 4			(2)

T2l2			(2)
Taranis			(2)
Thd-Sat			(2)
Theia			(2)
Themis	x		(2)
TOPEX/Poseidon	x		(1)
UARS	x		(1)
Ulysses	x		(2)
Vega			(2)
Vegetation			(2)
Venus	x		(2)
Venus Express			(2)
Xmm-Newton			(2)

(1) = (CNES, 2019)
(2) = (CNES, 2019)
(3) = (Kramer, 2002, p. 130)
(4) = (Astronautix, 2019)
(5) = (Butler, 2003)
(6) = (Bonneville, 2003)

Appendix 4 – Calculation of Risk Rates

	Risk Categories			Risk Rates			Total Cancellations
Agency	**Political**	**Partner**	**Financial**	**Political**	**Partner**	**Financial**	
NASA	Champollion		Comet Rendezvous Asteroid Flyby (CRAF)	Amount of "Political" NASA cancellations	Amount of "Partner" NASA cancellations	Amount of "Financial" NASA cancellations	**18**
	Constellation		GEMS				
	HL-20		IXO				
	JIMO		LISA				
	Space Shuttle		Pluto Kuiper Express				
	SIM Lite						
	MAX-C						
	New Millenium Program			**13**	**0**	**5**	
	Project Prometheus						
	X-33						
	X-38			**Cancellation Ratio**	**Cancellation Ratio**	**Cancellation Ratio**	
	MTO						
	TPF			**72,22%**	**0,00%**	**27,78%**	
ESA	darwin		Hermes	Amount of "Political" ESA cancellations	Amount of "Partner" ESA cancellations	Amount of "Financial" ESA cancellations	**7**
	don quijote						
	echo			**6**	**0**	**1**	
	eddington			**Cancellation Ratio**	**Cancellation Ratio**	**Cancellation Ratio**	

	expert						
	hopper			**85,71%**	**0,00%**	**14,29%**	
CNES	Games		Hermes	Amount of "Political" CNES cancellations	Amount of "Partner" CNES cancellations	Amount of "Financial" CNES cancellations	**4**
	Netlander						
	Premier-07			**3**	**0**	**1**	
				Cancellation Ratio	**Cancellation Ratio**	**Cancellation Ratio**	
				75,00%	**0,00%**	**25,00%**	
				Total Ratio of "Political" cancellations	**Total Ratio of "Partner" cancellations**	**Total Ratio of "Financial" cancellations**	**29**
				75,86%	**0,00%**	**24,14%**	

Appendix 5 – Partner Scenario Analysis

	Events	Causes	Key indicators	Possibility	How could this happen?
Scenario A	Everything is going well	All partners are able to achieve their production goals within time. Budgets are not overdrawn.	Political, Economic and Technological	Medium	All partners of the LOP-G project (whether public or private companies) manage to at least keep their current performances.
Scenario B	Disruption of EU / Rise of populist parties	After the Brexit, France, Italy, Spain and Sweden are drifting away from the EU due to a rise of populism in their governments leading to lesser fundings of EU institutions such as ESA and CNES affecting funding of LOP-G	Governmental and socio-cultural	Low-Medium	Governmental and socio-cultural movements fail to weaken the influences of populism in the currently highly affected countries.

Scenario C	Industrial partner cancels partnership for financial reasons	One of the private partners is not able to keep the project financed	Economic / Financial	Low	Due to overdrawn budgets or suffering a crisis that disrupts the financial situation of the industry partner, the company has to move away from the LOP-G project to other projects of the company in order to manage the crisis. Prices of suppliers/costs for materials rise more than expected. Exchange and/or interest rates change, resulting in a financial disadvantage
Scenario D	Contribution of partner is delayed	The affected company can´t manage to finish/complete their part of the LOP-G project within time, delaying the whole project	Economic / Technological	Low	The partner is facing design problems, technological problems and/or construction problems which cause the project to be delayed. Suppliers of project partners are unable to deliver materials within time.

Scenario E	Partnership is canceled due to political reasons	The political conflict between East (mainly Russia) and West (mainly the US) escalates, so that the partnership is forced to be canceled	Political	Low	The current discrepance between mainly the US government and the government of Russia is further intensified and results in a political conflict, where embargoes and sanctions force the partnership to be canceled
Scenario F	Industrial partner has to reschedule the project	One (or more) private partnership company is restructuring itself and has to reschedule the project plan	Economic	Low	The affected organisation is merging with another company or is being taken over and therefore has to restructure itself to fit the new circumstances. Existing projects could be negatively affected and delayed by this procedure.

Appendix 6 – Partner Analysis

Partner	Country	Country Risk	Credit Rating	Political Stability	Overall
NASA	USA	B [1][3]	A [1][2]	B [1][3][4]	B
CNES	France	C [5]	A [5][6]	C [5][7]	B
JAXA	Japan	B [8]	A [8][9]	B [10]	B
ROSCOSMOS	Russia	D [11][12]	B [12][13]	C [11][14]	C
ESA	Europe	C [7][15][16]	A [17]	C [7][18][19]	B

Rating	
A	Excellent
B	Good
C	Average
D	Bad
E	Miserable

Partner	Country	Experience	Funding/Budget	Company Performance	Overall
Airbus	France	A [23][24]	A [20][21]	A [22][21]	A
Boeing	USA	A [25]	B [26][27][28]	A [29][30]	A
Lockheed	USA	A [31]	C [32][33][34]	B [32][35]	B
Energia	Russia	A [36]	C [37][38][39]	B [37][38][39]	B

A	Excellent
B	Good
C	Average
D	Bad
E	Miserable

Sources:

1 = (Coface, 2019)
2 = (Trading Economics, 2019)
3 = (AON, 2019, pp. 10-14)
4 = (Santander, 2019)
5 = (Coface, 2019)
6 = (Trading Economics, 2019)
7 = (AON, 2019, pp. 7-9)
8 = (Coface, 2019)

14 = (Trading Economics, 2019)
15 = (Coface, 2019)
16 = (Coface, 2019)
17 = (European Commission, 2019)
18 = (LIAA, 2019)
19 = (The Global Economy, 2019)
20 = (Finanzen.net GmbH, 2019)
21 = (Cbonds, 2019)

27 = (Yahoo! Finance, 2019)
28 = (Baker & Insider, 2019)
29 = (Boeing, 2019)
30 = (The Motley Fool, 2019)
31 = (Lockheed Martin, 2019)
32 = (Fool & Whiteman, 2019)
33 = (Reuters, 2019)
34 = (Nasdaq, 2019)

9 = (Trading Economics, 2019)
10 = (Santander, 2019)
11 = (AON, 2019)
12 = (Coface, 2019)
13 = (Trading Economics, 2019)

22 = (Airbus, 2019)
23 = (Airbus, 2019)
24 = (Airbus, 2019)
25 = (Boeing, 2019)
26 = (Boeing, 2019)

35 = (Lockheed Martin, 2019)
36 = (Energia, 2019)
37 = (Finanzen.net GmbH, 2019)
38 = (Yahoo! Finance, 2019)
39 = (Pitch Book, 2019)

Appendix 7 Critics

Dr. Robert Zubrin held a presentation, written by Craig Davidson (2018) which stated that building a lunar base would be a better project than building the LOP-G due to numerous reasons. The launch capacity needed to reach lunar orbit is about 3-4 times higher than to LEO and building LOP-G would require 4 currently unbuilt SpaceX Super Heavy Starship rockets, which is equivalent to twenty Space Shuttle launches, or from an opportunity cost perspective is equivalent to twenty major interplanetary missions (Davidson, 2018; Wang, 2018). In addition, the benefit of using the LOP-G as an actual gateway is criticised, because missions to Mars, or to the moon using the gateway would require a 30% cargo penalty due to the need of additional propulsion and therefore additional fuel (Davidson, 2018). Other critics say that the Gateway is not a purpose-driven, but a vendor-driven program that only exists to provide a destination for the administrations expensive Space Launch System (SLS) rocket and Orion spacecraft, neither of which are powerful enough to reach Mars or the Moon, concluding that this project is the next giant leap into quicksand (Berger, 2018). If SpaceX manages to develop their Big Falcon Rocket within their proposed timeframe, providing a cheaper solution with better capabilities, the political pressure could reverse and force NASA to cancel the SLS and Orion programs, as well as LOP-G (Hedman, 2018).

Appendix 8 – Turnitin Digital Receipt

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[QUALITATIVE EVALUATION OF LONG-TERM SPACE PROJECTS ON THE EXAMPLE OF THE LOP-G MISSION]

[HENDRIK-JOACHIM PEETZ]

[S1702887]

An Extended Essay submitted in partial fulfilment of the requirements of [MSc Risk Management (DL)]

GLASGOW CALEDONIAN UNIVERSITY

AUGUST 2019

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