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"Space Politics –
A Comparison of NASA and ESA"

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# Abstract

This master thesis focuses on the subject of outer space politics, especially on a comparison of the two space agencies ESA (European Space Agency) und NASA (National Aeronautics and Space Administration). Several political theories regarding space politics are discussed in this thesis. The comparison addresses numerous important aspects from the diverse space agencies policy papers as well as their space programmes. Thereby, different aspects, such as science, military, economy and environment, will be put under a detailed analysis and compared. The results of the comparison are clearly illustrated in this thesis and are interlinked to the existing political theories. Due to the comparison, this master thesis also discusses the possible future directions of outer space politics.

Keyword:
Outer Space Politics, NASA, ESA, space policy, space activities, geopolitical theories, environmental astropolitics, multidimensional comparison, science, research and development, military, economy, environment, knowledge democracy, innovation, future of outer space.

Diese Masterarbeit befasst sich mit der Thematik Weltraumpolitik, insbesondere mit dem Vergleich der zwei Weltraumbehörden ESA (European Space Agency) und NASA (National Aeronautics and Space Administration). Mehrere politische Theorien bezüglich der Weltraumpolitik werden in der Arbeit thematisiert. Der Vergleich befasst sich mit mehreren wichtigen Aspekten von den Policy Papieren und deren Weltraumprogrammen der beiden Weltraumbehörden. Dabei werden unterschiedliche Aspekte, wie Forschung, Militär, Ökonomie und Umwelt näher analysiert und vergleichen. Die Ergebnisse des Vergleiches werden anschaulich in der Arbeit dargestellt und mit den bestehenden politischen Theorien verbunden. Die Masterthesis thematisiert auch, aufgrund des Vergleiches, einen Ausblick auf die mögliche zukünftige Entwicklung der Weltraumpolitik.

Schlagwörter:
Weltraumpolitik, NASA, ESA, Weltraumpolicy, Weltraumaktivitäten, Geopolitische Theorien, Umwelt-Astropolitik, Multidimensionaler Vergleich, Wissenschaft, Forschung und Entwicklung, Militär, Ökonomie, Umwelt, Wissensdemokratie, Innovation, Zukunft des Weltraums.

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# 1 Introduction

The fascination with outer space has its boundaries at the end of outer space. The unique environment is so diverse, that researchers from many disciplines can study this area for decades. The universe holds many challenges and opportunities for the humankind. Outer space was studied since the ancient times. The knowledge from the stars was used for various purposes in other sciences, for instance for timekeeping or the guidance of ships in the night. Centuries later humans were able to send the first humans into the orbit and to the Moon. It all began with the space race in the 1950s outer space became a political stage for power demonstrations. Since then, outer space was not only used for scientific purposes, but also for geopolitical power relations. Rapid development of space technology were important for the United States of America as well as the Soviet Union. The existing conflict during the Cold War between those two states led to a boost of technological advancements. One of the main reasons for the ongoing development was national security of the two superpowers. Military technology as well as economic superiority was an essential driver for various space activities (Nucera, 2019).

After both state powers accomplished mayor achievements, the Soviet Union sent the first human into space, whereas the United States of America sent the first human to the moon, the interest in outer space decreased. Many projects were too expensive and too risky and because of this, fundings were cut for many national space agencies (Zurbin, 2019).

The Cold War was over, and the two superpowers did not have the need to demonstrate their power in outer space anymore. Nevertheless, in the past 20 years, the number of actors in outer space has increased significantly. More states became interested in the activities in outer space because space technologies are useful for many tasks, such as navigation, telecommunication, or weather forecast. Space-based systems provide services to society and can also accommodate defence and security needs of a state. In the recent years, a new important actor appeared in the outer space area. Private companies started to launch their own commercial satellites and offer space services. (Brachet, 2012, Fabrykowska, 2020). It was a long-lasting belief, that only national space agencies, which were mostly funded by their states, could deliver new developments and space activities. Private actors changed this perception, that outer space is just for wealthy states. With new ideas and technological developments, more and more companies will enter into the space industry. New actors will change the landscape of outer space. (Zurbin, 2019). The uprising of the private companies may also lead to a geopolitical shift in outer space. As outer space becomes more crowded, with more actors, it is necessary to explore the ambitious goals of these stakeholders and their various impacts, especially regarding society, environment, politics and outer space as a place. The possibilities for research within this far-reaching field are endless. Due to the vast space activities, this master thesis will focus on the comparison on the two space agencies National Aeronautics and Space Administration (NASA) from the United States of America and European Space Agency (ESA) from Europe. This master thesis strives to answer this main research question:

> *To what extent do the two space agencies, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA), differ or are the same regarding their current space policies in reference to the following four dimensions: science, military, economy and environment?*

To answer this question, this master thesis is organized in the following sections: First, the conceptional framework is presented with the four dimensions which will be used for the analysis, several geopolitical theories will be discussed which are relevant for space politics, as well as new theories that could be considered for future space activities. Afterwards, the empirical framework describes the methods of the research design of the comparison of the ESA and NASA. Consequently, the comparison of both institutions follows, with an in-depth analysis of the different hypotheses. The findings allow a systematic overview of the four key dimensions that are of importance for the further development of space politics within the two space agencies.

# 2 Conceptional framework of the analysis

This master thesis focuses on the comparison of the European Space Agency and the National Aeronautics and Space Administration. NASA is the leading space agency when it comes to space activities, whereas ESA is the nearest space agency to the University of Vienna. As politics influence the space activities of space agencies, it was better to choose an European agency, as the information are more accessible, especially also due to the language barrier, than for instance from the Chinese or Russian space agency.

The main research question "*To what extent do the two space agencies, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA), differ or are the same regarding their current space policies in reference to the following four dimensions: science, military, economy and environment?"* is relevant from a political science perspective, as space politics becomes more and more important as it engages more and more actors within its realm. Due to the expanding usage of space technologies in everyday life as well as in businesses, space activities are becoming significant. States and companies present their political and entrepreneurial will and influence the space politics and the existing regulations through their actions.

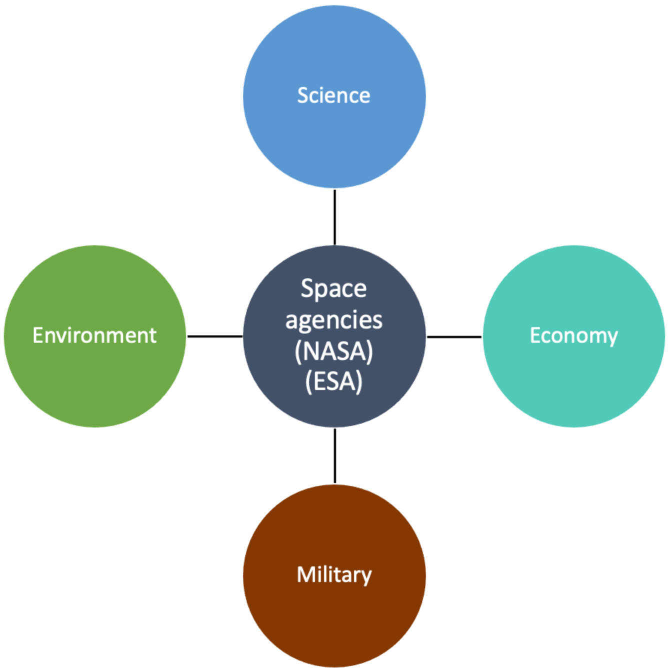
Additionally, this question is also relevant from a comparative political science perspective. A comparison of the two space agencies shows the strengths and weaknesses of each space agency. This information can be used for further analysis and for further development of the space agencies.

The comparison of these two agencies wants to answer the question, in what extent do these agencies differ or are similar. This is an essential question, as it can be used for the future development of these space agencies. If there are differences, these discrepancies can be used by the other space agency for improvement and vice versa. Especially the rise of the commercial actors is interesting for the space agencies, as they must adapt to the changing space sector.

Unquestionable this thesis cannot examine all possible stakeholders and their impact on others. States still play the main role in outer space activities. Therefore, the thesis will focus on a comparison of National Aeronautics and Space Administration and European Space Agency in the current period (2018-2022). Those two space agencies are significant when it comes to various space activities, NASA in the United States of America, and ESA in the European Union. Both agencies started to work closely with private companies and as a consequence, a small part of their impact on the space economy can be examined in this thesis. Nevertheless, the focus of this thesis will lie on the comparison of the newest space strategies and programs of both space agencies. Similarities and differences shall be examined in the strategic papers of NASA and ESA. This kind of comparison is necessary, for the reason that the central research question focuses on these two space agencies. Additional hypotheses were created to explore the similarities and differences of NASA and ESA.

Four hypotheses emphasize the main topics of the comparison: scientific research, military, economy, and environment, as presented in Figure 1. Such topics are essential for the future development of outer space activities and their impact on the various parties concerned, such as society, nature, or enterprises.

*Figure 1: Four different dimensions for the comparison*




*Source: Own description.*

◊ *Science*

The scientific research aspect is one of the most important aspects of the comparison, because most space activities are done for the purpose to acquire new knowledge. Therefore, it is interesting to see, whether the research projects are based on fundamental research or rather applied research, because both kinds of research have a different output and impact.

◊ *Military*

The military aspect is important, because outer space devices, like satellites, can be used not only for civil activities, for instance, weather forecasts, but also for strategic surveillance. Such a dual use of satellites or other space objects may become relevant when more states will have an increased role in outer space.

◊ *Economy*

The economical aspect is also important, because with more private entrepreneurs new developments may be funded aside from the national agencies with a state's budget. Different ideas can boost the whole space industry. Synergies of national space agencies and private companies may lead to greater accomplishments in outer space activities. Those achievements may benefit societies in various ways.

◊ *Environment*

The environmental aspect is essential for any further developments since an intact environment is important for any living beings. Therefore, the environmental issues are also worth considering in relation to outer space activities.

Therefore, these following four hypotheses will be analysed in detail in this master thesis:

- H1: NASA focus their future projects more on research development than ESA.

- H2: NASAs strategies focus more in strategic/military projects than the ESA.

- H3: NASA is more economically oriented and works more active with private companies than the ESA.

- H4: NASA is less cautious when it comes to the environmental impacts of space activities than ESA.

All four dimensions have several interlinkages, which will be also addressed in the analysis of the four hypotheses. But first, a few political theories about outer space will be presented in this thesis.

## 2.1 Political theories of Outer Space

The beginning of the space age can be traced back to two separate operations. In the 1940s Wernher von Braun launched in Germany the V2 rocket. It was the first guided ballistic missile which entered into space by crossing the Karman line in 85km. This led to first consideration about possible national regulations for space activities. Those thoughts were intensified when the Russians launched their first satellite Sputnik 1 into the orbit in 1957. The Americans responded with their own satellite Explorer 1 in 1958. (Görlich, 2019) Those outstanding first achievements in outer space led to the development of space politics on an international and national level. New developments and innovations are essential for a knowledge economy and knowledge democracy, as it focuses on the relationship between knowledge production and knowledge application. This theory also acknowledges the importance of multiple knowledge systems for a properly informed democracy. “Knowledge democracy is a blissful state in which people are well-informed about social problems and politicians behave as honest brokers of individual preference.” (Wolfson in Knowlegde Democracy, 2010, p 37). It interlinks several actors like states, economies, scientific communities, civil societies, media as well as the environment. (In’tveld, 2010). Knowledge democracy presents a broad and complex governance theory, which will be used as a framework for the further analysis of this master thesis. Nevertheless, the main geopolitical theories will be explored in detail for a better understanding of space politics itself, especially how space politics developed over time.

Regarding the subject of outer space politics within international relations, there are several geopolitical theories, that need to be considered, when analysing space activities of different actors, such as states or, now newly emerging actors, entrepreneurs, and private companies. Geopolitics is an academic practice, often combined with geography, political science, and international relations. As a political practice geopolitics interlinks power relations, subjects and places and presents theories as well as political actions. (Moisio, 2015). For the exceptional place of Outer Space, several geopolitical theories were developed to explain the actions of the different actors.

### 2.1.1 Classical Geopolitics

The space age started after the Second World War with the space race of the two superpowers, the United States of America and the Soviet Union. During the Cold War the geopolitical dynamics regarding outer space activities started to evolve. Since the launch of Sputnik in 1957, the international community realized it needed regulations for further space activities.

States have recognized the importance of outer space and its value from a geopolitical perspective. Outer space has become a strategic and economic playground for the two superpowers. (Nucera, 2019). The classical geopolitical theory for outer space, also called astropolitics, comes from an analogy: if geopolitics is possible for Earth, it is also possible in Outer Space. The first geopolitical conflicts emerged between states that were sea powers and land powers. One of the turning points was the invention of new transport technologies, which allowed new ways to secure its power, especially by military mobility. With further advancements over the decades, the development of space activities led to a new geopolitical area. First, outer space was seen as one political arena, but over time, geopolitical theorists divided outer space into more spheres, where states could gain advantage over other states if they could control strategic those space locations. Outer space offers a broad range of resources, and should one state have effective control over it, it could dictate the political, military, and economic conditions for other states. (Dolman, 1999).

With regards to the division of outer space, there are several Earth orbits that are important for military activities as well as for the daily lives of civilians. The Earth orbits are characterized by different altitude ranges and used for different astropolitical purposes. From the surface to 150 and 800km one finds the Lower Earth Orbit (LEO). This orbit is the most crowded, as it is used for military reconnaissance satellites as well as manned flight missions. (Fabrykowska, 2020, MacDonald, 2007). From 800km to 35,000km lies the medium earth orbit (MEO). Within this orbit most navigational satellites are placed. Beyond 35,000km the high-altitude earth orbits start. In this geosynchronous orbit, the orbital period (so one whole circulation around another object) matches the Earth's rotation and therefore, provides the possibility of a maximum coverage of the Earth with only a few satellites. Beside elliptical and inclined orbits in the high-altitude orbit, there are also circular orbits. Those circular orbits are geostationary equatorial orbits (GEO) and enables near continuous contact with the Earth. The GEO is often used for telecommunication and weather satellites. (MacDonald, 2007). But it can be also used for missile early-warnings, nuclear test detections or electronic intelligence. (McCall, 2020, p 2).

These different orbits are important, as they can be seen as a resource, because the possibility to place a satellite within these orbits are limited. Nevertheless, the orbits around Earth are not the only resources in outer space. Other resources, such as aluminium, titanium, iron, or water can be found on asteroids, comets, and other planets. For this reason, Dolman determines four different areas for geopolitical processes:

- The first region, Earth with its atmospheres, is crucial, because firstly, the Earth is essential for the launch locations and secondly, the atmosphere allows an appropriate environment for further space activities. The atmosphere can be compared to the coastal area of the sea. Any object that wants to go to outer space or returns from outer space needs to pass the atmosphere and land on Earth.
- The second region, Earth Space, represents the orbits. Within this region most military activities take place, such as an investigation with satellites or general navigation. Within the GEO, communication and weather satellites can also play an important role. It is the most critical area for astropolitics, as it is within its reach. A control of Earth Space guarantees a near-term advantage on terrestrial battlefields as well as a long-term control of outer space.
- The third region, Moon Space, consists of the Moon and the orbits of the Moon. Those orbits can be also used for several strategic positions, especially for future launches from Moon to more distant spaces.
- The fourth region, Solar Space, is everything in the solar system, after the orbits of the Moon. Near planets, like Mars or Venus, as well as many asteroids contain many resources that are valuable for the humankind. (Dolman, 1999, p 92 et seqq.).

Space technology became more and more important to control space. Countries have realized that military space power is a part of national security and therefore develop their own space infrastructure. Whoever controls outer space controls the world, especially when it comes to security issues. Space activities can be seen as an important tool for military purposes, but also for international cooperation. (Nucera, 2019).

Till now, Earth is the starting point for all space activities, especially for spacecrafts. All launches, tracking and controls are earthbound. For this reason, the locations of launch sites are meaningful, as they have an impact on the spacecraft and its designated orbit. For instance, "the latitude of a launch site location affects the inclination of the orbited spacecraft." (Dolman, 1999, p 100). Due to the fact, that all launch sites are within national territory of a specific state, they are important from an astropolitical perspective. (Dolman, 1999).

Another very important aspect of astropolitics are the different orbits. Although space is like the sea, where one can pass it in any possible direction, some routes are more efficient than other routes, especially when it comes to fuel usage. In stable orbits spacecraft don't waste any fuel due to orbital mechanics. Specific orbits create therefore natural corridors where most spacecrafts can pass without using too much fuel. "The geostationary equatorial orbit is one of the most important strategic areas, because it is the only natural orbit, which provides a stable position relative to a given point on Earth. A geostationary position is essential for a broad field of view for satellites. A network of at least three satellites is necessary to view any point on Earth between 70° north and south latitude." (Dolman, 1999, p 96 et seq). Only a given number of satellites can operate within this orbit and is therefore seen as a rare international natural resource. If one state wants to control outer space, it must control certain terrestrial and outer space locations to have an advantage over other states. The access to an outer space location cannot be denied by any state, due to the international legal principle of the common heritage of mankind, but the state can create a very costly permission. The classical geopolitical theory focuses on critical points and locations on Earth and Outer Space, which can be used by states for military and economic space activities and consequently influence other states thereby. (Dolman, 1999).

The main focus of the classical astropolitical theory lies on states and their national securities as well as foreign policies and how they can influence the international relations with their space activities. For this reason, Outer Space is often used as a source of state authority or the expansion of imperial power. This geopolitical view led to a continuous militarization of space by the major powers such as the US, Russia, China or India. (Klinger, 2019).

In international relations, the spotlight is very often on states and how they act in a certain situation. Nevertheless, this perspective was criticized by other academic scholars in various ways.

### 2.1.2 Critical Geopolitics

The critical geopolitical theory gives new perspectives to the traditional understanding of geopolitics and international affairs. Classical geopolitics presented some main political characteristics of the 20$^{th}$ century: Control over territory and natural resources were understood as a fundamental element of a state status. Critical geopolitics challenges this traditional geopolitical view. In the 1980s and 1990s critical theories developed from a cultural and linguistic trend in the social sciences as well as human geography. (Moisio, 2015). Critical geopolitics is seen as a "set of socially constructed, rather than naturally given, practices and ideas through which the international political economy is realized geographically." (Agnew & Corbridge in Moisio, 2015, p 223). For this reason, geography plays an important role in international politics, as it is socially constructed and is interlinked to matters such as identity. National identity-building is one of the main aspects of critical geopolitics. The theory investigates how national identities are narrated and performed in different surroundings.

Several cultural mythologies of the state are important for the geopolitical theory. Socio-spatial theories are included into the international affairs and geopolitics should be understood as a spatial practice of a statecraft, material as well as representational. Geography and politics are co-constituted, and space is understood as power (Moisio, 2015).

Although the first scholars of critical geopolitics have understood space as part of human geography on Earth, it was then expanded to Outer Space. Space is produced through social actions and outer space is also a part of the sphere of the social. For many centuries, outer space was unreachable for humankind. The outstanding developments in the last decades led to the transformation of outer space from a distant alien place to a daily ordinary place that is used by almost everyone. With many military, civilian and commercial satellites within the orbits, the International Space Station and many other different launches for space explorations, such as robots on Mars or further distant planets, outer space became within our reach. With ongoing technological innovations, the costs to enter into space are becoming lower and lower. Everyday lives are connected to outer space, for instance through telecommunication satellites or the Global Positioning System (GPS). Therefore, it can be argued, that new forms of sociality are created on Earth through various space activities. States try to extend their sovereignty into outer space and for this reason, terrestrial geopolitics are increasingly influenced by outer space strategic interests and plans. (MacDonald, 2007).

Outer space can be seen as a logical extension of imperial exploration. In the early space age days, military space applications were the only way to get data for scientific research. Satellite technologies can have a dual use – once for military purposes and once for scientific purposes. Despite the fact, that the UN Outer Space Treaty 1967 states in Article IV, that outer space can be used only for peaceful purposes and bans nuclear weapons in space, on the Moon or any other celestial bodies, it is still possible to use military personnel for scientific research for any other peaceful purpose, such as peacekeeping operations or satellite surveillance. (Fabrykowska, 2020, p 2, MacDonald, 2007). Satellite surveillance can be used for strategic and diplomatic missions, but also for daily matters, such as tracking a parcel, mobile phones or a car through GPS or Galileo. At the beginning, GPS was developed as a military system for missile guidance and to monitor the artificial satellite Sputnik and was then gradually changed for possible civilian applications. Galileo was presented by the ESA as specifically for civilian purposes, but in special cases it could surely be used for EU defence. This example of navigation systems shows an interlinkage of interpersonal, interstate and citizen-state relationships. Outer space infrastructure such as satellites can be used for civilian but also for military actions. Space activities have therefore an impact on the states, individuals, economy, and societies. (MacDonald, 2007).

Critical astropolitics, also called Anti-Astropolitics, focuses on the idea, that the interlinkages between the different actors were not analysed enough in the classical geopolitical theory. Space is not an empty place anymore, where states can achieve their dominance with their space actions, because outer space is to some extent regulated by several international space regulations. Anti-Astropolitics criticize that the colonization of outer space by the main spacefaring developed countries needs to be reconsidered, as outer space is represented in many other areas than just international relations. Space infrastructure is too much integrated into the daily lives of citizens. The consequences citizens would have to bear if a state would only focus on their military and strategic international actions could be severe. (MacDonald, 2007). Other issues, like the environmental impact or social justice of space activities were discussed just marginally within the Anti-Astropolitics, due to the fact, that the social implications of outer space activities were the main indicators of the critical astropolitical theory.

### 2.1.3 Other geopolitical theories

There are numerous variations of the classical and critical geopolitical theories with different focuses, which cannot be discussed here in detail. Nevertheless, there are some trends that are worth mentioning.

For instance, Haverluk, Beauchemin and Mueller (2014) argue for a new neo-classic holistic geopolitical approach. Classical geopolitics is "too imperialist, racist, environmentally deterministic and works closely with imperial state governments to achieve geopolitical goals," (Haverluk et al. 2014, p 19) whereas critical geopolitics is a kind of "anti-geopolitics". Beside other forms of geopolitics, like formal geopolitics, feminist geopolitics, radical geopolitics and popular geopolitics, anti-geopolitics was a critique of the other forms of geopolitics. Nevertheless, the authors point out, that this approach is anti-cartographic, as geographic techniques and geographic information are not included in the study, especially because there were huge developments in geography in the last decades. Additionally, critical geopolitics are also anti-environmental, as they present environmental problems within the discourses where the societies from the North exploit societies in the South and find other reasons to protest against globalization and neo-liberalism. Environmental degradation is often the result of an exploitative global North of the South. Haverluk et al. suggest, that there is no global North that exploits the global South, but rather metropoles and ecoregions that take advantage of other regions. Within this global North-South understanding, environmental issues are often seen exclusively as anthropogenic problems. However, according to Haverluk et al., the environment can be a causal factor in geopolitics and should be taken more into consideration when analysing a specific situation. The authors give as an example the "Indonesian tsunami in 2004 that led to a peace agreement between the Achenese and Javenese, which ended a forty-year-long civil war." (Haverluk et al., 2014, p 31). Another example was the Hurricane Katrina, which destroyed offshore oil rigs, that caused an increase in the oil price and set off riots in Indonesia. The new neo-classic geopolitics should therefore be holistic and consider many various factors from the geographical perspective, so that one could have the full potential of geopolitics. (Haverluk et al., 2014).

Although these authors did not mention outer space per se, there are other academic scholar who argue for a broader view in Astropolitics.

Meta-geopolitics presents a comprehensive picture of the geopolitics of outer space and tries to fill the gaps from the classical and critical geopolitical theories. It combines traditional and new features of geopolitical analysis and suggests a multidimensional spatial framework with seven different key power capacities: social and health issues, domestic politics, economics, environment, science and human potential, military and securities issues and international diplomacy. These capacities show the stability of states as well as the highly complex strategic relationships between states. The spatial framework analyses "how global actors use these capabilities to influence their geopolitical position." (Al-Rodhan, 2021, p 15). Such a multidimensional view allows to consider several kinds of power, such as soft, hard, smart and just power tools for geopolitical actions. Space technologies affect those capacities in various ways. (Al-Rodhan, 2012).

Due to the fact, that outer space is becoming more and more integrated into the economy and daily lives and has important implications for geopolitics, political and societal change, it is even more necessary to understand outer space. Within the meta-geopolitical theory, outer space is essential for global peace and security. Therefore, the theory also presents an assessment tool for the current geopolitical realities in outer space and potential threats, so that policy recommendations can be created. (ibid). Meta-geopolitics focuses mainly on space power within a multidimensional framework, where states are the main actors and contributors. Although the multidimensional framework presents various angles and aspects, which are important for outer space, solely states have an active leading role within this theory. Therefore, it is necessary to analyse other elements and perspectives, in order to avoid non-consideration of important additional actors.

### 2.1.4 Global Political Ecology

Geopolitics in ecological terms is a quite new phenomenon which focuses on complex new tendencies. After the end of the Cold War, the world system was seen as one, where economists, industrialists, political leaders and nations compete against each other to control the future development of the world economy. The competition is based on development of new technology, domination of diverse markets and the exploitation of every possible national economic asset. Several economic practices, which created economic growth, simultaneously abused nature. (Luke, 2003). Over the time, "ecology has evolved into a public potential; it called for management procedures; it had to be taken charge of by analytical discourses,' as it was recognized in these more environmentalised manifestations to be a 'police matter' – 'not the repression of disorder, but an ordered maximization of collective and individual forces." (Foucault in Luke, 2003, p 354). Ecology within a geopolitical framework emerged as a critique of the two main ideas of capitalism and communism. Both systems had fixed patterns of growing industrialization and urbanization, without taking the environment into consideration. Many ecological crises are caused by the global economy and the daily habits of humankind, such as "wasteful resource-intensive modes of production and excessive material consumption." (Luke, 2003, p 362). Consumption is often outsourced to various countries and the usage of energy, natural resources, water, and labour varies within the countries. Connecting this consumption to a new geopolitical theory, it can transform the states and the economy through a sustainable development. The environments have to be re-engineered within the practices of sustainable development. (Luke, 2003). "The existing economy cannot grow in separation from the natural system and resources, which the economy uses. Any economic process that undermines the global ecosystem cannot continue indefinitely." (Bourdieu in Luke, 2003). Therefore, one must consider nature as part of a bigger system. It is no longer one small ecosystem or a biosphere, that needs to be considered within a geopolitical strategic space. But rather nature as a whole system, which is interlinked not only to society, but also to the economy as well as to the politics. For this reason, nature must be also studied within economical geopolitics. Issues of environment and development are connected to such an extent, that they cannot be viewed separately anymore. In order to create a sustainable economy, one must consider different environmental subjects. Environmental technologies and practices such as wind power, can reinvent the economy. A more sustainable development would lead to new consumer power, new jobs and new leisures. (Luke, 2003). "It is no longer possible to treat various struggles for space in isolation from one another, for all are part of a single world-wide system of closed space. The world of international interactions is now global." (Ó Tuathail in Luke, p 356).

Additionally, humankind has realized that not only international interactions are global, but also environmental issues are often on a global scale. For instance, the climate change has a planetary character. For this reason, the theory of global political ecology tried to establish an international system for environmental subjects and problems. Global environmental governance is an international environmental regime with several features, such as institutions, organizations, numerous principles, and norms as well as decision making procedure. Although the idea of sustainable activities started with state-directed commands and controls, it led to the creation of markets for environmental goods and services by the different governments to provide incentives for green economy. This kind of governance through markets induced several voluntary agreements for new practices and standards set by the industries for themselves. This enabled the industries to pursue their economic interests in such a way, that they simultaneously also could promote those activities as sustainable activities. To avoid such misapplications, the theory of global political ecology focuses on various aspects that have not been considered before: social and cultural ecology, political economy and the operations of power, such as relations between the state and corporations. (Peet, Robbinson, Watts, 2010).

There are several definitions and goals of political ecology, which differ in their understanding. Some of the definitions focus more on the political economy, others on the formal political institutions. Most goals emphasis environmental change, but some prefer a narrative or story of change. Nevertheless, one of the main elements of any political ecological approach and research is, that "environmental change and ecological conditions are the product of a political process." (Robbins, 2004, p 11). Therefore, political ecology evaluates the influence of variables on various levels and interlinks them together. For instance, a political ecologist, analyses local decisions, which are influenced by regional policies and these are again influenced and directed by global politics and economies. From individuals to multilateral and international connections, many levels are examined through this global theory. One finds intersections of political science, sociology, geography and development studies. (Robbins, 2004). According to Robbins, "these many understandings of political ecology together appear to describe: empirical, research-based explorations to explain linkages in the condition and change of social environmental systems, with explicit consideration of relations of power." (Robbins, 2004, p 12).

Global political ecology sees ecological systems not only as political, but they are also directed through different political and economic processes.  Political ecology tries to denaturalize specific social and environmental conditions by presenting them as an outcome of power. It exposes the weaknesses of the dominant approaches of states, business sectors and companies and international authorities, especially through their impacts of policies and market conditions. This theory presents the perspective of local people and marginal groups which can be easily overlooked in an enormous system. It also shows how individuals respond to changes and how new technologies can be used in a more sustainable economy and way of living. (Robbins, 2004).

There are several themes within political ecology that are essential for this theory: on the one hand environmental degradation and marginalization, which can explain environmental system changes, on the other hand environmental identity and social movements, which can explain social system changes. Additionally, the environmental conflict, especially scarcities of resources and the control of resources and landscapes as well as the conservation of local systems and productions are taken into consideration within this theory. For instance, environmental problems can become socialized when specific groups secure the control over resources and exclude other groups from those resources. (Robbins, 2004). Environmental production is also an important aspect because political ecology sees nature as produced by humankind. It does not mean, that nature is controlled by people, but that people create specific environmental conditions through their activities, such as harvesting or genetic modification of plants. Those kinds of activities are often combined with political intentions. Therefore, it is important to analyse the complex forms of social control and hegemony, but also the ideology and governmentality. Also, the knowledge about an environmental problem has to be examined, because that information are not always available. (Peet, Robbins, Watts, 2010). "Hegemonic control of knowledge about environmental crises themselves (from global warming to Katrina) is a fundamental part of the political economy of nature." (Peet, Robbins, Watts, 2010, p 31).

To solve environmental problems, science and scientifical studies are necessary. Nevertheless, environmental problems are also rooted in the past and connected to societal issues and need therefore a broader context than just a natural scientific approach, which measures and described environmental conditions. It should be kept in mind, that science can be biased and partial and can for this reason it can be used for obtaining political control with specific facts. To avoid such restrictive points of view, political ecology underlines the importance of the combination of a study of power forms, a discourse and knowledge production in a complex multilevel setting. (Peet, Robbins, Watts, 2010).

Within the global political ecology, the theory of the societal nature relations connects to this idea, as it focuses on the inequalities between the different actors and activities. It also includes the imperial mode of living, which assumes that all natural resources as well as work capacities are unlimited and can be used in the existing patterns of production, distribution, and consumption on a daily basis by the global North. (Fabrykowska, 2020, Brand, Wissen, 2013). Such an imperial mode of living destroys natural livelihoods of other societies in different regions, especially in the global South. The power structures of the global North are deeply connected with multiple crises (Brand, Wissen, 2013, Görg 2010) and should not be overlooked when establishing new sustainable modes of living. This power relations should be also analysed in a deeper analysis within space politics, but this would go beyond the scope of this master thesis.

Global political ecology interlinks various levels and combines several topics together to present a broader, but at the same time, a more precise and detailed picture of a specific subject. The main theory regularly researched and analysed different phenomena on Earth, but only sometimes expanded to Outer Space. Therefore, this thesis wants to discuss the possibility to integrate Outer Space even more prominently into the global political ecology. To understand the political challenges and implications within a complex setting, one must understand in the first place the unique environment of outer space, where the theory is embedded.

#### *2.1.4.1 The Environment of Outer Space*

The environment of Outer Space is a global and dynamic environment, which cannot be directly compared and categorized into the same types of environments like on Earth. Although there are some analogies to the High Seas, deep ocean, Antarctica or the Airspace there are still several distinctions, especially when it comes to the unique material and structural features of the outer space environment. (Klinger, 2019, Mendenhall, 2018).

Outer space has a harsh and complex environment with extreme conditions. There are several basic elements of the outer space environment that need to be taken into consideration when it comes to any activity in outer space.

- Space radiation and charged particles: In Outer Space energy is carried through electromagnetic radiation. The most dangerous elements of the outer space environment are charged particles. Primary they come from solar winds or solar flares, galactic cosmic rays and the Van Allen radiation belts. Those charged particles can damage space objects and their electronic components and detectors in various ways.

(FAA, 2018). Additionally, cosmic rays and solar winds can damage biological tissue due to their high-energy particles. (ESA, 2021c).

- Temperatures: Outer Space has temperatures from extremely cold to extremely hot. Depending on the space activity, different kinds of technologies and materials need to be used for those extreme conditions. (ESA, 2021i).
- Gravity: Gravitational forces exists not only on Earth, but also in Outer Space. When an object is in the state of free fall, it doesn't feel the force of gravity even though gravity is present. Gravitational pull of a celestial body dictates the size and shape of a spacecrafts orbit. Astrodynamics determines the effects of gravity within the space environment on spacecrafts and planetary motions. (FAA, 2018). Microgravity can be used for different experiments within outer space, which would be impossible on Earth. The absence of gravitational Earth effects physical processes and organisms react differently. Such a microgravital environment can be used for basic research, such as medicine or engineering, as well as industrial production processes and other technologies. (ESA, 2021j).
- Vacuum: Outer Space has a high-quality vacuum because one still finds some particles per cubic centimeter at high altitudes. A vacuum environment can create possible problems for spacecraft:
    - outgassing, where trapped gases are released from the spacecraft materials and damage delicate sensors;
    - cold welding, when metal elements fuse themselves together;
    - heat transfer problems, which is limited to electromagnetic radiation. (FAA, 2018).

A lack of fluidity in outer space environment creates also additional problems. Vacuum doesn't have any patterns of dynamism and circulation. Without a dynamic flow, space debris cannot be distributed by a dynamic flow into one place, but it is rather spread out evenly as a shell around the Earth. (Mendenhall, 2018).

- Micrometeoroids and orbital debris: Outer Space consists of billions of very small objects, natural materials, such as dust, meteoroids, comets, or manmade objects, such as pieces of old spacecrafts or satellites. Space junk, even the smallest part, is problematic, because it travels often at high velocity and a collision with another object can be fatal. The increasing number of orbital debris create a risk for space activities.

- Ecology: Till now, no ecosystems has been discovered in Outer Space. Due to the fact, that outer space doesn't have an ecosystem with self-sustainable and regulating characteristics, like ecosystems on Earth, the outer space environment is very fragile as it has only limited abilities to repair itself. It also doesn't have renewable resources for multiple usage. (Mendenhall, 2018).

### *2.1.4.2 Environmental Astropolitics*

The extraordinary and challenging environment of Outer Space is an important aspect for geopolitics, as human interaction with outer space happens on a daily basis. This kind of interaction is also an issue regarding environmental justice. There are different environmental elements that needs to be considered on various levels. Firstly, on Earth, on the local level one also has to consider the impact of outer space infrastructure, which is used for launches. During launches, fuel waste is often discharged into the oceans. Additionally, emissions from space launches are problematic on a local level as well as in the stratospheric level. Secondly, after surpassing Earth atmosphere the questions remain regarding orbital debris, conservation issues as well as the societal fair distribution of the future goods, due to the principle of international law common heritage of mankind. (Klinger, 2019). This legal principle is a general clause within several international treaties, such as the Convention on the Law of the Sea, 1982 or the different space treaties, and is used to establish a certain approach and course of action, without regulating every possible case explicitly. Because of the reason that the exploration and the use of outer space is a global activity and a joint effort, it should not be restricted to one state or group of nations, so that this advantaged group could have benefits, for instance from exploitable resources. This principle protects therefore the interests of technologically less developed states. (Gal, 2004). The Outer Space Treaty 1967 (OST 1967) states in Article I that "all exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind. The Moon and all other celestial bodies are free for exploration and use by all states without any discrimination on a basis of equality. The access to all areas of celestial bodies is free for all states." (OST, 1967). Although there are discussions whether this principle is a legal-binding instrument, or rather a socio-political or philosophical idea (Gal, 2004), it still remains important and is therefore included in the environmental astropolitical theory.

Environmental astropolitics is strongly interlinked by the spatial politics of privilege and sacrifice, as it takes into account several actors: people, places and institutions. "Environmental

geopolitics enables us to rethink outer space through concrete processes that transform environments on Earth, in space and in the atmosphere, the latter of which we typically define as the boundary between "inner" and "outer" space." (Olsen and Messeri 2015 in Klinger, 2019). To transform and use those outer space places, one needs knowledge and power. This knowledge and power are often exercised through states, and now with the increase of commercialization of outer space activities, also through companies and individuals. With the expanded number of actors, the impact on the environment also increased. Outer space is mutually transformed when humans interact with it. Extended human interaction with outer space creates spaces where injustice can occur. For instance, when a state appoints a location for a launch site within its territory, a group of people may suffer health issues or environmental harm from the rocket launches and the toxic waste, just because the group was displaced by another powerful actor. Toxic elements can be also found in the ecosystem which surrounds the launch site. "The placement of outer space related infrastructure is therefore not only a strategic geopolitical calculation of one actor, but also a question of environmental justice." (Klinger, 2019, p 12). Beside the environmental impact, the social aspect, peculiarly the access to technology, needs to be considered within this theory. Technologies, especially space-based technologies are distributed unevenly within and across countries and reflect the existing power relations. (Klinger, 2019). This presents a space gap where less developed states cannot support or invest in outer space programs and are often left behind, whereas developed states and space-faring states use the benefits of outer space for themselves. For instance, developed states can use the satellites for navigation or surveillance, while less developed states cannot afford such data. This inability to access to satellite-based data created further inequalities. (Way, 2018).
Environmental astropolitics doesn't analyse only the impact of astropolitics on Earth, but also beyond Earth. "Human actions in Outer space can directly shape politics on Earth." (Klinger, 2019, p 18). For example, existing space debris may hinder states to launch their rocket, because the orbital debris in near-Earth may be on the trajectory of the rocket. Even the smallest debris can be a threat to another space activity at their high velocity, because a collision could harm the rocket or any other object that was sent to space. For this reason, it can be concluded, that "access to orbital space is critical to national development and sovereignty." (Al-Rodhan, 2012).

Earth's orbit can be seen as a public space that belongs to all mankind, but with the existing debris, inequalities already arose for the less developed space power, as their access is limited. The main space powers degraded the orbits and hence excluded others. Such an environmental degradation was used for a geopolitical strategy and advantage over others. (Klinger, 2019).

Another theoretical analysis beyond the Earth focuses on the environments of other celestial bodies and how to protect those environments from human actions. The protection is an important question because there is a risk of contamination of sensitive organisms. Such a recognition of possible life forms can lead to changes within the exploration strategies, ideologies and policy decisions. (ibid).
Environmental Astropolitics discusses several important issues such as the production of nature in outer space through humankind, the environmental pollution on Earth, but also in space, environmental and societal justice on Earth as well as the environmental degradation and protection of other spheres and biological organisms. Those kinds of topics are essential for the theory of global political ecology. Within the broad framework of political ecology, one can analyses the different and complex interlinkages between states, corporations, societies and nature. Considering the fact, that Outer Space is an immense territory with a vast of opportunities as well as challenges, it needs for further careful analysis a theoretical framework that can indicate these multilevel interactions and connections of various actors.

Overall, knowledge democracy as well as global political ecology will be used as a framework in this thesis to determine the interlinkages between states, science, economy, and nature.
Especially the theory of knowledge democracy is strongly interlinked to the research question as well as the dimension of science as it presents a complex governance theory and interlinks the different actors, such as states, economies, scientists as well as societies. There are essential to understand the various differences within the both space agencies. Therefore, knowledge democracy is important for the main research question, as the research question focuses on a complex and broad topic with several actors that need to be analysed.
Furtheron, knowledge democracy also focuses on knowledge production and knowledge application. As this is an important relation within knowledge democracy, the first hypotheses focuses therefore on the question of science and how knowledge production and knowledge application is conducted within both space agencies.
Although science is a crucial aspect of space activities, other elements have to be analysed. Not only knowlegde democracy, but also the classical geopolitical theories highlight the importance of economic actors as well as the state itself. Therefore, the second and third hypotheses focuses on military and economic aspects of both space agencies.
Nevertheless, the newer geopolitical theories, especially the global political ecology and environmental astropolitics also present the important aspect of nature. Therefore, the forth hypotheses will focus on the subject of nature and sustainability of both space agencies.

All four hypotheses are connected to the different theories and present consequently important key points that need to be analysed. These various aspects also highlight the political significance of this research, as it affects several actors within a global political world.

## 2.2 Method of research design

This following section presents the methodological approach of this master thesis. This master thesis is set up as an exploratory research with an innovative method. It presents an explorative positioning of NASA & ESA along the following 4 dimensions: science, military, economy and ecology. The research focuses mainly on qualitative methods, especially literative review, comparative analysis and an innovative rating scale, which was created by the author. Due to the fact, that the subject of outer space politics is quite broad, triangulation was selected as a research strategy. According to Carter et al. method triangulation mixes multiple methods within the qualitative research to obtain a comprehensive understanding on one subject from different sources. Various sources are also important to test validity through the consistency of information. (Carter et al., 2014). This multidimensional analysis is beneficial to overcome the limitations of one qualitative method by using information from another qualitative method, so that a combination of both methods produces a more valuable finding. (Lauth et al., 2009). While using several qualitative methods, all methods have an equal relevance for the research and there is no prioritization. For the analysis results it is therefore useful to combine diverse methods, to obtain a "whole" picture of the researched subject. (Flick, 2006; Flick, 1991). This master thesis is based on the principle of complementarity where the different methods are conducted separately, but the results are connected to provide a more in-depth answer to the research question.

### 2.2.1 Literature search

An exhaustive systematic literature search was done to find the right literature for the different sections of this master thesis. The corpus of documents includes a broad variety of topics:
from the different theoretical approaches regarding space activities to the strategy papers of ESA and NASA and policy documents of the EU and the USA. Most of the literature can be found online, especially the official policy documents of the last years (2018 – 2022) and the strategies of both space agencies. The material focuses mainly on the timeperiod of the last four years (2018 – 2022), but when necessary, it also includes older documents for clarification and a better understanding (for instance, regarding the beginnings of both space agencies). The literature search was carried out continuously, due to the fact, that during the research, new aspects and new relevant documents were found. Additionally, due to the fact, that space activities are continuously developing and increasing, new information could become significant for this research. The ongoing literature search influenced the application of the further methods.

### 2.2.2 Literature review

After the literature research, the sources were sorted and selected in regard to their relevance and significance. The evaluation of the relevance of a document was based on the importance to the research question and the correlated hypothesis. The selected documents were studied to understand their substantive content as well as the deeper meaning, with the interlinkage to other mentioned documents. A linguistical and systematic textual analysis was conducted. Nevertheless, the focus lies on the content of the different sources. The qualitative content analysis does not only analyse the content per se but has different levels that needs to be considered: the main ideas and themes of a document as well as the context information. It is therefore an approach of empirical and methodological controlled analysis of texts within their specific context. (Mayring, 2000).

Beside the documents for the theoretical framework, the other diverse documents were divided into two groups (ESA and NASA) and within these groups, several topics were studied. The topics were chosen on such a basis, that they present the four main aspects of this thesis (research, politics, economy, and environmental issues). These four topics were deducted from the four hypotheses and used as main categories for the further qualitative content analysis of the literature. The different strategy papers of the space agencies contain vast topics, not all of them could be included into the further analysis. Therefore, other sources had to be included into the analysis to present a broader picture regarding the four main categories.

The four hypotheses and their four topics can be seen as the main categories/dimensions within a deductive coding approach. During the analysis of the different papers, additional subdimensions were distinguished and coded. These subdimensions were used for a further comparative analysis.

### 2.2.3 Comparative multidimensional analysis

A further analysis was done by comparing the findings from the documentary analysis within their four aspects. "All scientific research is in some way comparative." (Palmberger, Gingrich, 2014, p 97). According to Denk, comparative methods are one of the principal methods of political science, as they increase the knowledge and understanding of politics considerably. Nevertheless, the comparative method have several weaknesses that limit its use, such as too many variables and too few cases. A high complexity regarding the variables with a low number of cases may be insufficient for answering a research question. Within comparative research, intrasystem comparisons are often used to study a set of subsystems within a system, for instance the performance of democratic systems. In political science intrasystem approaches are preferred, as they can increase the number of comparable cases. They also can reduce the complexity of the analysis because the comparison focuses only on important aspects of the similar cases. Additionally, such comparisons are more responsive to variations within systems. This kind of comparison presents the possibility to construct controlled comparisons, when the two compared cases are similar in several aspects, such as political, economic, or social issues. Although this intrasystem comparison has many benefits, it also has its limitations. A significant limitation is the context of the cases. When examining two cases from two different systems, the context of both cases must be similar for an intrasystem approach. (Denk, 2010).

The ESA and NASA are two institutions that are exploring the space and conducting several projects concerning outer space. They are therefore similar cases because they activities are resembling. Nevertheless, these two institutions are situated in two different systems. NASA is a state agency of the USA, whereas the ESA is a space agency which works with the EU. Consequently, the context of both institutions differs. Due to the fact, that the context of both cases are not similar, one cannot use the intrasystem comparison.

Traditional comparative methods don’t look at contextual differences. That is the reason why Denk presents in his paper a comparative multidimensional analysis. Within the multidimensional structure the analysis is divided in four steps: First, cases are grouped according to their membership on the system level. Further on, the cases are compared to one another within their group according to the method of paired comparison and create comparative expressions. These comparative expressions are then analysed and compared between the two groups. If those expressions differ, it is an indicator, that the specific context may play a role. This third analysis focuses on whether the different comparative expressions vary among different contexts or if it stays constant. In the last step, the context on the system level is analysed and compared. (Denk, 2010).

“In this way, it is possible to:

(1) include factors on different analytical levels,

(2) examine the relationship between factors on different analytical levels, and

(3) study effects of contexts using comparative analysis.” (Denk, 2010, p 34 et seqq.).

This comparative multidimensional analysis gives the possibility to compare cases from diverge contexts. Nevertheless, it is not necessary that the comparable cases are subsystems within different contexts. It is also feasible to use this approach within international contexts. (Denk, 2010). Especially in the relation to globalization and time-space compression, qualitative comparative methods are important to describe different phenomena (Palmberger, Gingrich, 2014) and this multidimensional analysis improves the comparability for such complex cases.

This master thesis follows this concept of a comparative multilevel analysis, to highlight the contexts of both space institutions.

For this reason, the ESA and NASA are grouped within the systems of the EU and USA. Within ESA and NASA comparative expressions will be created and analysed. Those expressions focus on the four main hypothesis: Science, Politics, Economy and Environment.

- Science: A distinction will be made between the basic research and applied research. Basic research focuses on the creation of new theories or testing existing theories within a discipline, while applied research uses the results of a research to understand a contemporary issue. Therefore, the requirements and settings for the kind of research differs. (Ritchie, Lewis, 2006). Such a differentiation is important to show in what directions the projects of ESA and NASA are focused.

  Possible subdimensions for research can be the number of publications, accessibility to the publications fundings, available projects, quantity of researchers, etc.
- Military: Space activities are often connected to national security and a strict division between national security and civil space systems, such as navigation satellites, can be quite difficult. Space objects can be often used for civil or military purposes. It will be examined how the strategies of the two space institutions are possibly connected to security issues.

  Possible subdimensions for military can be the number of military space activities, military cooperation with other stakeholders, the narrative of the military activities in outer space, etc.
- Economy: As commercial actors are emerging and changing the space sector with their space innovations, it will be analysed how the ESA and NASA include those actors within their strategies and projects.

  Possible subdimensions for economy can the number of cooperation with various companies, advantages for companies, fundings or other kind of incentives for companies, etc.
- Environment: Space activities also affect the environment. Therefore, it will be looked at different strategies how to protect the environment in the future with sustainable activities.

Possible subdimensions for environment can be the number of sustainable projects, various cooperation with environmental organisations, etc.

Overall the following dimensions and subdimensions were used in this master thesis:
The different subdimensions were developed during the analysis of various policy papers through a deductive approach and included in this table after the completion of the analysis of both space agencies.

| Dimensions: | **Science** | **Military** | **Economy** | **Environment** |
|---|---|---|---|---|
| Subdimensions: | Scientific activities | Main idea of the space agency | Objective and policies | Environmental vision |
| | Research methods and outreach | Narrative | Collaboration | Measures and cooperation |
| | Innovation | Organisational structure | Shift of risks | Sustainable activities |
| | Commercial participation | Space activities | Data accessibility | Space debris |

### 2.2.4 Rating

Those aspects were further compared between the two institutions. Through the qualitative context analysis, especially through a deductive approach, several subdimensions could be identified. These subdimensions were then weighted and rated between the two space agencies in accordance with the outcomes of the analysis of the two space agencies. The rating was conducted on basis of the available material. On a scale from 0 (does not apply) to 10 (does fully apply), the rating presents where the space agencies NASA and ESA are positioned by the author according to the existing space policies and other relevant documents. The scales show an overview with the clear indication where the space agencies stand in their current development.
This rating scale was developed by the author, and it presents an innovative part of the methodological approach, as it is usually not used within a comparative analysis and research. Although the rating is based on the analysed policy papers, it presents a subjective assessment of the researcher regarding the different subdimensions. Nevertheless, such a rating can be used for further research, for example by verifying the rating with experts from NASA and ESA.

When there are differences between the various subdimensions, it will present a possible connection to the organisational structure on the system level. Therefore, the master thesis also analyses whether the context to the EU and USA is related or not. For this reason, several policies were considered for the analysis. Nevertheless, this rating is done only by the author herself and it doesn’t include other experts, which would confirm the possible positioning of the NASA and ESA regarding several topics within the four dimensions. A further examination and verification would go beyond the scope of this master thesis.

The main outcomes of the research can be found in the sections of the analysis: four different dimensions, assessment of the NASA and ESA, and the final discussion.

# 3 Two space agencies and their future directions

## 3.1 National Aeronautics and Space Administration

The National Aeronautics and Space Administration was established in 1958 as an independent agency of the federal government of the United States to conduct civil space programmes and military space activities, which are assigned to the Department of Defence. NASA is the successor of the 43-year-old NACA organization. The National Advisory Committee for Aeronautics conducted aeronautical research and experiments as well as developments to provide advice to the federal government from 1915 to 1958. With the transformation of NACA into NASA, the main focus of research and development also changed from aeronautical to space research and civil space programmes. (Rumerman, n.d.).

In contrast to NACA, NASA does not only focus on research but also on the different space operations. The agency is not only responsible for the research and design of rockets and satellites, but also for the launches, the whole operation, the acquirement of data from the space activities and so on. In the first few years, NASA was with its projects and achievements behind the soviet space program. With the announcement in 1961, that NASA has the goal to land a man on the Moon and return him safely to Earth, NASA became prominent. For this reason, new facilities and testing sites were necessary and therefore NASA expanded its locations. Additionally, scientific manpower was supported through a broad program and several fellowships by NASA and several dissemination centers were created to work directly with different industries on technological innovations. The technology and knowledge transfer within an interdisciplinary field led to numerous developments. (Anderson, 1981). The Apollo program was the main focus of NASA in the 1960s, because manned spaceflights were seen as a priority in the space race. Many other space programs also contributed to the success of the Apollo program. The Apollo 11 mission was a ground-breaking accomplishment in human spaceflight and for any further space activity. Nevertheless, after the success of Apollo, the NASA budget was extremely reduced. The Congress had decided that Outer Space can wait, while other matters, like the Vietnam war, was more important. Science projects and research centres were hit hard. Although several space science programs were carried out, such as the Orbiting Astronomical Observatory, which provided evidence about black holes, Mariner 6 and 7 which flew close to Mars or Mariner 10 which flew past Mercury, or the program Uhuru, which scanned almost all of the celestial sphere for x-ray sources, the American government agencies and Congress were much more interested in Earth-near programs, such as satellites within the polar orbit, in order to obtain data about Earths land surface. Not only foreign governments, but also universities and industrial companies were interested in this new technique of gathering information and data. Due to the political climate, NASA was not supported to carry out far-away-from-Earth programs, but rather programmes, which could find solutions to everyday problems. Additionally, NASA has increasingly become a service agency for other governmental agencies as well as foreign governments. (Anderson, 1981). For instance, the Space Shuttle program was carried out for 30 years. It did not only develop new technologies but was also an important step to build the International Space Station. (NASA, 2018 April 2). The ISS is the largest international cooperative project in science and technology between NASA, Roscosmos (Russia), CSA (Canada), JAXA (Japan) and ESA (represents various European countries). (ESA, 2021b). This example shows the shift from far-reaching-projects to near-Earth programs in NASAs management strategy.

Despite the several cuts, reductions and changes, NASA is nowadays the biggest civil space agency in the world. The headquarter lied in Washington D.C. and other ten research centres and test and flight facilities are allocated through the US. (Spacepolicyonline, 2022a, September 7).

The main vision of NASA is: To discover and expand knowledge for the benefit of humanity. Additionally, the main mission is to "lead an innovative and sustainable programme of exploration with commercial and international partners to enable human expansion across the solar system and bring new knowledge and opportunities back to Earth. Support growth of the Nation's economy in space and aeronautics, increase understanding of the universe and our place in it, work with industry to improve America's aerospace technologies and advance American leadership." (NASA, 2021b, p 2).

The four main strategic themes of NASA are: Discover, Explore, Develop and Enable.

- *Discover*: Expand human knowledge through new scientific discoveries,
- *Explore*: Extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization,
- *Develop*: Address national challenges and catalyse economic growth,
- *Enable*: Optimize capabilities and operations. (NASA, 2021b)

Those four topics are NASA's main goals for the next few years, which were initiated in NASAs Strategic Plan 2018. The progress towards these strategic objectives is measured by the NASA through performance goals and annual performance indicators. (NASA, 2021b, p 3).

It is essential to note, that NASAs direction is strongly determined by the US space policy. The civil space policies are defined by law and presidential directives. Those directives remain in force until a new presidential directive revise this specific directive. For this reason, a variety of directives from different presidents are still in force today. (Spacepolicyonline, 2022a, September 7). Beside the presidential directives and laws, another important aspect for NASAs ambitions is the budget of the organization. The budget is annually requested by the President and decided by the Congress through legislation. (The Planetary Society, n.d.)

The approved budget depends on the accordance between the Presidents vision and the imagined direction of the Congress. President George W. Bush envisioned to return humans to the Moon by 2020 and someday to Mars, therefore the US human space flight program Constellation was in focus. Additionally, Bush wanted to cancel the Space Shuttle program after the finished construction of the ISS. When President Obama took office in 2009, within his first years, he cancelled the Constellation program and changed the direction of the next human flight program. Instead of going to the Moon, the next human should orbit around Mars in the 2030s and for this reason the program Asteroid Redirect Mission was implemented. Furthermore, it was planned, that the private sector will be engaged more into the development of space transportation systems for LEO and the ISS, whereas NASA will focus on the development of new technologies for space flights beyond the LEO. This proposition was seen as a controversy and led to congressional hearings where the Congress discussed its concerns. One of the concerns was, that the private sector would need longer to develop such technologies and systems than NASA. The Congress decided that NASA will build these Space Launch Systems (SLS) and not the private sector. When Obama requested $19.0 billions for NASA for these changes, the Congress provided only $ 18.45 billions. In the following year, Congress gave about $1 billion less than the requested budget to NASA. The President and the Congress were divided on the question of how the future of the human space flight program should look like. In the next years Congress cut the funding for several NASA space exploration programs whereas he funded more the development of the SLS. Additionally, the Congress was not convinced about the Asteroid Redirect Mission. Nevertheless, the funding for the financial years 2015, 2016 and 2017 were always higher than the budget requested. (Spacepolicyonline, 2022a, September 7).

In 2017, when President Trump took office, he re-established the White House National Space Council. It was responsible for creating the leading space policies. In 2018, Congress increased NASAs budget to $ 20.7 billion to fund four earth science missions and the NASA education programmes as well as the SLS program. From the beginning on, Trump wanted to cut NASAs earth science programmes and eliminate the NASAs Office of Education. Over the next years, Trump always proposed to cancel those programmes. In 2019, the National Space Council changed NASAs human space flight programme, where the first woman and the next man would land on the Moon within the new Artemis programme. For the financial year 2020 the Congress approved $ 22.6 billions for the new Artemis programme and other programmes, whereas for year 2021, the total budget for NASA was increased to $ 23.3 billions. (Spacepolicyonline, 2022a, September 7). Although NASA has its main strategic themes, those four topics can vary in their execution due to the political mood of the President and the Congress.

Additionally, there are also some directions from other sides. For instance, the Presidents Management Agenda 2018 established a modernisation plan which reforms the US Federal Government with 14 cross-agency performance goals, focusing on modern information technology, data accountability and transparency. NASA contributes to all the 14 cross-agency performance goals. (NASA, 2021b, p 4).

### 3.1.1 Future direction of NASA

2018 and upcoming 2022 are important years for NASA as they celebrate their 60th anniversary and the 50th anniversary of the Apollo missions. In the future, NASA wants to maintain their focus on human exploration, technology, and science. For this reason, it will strengthen its cooperation with industrial, international, and academic partners. NASA highlights the importance of commercial companies, which will play an increasing role for different space services, such as launching rockets and satellites, transporting cargo and crew as well as building infrastructure in LEO. (NASA, 2021c).

NASA's future focuses on the four main strategies: Discover, Explore, Develop and Enable. Several subthemes and strategic objectives can be found under these four main themes.

For the existing challenges of the ongoing missions and science plans, NASA carries out annually reviews, which are presented in the NASA Fiscal Year Annual Performance Report, with specific details about each strategic objective and performance goals.

#### *3.1.1.1 Discover: Expand human knowledge through new scientific discoveries*

The first goal of NASA has two strategic objectives. The first one is to understand the Sun, Earth, solar system, and universe, whereas the second is to understand the responses of physical and biological systems to spaceflight (NASA, 2021b, 2021). The first strategic objective focuses on the main themes: discovering the secrets of the universe, searching for life elsewhere and safeguarding and improving life on Earth. NASA conducts several scientific studies about the Earth and outer space and with its programmes and partnerships it supports innovative approaches to advance different areas of science. The second strategic objective focuses on space-based research to understand the diverse responses of the biological and physical systems in the extreme space environment and during the spaceflight. For this strategic objective, NASA collaborates with different other agencies to enhance the space-based research, especially on the ISS. Different agreements between the space agencies and other research organisations will be used to address several research projects on the ISS. (NASA, 2018, p 14 et seq).

#### 3.1.1.2 Explore: Extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization

The Presidents Space Policy Directive 1 of Trump changed in 2017 the national space policy, as it stated, that NASA must "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations". (The White House, 2017, December 11). NASA plans to land the first woman and first man on the Moon in 2024. (NASA, 2021c). To realize this national space policy, NASA implemented those goals into their strategic plan 2018.

Therefore, the second goal of NASA has two strategic objectives: First, lay the foundation for America to maintain a constant human presence in low Earth orbit enabled by a commercial market, and second, conduct human exploration in deep space, including to the surface of the Moon. (NASA, 2021b). For the first strategic objective, NASA wants to maximize the use of the ISS for research purposes until 2025. Simultaneously, the developing U.S. low Earth orbit commercial space industry will be supported by NASA. After 2025, the direct funding for the ISS will be ceased, whereas new research will take place in LEO in the cooperation with commercial actors. NASA envisions the LEO as a "self-sustaining space-based marketplace, which will provide economic benefits to the Nation and societal benefits to all people." (NASA, 2018, p 18). For this reason, NASA continuously explores new partnerships, which would enable different commercial activities and markets in LEO and therefore created the

Commercial LEO Development Program to directly support several developments in the commercial space industry. (NASA, 2018, p 17 et seq).

For the second strategic objective, NASA is using a phase approach to expand human exploration. It is developing new systems for transporting people and cargo into space, flexible hardware, that can be used in several complex missions, and researching astronauts' health and performance during long-duration missions beyond LEO. Future LEO platforms will be used for further technological developments and processes as well as research. For the different missions, the early missions to lunar orbit and the deep space, NASA will continue to invest into exploration R&D to make future missions safer, more reliable, and more affordable. (NASA, 2018, p 19 et seq).

#### *3.1.1.3 Develop: Address national challenges and catalyze economic growth*

The third goal of NASA focuses on three strategic objectives: Develop and transfer revolutionary technologies to enable exploration capabilities for NASA and the Nation, transform aviation through revolutionary technology research, development and transfer as well as inspire and engage the public in aeronautics, space, and science. (NASA, 2021b). Various studies have shown that technological innovation is strongly interlinked with economic growth. For this reason, NASA created for the first strategic objective a strong interlinkage between technology developments and the economy. Adequate developed technologies are transferred from NASA to the industry and to the public for a broader welfare. The future technological investments of NASA are focused to "expand industrialisation of space, improve efficient and safe transportation into and through space, expand capabilities through robotic exploration and discovery as well expand the possibilities of humans to live and work in space." (NASA, 2018, p 24). For such essential advancements in technology and exploration research, NASA relies on several collaborations with many other governmental agencies, commercial partnerships, and academia. For instance, "NASA established public-private partnerships with the U.S. aerospace industry." (NASA, 2018, p 25). Although there are often mutual benefits for both parties, NASA also has the challenge regarding the possibilities to access space, because they rely on rideshare and hosted payloads. (NASA, 2018, p 22 et seqq.).

The second strategic objective focuses on maintaining and advancing the US global leadership in aviation and several national and international partnerships. NASA supports the aviation industry through various high risk and high-reward research activities and technology developments. It explores early-stage projects and develops new technologies and strategies through foundational research. This research concentrates on multi-disciplinary collaboration with different national and international partners. National partnerships are essential to avoid duplications and to support the mutual objectives. Aeronautics high risk research creates an increasing knowledge base, which can lead to new solutions for several aeronautical problems. Some of the current issues that concern NASAs aviation research are, for instance transition to alternative propulsion and energy, supersonic aircrafts, and assured autonomy for aviation transportation. (NASA, 2018, p 26 et seqq.).

With the third strategic objective, "NASA presents their education and outreach functions, to inspire people for STEM, engage the public as well as increase the public knowledge and understanding of NASAs work and value." (NASA, 2018, p 29). NASA also highlights the importance of diversity and inclusion. Equal opportunity laws are important for NASA grants and funds to broader the possibilities for more underrepresented and underserved groups in STEM fields. (NASA, 2018, p 29).

#### *3.1.1.4 Enable: Optimize capabilities and operations*

The fourth goal of NASA has several strategic objectives, which focus on different aspects. NASA wants to engage in partnership strategies, enable space access and services, assure safety and mission success, manage human capital, ensure enterprise protection as well as sustain infrastructure capabilities and operations. (NASA, 2021b). These different strategic objectives are interlinked with management objectives and are therefore hybrid goals of NASA.

NASA creates and fosters national and international "mutually beneficial cooperative space work groups, projects, missions, and ground-based research activities." (NASA, 2018, p 32). The different partnerships are essential for the strategic goals and objectives of NASA as they enhanced unique expertise and expand the capabilities as well as increase mission flight opportunities and deepen the scientific return. (NASA, 2018, p 31 et seqq.).

The next strategic objective, the goal to establish a safe, reliable, and cost-effective access to space is closely linked to the strategic objective of NASA to engage in partnerships. "According to the National Space Transportation Policy is NASA the launch agent for the US civil sector." (ibid, 35). The Launch Service program as well as the Commercial Crew program are essential to support the space economy as well as "provide transportation of crew, cargo and scientific payloads into space." (ibid, 34). NASA is encouraging the space industry to provide commercial transportation to and from the ISS as well as human transportation services to and from LEO with the Commercial Crew program. By fostering partnerships with the national space industry, NASA can focus more on the development of rockets and spacecraft

for deep space missions. Additionally, NASA wants to ensure responsive and reliable space communication and tracking services for their missions. With the Space Communication and Navigation programme, NASA wants to reduce its reliance on Government systems and increase the possible usage of commercial services. (NASA, 2018, p 34 et seqq.). The Safety and Mission Success programs assure effective management of NASA programmes and activities by analysing technical, safety, health risks and evaluating risk acceptability, providing independent reviews, assessment and technical analysis as well as developing policies, procedural requirements, and recommendations to the NASA management. For this reason, "the hardware, software, environmental and human performance aspects are evaluated to find hazards and potential risks." (ibid, 38). The protection of NASAs workforce is essential to its programmes and operations success. Beside the protection of the human capital, NASA address the importance of a diverse and innovative workforce with the right balance of skills and experience. With their strategic objective to manage human capital, NASA wants to create a work environment with key principles of equal opportunities, such as equity and fairness. Additionally, NASA designs and implements a new functionally aligned architecture for human capital management, new recruitment measurements and engagement in STEM education. (NASA, 2018, p 37 et seqq.).
With new missions and new commercial capabilities, new risks and complex issues evolve. NASAs success depends on the cooperation and partnership with others, to exchange knowledge, technologies, tools, and techniques. To reduce the complex ecosystem, NASA will optimize protections and "ensure that enterprise protection, restrictions and safeguards are addresses throughout the whole life cycle of NASAs programmes and missions." (ibid, 42). Consequently, NASA will enhance their cybersecurity capabilities. Nevertheless, NASA has to balance between its protection and transparency of its programs, to promote accessibility and citizen engagement in NASAs missions. Furthermore, NASAs infrastructure capabilities and facilities need to be redefined and modernized, to be more efficient and sustainable as well as support the mission objectives. NASA adopts a sustainable infrastructure management and facilities maintenance. (NASA, 2018, p 41 et seqq.).

Overall, NASA presented in its Strategic Plan 2018 a long list of strategic objectives, which are very diverse, but also interlinked to each other. It's a guide to "a new era of exploration and discovery." (NASA, 2020b, p iii). The following financial year performance reports showed the current focuses and reflected the administration priorities. For example, in FY 2018, NASAs attention lied strongly on the development of a commercial space industry through several cooperation with commercial partners as well as improvements in several flagship missions, whereas in FY2019 and FY2020 the focus shifted slightly from the space industry to the exploration activities and research of the Moon and Mars. (NASA 2020b, p iii et seqq.). The Biden-Harris Administration has made NASA a priority again. NASA joined in 2021 the National Climate Task Force to support climate change activities with their knowledge and data. "The vice president announced in the National Space Council, that there will be a new whole of government framework, which will ensure, that space activities create beneficial opportunities. Furthermore, the National Space Council gained five new members: the Secretaries of Education, Labor, Agriculture, Interior, and the National Climate Advisor." (NASA, 2022, January 9). This extension shows the administrations emphasis on a broader approach and inclusion of the society to space activities. Additionally, the administration reasserted the commitment to extend ISS research work with international partners. NASA created a strategic partnership with ESA to observe Earth and its environment. (NASA, 2022, January 9). With the present Strategic Plan 2018, NASA presented several long-term and wide-ranging goals, which are yearly assessed and adjusted to the current needs and developments of the Agency and the US Administration.

## 3.2 European Space Agency

The idea of a European space agency can be found in the early 1960s. The first steps were taken by six countries to create the European Launcher Development Organization (ELDO) with the aim to construct a launcher called "Europa". A few years later, ten countries established the European Space Research Organization (ESRO) to develop scientific satellites. The European Space Agency was established in 1975 with a Convention, where the ELDO and ESRO were merged. The Convention entered into force in October 1980. (ESA, 2022c). Since then, the ESA concluded several cooperation agreements, for instance with Canada or Ireland and various other European countries joined the space organization. The ESA is now an intergovernmental organization with 22 Member States, with the headquarters in Paris. There are several other ESA offices in different European countries, each with specific responsibilities, for example EAC (European Astronaut Centre) in Germany, ESRIN (Centre for Earth Observation) in Italy, ESTEC (European Space Research and Technology Centre) in the Netherlands. All member states work together, share their financial and scientific resources to achieve the best results. The general budget and the mandatory space science programmes are funded by a contribution from all member states. The ESA is also conducting additional space programmes, where the member states can choose optionally if they want to participate in the programme or not. The financial contribution is calculated in accordance with the member states gross national product. Nevertheless, the amount of the financial contribution doesn't play a role when it comes to decisions and operations of the ESA. The governing body of the ESA is a Council, where every member state of the ESA is represented equally with one vote and it prepares all policy guidelines for the European space programmes. The Council elects every four year a new Director General. All research sectors report directly to the Director General. (ESA, 2021a)

The main mission of the ESA is to shape the development of Europe's space capability and ensure that investment space continues to deliver benefits to the citizen of Europe and the world. Article II of the Convention of establishment of a European Space Agency states the purpose as following: "ESA's purpose shall be to provide for, and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems. (ESA, 2021e).

The vision of the ESA is a peaceful exploration and use of space for the benefit of everyone. For the ESA is outer space the future and the diverse activities are all part of a clear vision for Europe in space. Those diverse activities are grouped into four main categories:

- *Science & Exploration*: the ESA explores the solar system and the universe with several programmes for space science, human spaceflights, and robotics explorations. The ESA plans to send the first European to the Moon and a crewed mission to Mars.
- *Safety and Security*: the ESA monitors space and protects the planetary environment from hazards from space such as space debris, asteroids, and space weather.
- *Applications*: the ESA uses outer space to benefit citizens and meet future challenges with satellite technologies, such as weather satellites, telecommunication satellites or navigation systems.
- *Enabling & Support*: the ESA makes space more accessible and builds technologies for the future. The European Spaceport in French Guiana provides an independent rocket launching site to space, especially for space transportation. Additionally, new innovations in space technology as well as operating spacecrafts or ground stations to study the universe are part of the ESAs space accessibility plans. (ESA, 2020).

All those elements are part of a broader vision of several European countries. These common visions and goals are also shared by the EU, especially the vision to strengthen Europe and benefit its citizens. The ESA is not part of the EU institutions, it is an intergovernmental organization with its own regulations. Both organizations have difference rules, procedures, ranges of competences and different member states. Although they are two independent organizations, with the growing global challenges in the space sector, the ESA and EU are increasingly often working together and creating new collaborations and strengthen their cooperation. (ESA, 2021d)

The EU and ESA cooperated for the first time in 2000, where they formulated a resolution for the European Strategy for Space and set up a taskforce which would continuously develop and implement the European Strategy for Space. In 2003, a green paper on European Space Policy was presented by the EU in cooperation with the ESA. It analysed all European assets and weaknesses in the outer space sector. In the same year, both parties signed the Framework Agreement, which states, that the EU and the ESA have to establish an efficient and mutually beneficial cooperation and gradually develop together a European space policy. Additionally, a Space Council was established, where all EU and ESA member states could discuss the development of space programmes, orientations regarding space and other issues related to space activities. In 2007, the European Space Policy was enacted. It presented the main goals and visions for the European space sector and addressed various issues regarding satellite navigation and communication, earth observation and security and defence. 29 European countries signed the European Space Policy. (ESA, 2021g). Three major EU space programs (Copernicus, Galileo and EGNOS) were set up to concentrate on key societal challenges, industrial growth, and EU autonomy. In 2016, both organizations signed a "Joint statement on shared vision and goals for the future of European space", which highlights the increasing cooperation. The main vision is that Europe remains a world-class actor in space and in the international landscape and to ensure, that scientific discoveries are fully integrated into the European society and economy. The common goals for the future are to maximize the integration of space into the society and economy, to foster a globally competitive European space sector and to ensure European autonomy. In the same year, the resolution "Towards Space 4.0 for a united space in Europe" was adopted. The resolution states, that the ESA is the main organization for European space activities and that the ESA is ready to support the EU. (ESA, 2021f). The collaboration between the two institutions has grown over the years and is becoming more and more important due to the expanding space sector.

It is important to note, that the ESA has two sides. One the one hand it is a space agency which implements mandatory and optional programmes of its Member States, on the other hand it is also an agency which implements the EU space programmes. (ESA, 2022e).

### 3.2.1 Future direction of ESA

Over the last few decades, "European success in space have not been guided by a single unified European space strategy plan, but rather by a mixture of different space strategies from various parties." (ESPI, 2020b, p 1). Different actors have their own strategies that interlinks each other. The European space governance consists of a complex interplay within a triangular structure: firstly, the strategy of the ESA, secondly the space strategy of the EU and thirdly, the individual space strategies of the member states of both institutions, the ESA and the EU. Each strategy represents distinctive interests and conflicts. With the joint statement of the EU and ESA from 2016 they started to progressively consolidate their strategies to a set of common goals. (ESPI, 2020b). Therefore, the ESA worked on a new agenda, which was published this year in March 2021.

Before the final presentation of the ESA Agenda 2025, the 13th European Space Conference took place in Brussels and brought together different actors to discuss the future developments of EU’s new space strategy. Representatives from the EU Council, the European Commission, European Parliament, ESA, Ministers from different countries as well as CEOs from various companies discussed the issues regarding climate change and digital transition, means to meet the goals and Europe’s independence. (European Space Conference, 2021). Those essential topics are reflected in the future direction of the ESA.

In the newest ESA agenda 2025 from March 2021, the organization presents its high ambitions for the following next four years and more. According to the ESA, Space is at a crossroads of global changes. Although Europe has the necessary expertise, know-how and competitive industrial capacities, it needs a common vision among the European states to unlock the full potential of outer space activities. ESA wants, that Europe benefits from space as much as the US and China, which already created political and technical space strategies. Additionally, the rapid commercialization of space leads to a new space revolution and it changes the growing space economy. In the next few years, the global space industry sector will produce a revenue of many billion dollars. If Europe wants to take part in this growing industry, cooperation between the EU, the scientific community and the space industry sector is fundamental. (ESA, 2022e).

Another aspect, why Outer Space is an urgent matter for Europe, is the reason, that there are several crises on Earth, such as the current health, economic and climate crisis. Those crisis needs to be managed in fairer and sustainable ways. Space can not only provide data and information but also autonomy and technological independence from other countries. It is too dangerous to rely on other countries that would provide societal needs of Europeans. Therefore, it is important to strengthen and grow its own systems. Additionally, the role of science needs to be highlighted as well as a “more sustainable economic development, with healthcare access and digital connectivity for all citizens.” (ibid, p 3). The new ESA Agenda 2025 introduces clear targets without any specific predetermined order. Five different ESA priorities for 2025 were set up by the Director General Josef Aschbacher and the Member States of the ESA:

- Strengthen ESA-EU relations
- Boost green and digital commercialization
- Develop space for safety and security
- Address critical programme challenges
- Complete the ESA internal transformation (ESA, 2022e).

Those five goals will increase the ESA value for European societies and be the starting point for further long-term ambitions for Europe in Space. Such long-term ambition of ESA for 2035 is one coherent space programme for Europe which includes European culture, values, and political core elements. All parties, the EU with the European Commission, the Member States of ESA as well as the ESA will contribute to the creation of the new space vision. (ESA, 2022e).

### *3.2.1.1 Strengthen ESA-EU relations*

Outer Space activities and their data are already heavily integrated in many European and EU policies. Space can be seen as an “instrument for safety, security, diplomacy, soft power, development, and international cooperation. It is a political and economic necessary tool to grow Europe.” (ibid, p 5). Since 2004, space became more and more integrated in the EU policies to develop a European space sector. The EU invests into different space activities, as it provides the largest EU budget ever for space, as part of the 2021-2027 Multiannual Financial Framework and it highlights the importance of a collective space vision for Europe from the EU, ESA, and its Member States. At the present time, it is necessary to clarify the different roles within the Financial Framework Partnership Agreement between the EU and ESA, which is managing the implementation of the EU Space Programme. The focus lies on the identification of the strengths and weaknesses of each partner and to prevent overlaps and duplications. Therefore, a “stronger coordination with more trust and coherence of actions is necessary between the different actors on different levels.” (ibid, p 5). Individual institutional settings and the complementarity between the different actors must be taken into consideration in any future cooperation. To define Europe’s space ambitions, the cooperation cannot exist only between the EU and the ESA, but also between other national agencies, industry sectors as well as other public entities, which rely on space assets. All those actors need to have a defined role and be well coordinated. The ESA will enter into political dialog with different stakeholders and also analyse and identify new potential partnerships for future projects, always in close cooperation with the EU and ESAs member states. (ESA, 2022e, p 5 et seq.).

### *3.2.1.2 Boost green and digital commercialization*

The development of smaller satellites and the reduction of launch costs broadened the possibilities within the space sector. The increased innovation and new commercial-supply oriented policies led to the investment of private companies and growth of this industry sector. According to the ESA 2025 Agenda, Europe needs to adapt the “commercial space sector to its own societal and economical needs and values” (ibid, p 6), especially with the focus of a green and digital transformation. Big data, AI-based data analytics and quantum technologies can be used to create smart information and new market sectors. For example, climate data from satellites can be used to create simulations and scenarios to test the effectiveness of

policies and help in well-considered decision-making choices. One of the main focuses of ESA will be energy efficiency, because it is important for the environmental sustainability. Other focuses will be robotic technologies and innovative materials as there are important for future space missions. To achieve breakthroughs in these areas, the ESA and its partners needs to improve their talented workforce, the access to capital and their adaptation to fast innovation. For this reason, Europe needs to "increase the number of students in STEM fields, create sufficient public demand and ensure easier access to capital from investors and create an integrated and agile framework for innovation." (ibid, p 7).
ESA will adapt their procurement approach and technology strategy for a broader innovation. Industry-driven technology developments will be increased by different grants and prizes. Start-ups, SMEs and new space companies will be encouraged by the ESA to participate in different programmes and activities to be integrated better into the space market. The main idea is to create a dynamic network with different laboratories and testing facilities within Europe, teaming up with different actors such as academia, research entres, national space centers, private investors and act with an "innovative and under-one-roof approach". Such an united approach should boost fast innovation in the areas of green and digital transitions. (ESA, 2022e, p 6 et seqq.).

#### *3.2.1.3 Develop space for safety and security*

Several space applications have a dual use possibility. For instance, weather satellites can be used for civilian purposes or military activities. The ESA wants to "increase its activities in safety and security by creating synergies between the ESA Member states, the EU and its member states, civil protection, and security agencies as well as the European Defence Agency to protect from hazards and threats on Earth and in Space." (ibid, p 9). Therefore, ESA plans developments in "the areas of space traffic management, debris mitigation and removal, space weather, planetary defence, space logistics and cyber resilience." (ibid, p 9). Several projects are already in their starting points. ESA is the first space agency that tries to minimize Europe's contribution to space debris by 2030. For this reason, there will be an active debris removal service in 2025 in an orbit at 800km. In the following years, there are also plans for an asteroid deflection demonstration mission to study possible deflection techniques for planetary defence. Besides the safety and security in Space, safety and security "on Earth covers also the state and collective security, safety of people, access to resources and critical economic activities." (ibid, p 10). To help with those matters, ESA wants to support activities within other areas, such as maritime safety and security by using satellites. Additionally, an in-depth analysis of ESAs member States and EU's needs and priorities in terms of safety and security will be carried out by ESA. This will be used to define specific programmes for the different states in Europe. Overall, those different activities are established to strengthen Europe's independence. (ESA, 2022e, p 9 et seq.).

#### *3.2.1.4 Address critical programme challenges*

In the following years, ESA will emphasize on different projects, that are "the most pressing issues and require an immediate and high-level response." (ESA, 2022e, p 10). One of the projects is the access to space and the freedom of actions in space is changing due to destabilising external challenges. Technological innovation and new industrial actors will be necessary to create new and better ways for space transportation. New launch sites will be assessed for this reason.

Other projects focus on different services, such as telecommunication or navigation, which need to be improved and developed further with new innovative strategies, like AI and quantum computing. Space exploration is also part of Europe's upcoming challenges. Complex space operations will be planned more efficient with ever more automation and AI. Robotic missions will be set up for the Moon and Mars for further research. Science and knowledge acquisition will remain at ESAs focus, with new technology R&D initiatives. Most space operation will be cooperations between the public and private sector. (ESA, 2022e, p10 et seqq.).

#### *3.2.1.5 Complete the ESA internal transformation*

To realise all these ongoing changes, ESA itself must change and boost its effectiveness and attractiveness. For this reason, the internal processes of the space agency will be optimised, procurement and decision-making processes will become less bureaucratic and adjusted to the nature of the project according to the ESA 2025 Agenda. (ibid, p 12). Additionally, a new data strategy will be implemented to use the latest data analytics technologies. Data from space and non-space activities will be used for the benefit of society.

ESAs workplace as well as the communication and knowledge exchange need to be updated. Platform-based information will be used so that diverse actors, the Member States, the industry, and ESA's personnel can reach for the newest information about ESA's programmes.

This will lead to more transparency of ESAs decision-making and procurement procedures as well as avoidance of duplications. The project management will be fully digitalised to provide a digital continuity throughout the different programmes and it will reduce costs and errors. Furthermore, ESA will try to improve its own environmental responsibility within their workplace. The agency will develop sustainable goals within the Corporate Social

Responsibility Principles and is “ready to sign a Charter for a Responsible Space Sector, which will focus on sustainable practices within the space industry.” (ESA, 2022e, p 13). To advance the workplace, ESA will also look at geographic and cultural diversity and create a better gender balance within the agency. Young people and people with disabilities will be motivated through different measure to engage into the space sector. (ESA, 2022e, p 12 et seqq.).

Overall, the ESA agenda 2025 is a short-term roadmap for four years, but with long-term implications. It presents the urgent matter of a common space vision. The agenda does not present any ground-breaking programmes for the future, as it is the beginning of a new space vision for Europe. Several strategic plans, such as the technology strategy and three R&D initiatives will be updated by the ESA Member States in the following months. (ESPI, 2021).
Many of these future plans of the ESA are interlinked to their partners, such as the EU, the Member States or private companies. There will be an EU-ESA Space Council which will initiate a political dialogue at highest level and guide the whole process to create a common understanding. Consultations will be held with stakeholders from science, industry, society and the Member States. (ESA, 2022e, p14 et seq.). So even though the ESA has ambitious plans, the partners who will join into the collaborations must have the same enthusiasm as the European space agency regarding all those different topics. It can be assumed that those new partnerships will have some kind of frictions at the beginning, due to the various interest from different sides. Nevertheless, ESA has a fundamental willingness to establish compromises between conflicting partners, especially when it comes to the common space vision for the future Europe.

# 4 Analysis: Four different dimensions

This section focuses on the four different hypotheses to answer the main research question. For this reason, the main strategy papers of both space agencies, as well as the most important policies and projects will be analysed. Although both space agencies have many various programmes, this master thesis will focus only on those space programmes, which are essential for the four areas of the hypotheses: science, military, economy, and environment. None of the strategy papers focus merely on one of the chosen subjects and therefore it will be a synopsis of different strategy papers and additional information. The comparison was conducted according to a rating, on the basis of several subdimensions on a scale from 0 (does not apply) to 10 (does fully apply). The rating scale wa created by the author and it focuses on the policy papers and materials collected from the literature review. The author weighted the different information within the subdimensions and positioned both space agencies according to the existing information.

## 4.1 Science

Outer Space presents a vast space of opportunities but also challenges. From space and interstellar travel, new infrastructures, asteroid mining and space life support systems for off earth habitation, outer space offers unique possibilities for scientists to explore and develop new technologies. Science and expanding knowledge are essential for advancements in outer space. Research from different academic disciplines helps to understand outer space. As academic disciplines are divided into several fields, the research results also differ. For technological developments, research is often done by the academic disciplines like science, technology, engineering and mathematics (STEM).

Many scientific developments for space activities are interconnected with STEMs. “According to National Science Foundation, the current advances in STEM fields are collectively considered core technological underpinnings of an advanced society.” (Weeks, Faiyetole, 2014, p 171). Humanities, such as social science or political science are less frequently confronted with outer space topics in their research. Within the global research, especially the climate assessments, biodiversity and other environmental issues, there is an ongoing notion to integrate and interlink social science gradually with natural science within diverse global research programs. (Mooney et al., 2012). Although Outer Space is not an environmental subject itself, it is often studied from a natural scientific approach. An inter- and

transdisciplinary approach would allow a broader understanding of Outer Space. Mixed research methods would also bring new outcomes and new perspectives on the subject.
As the realm of Outer Space develops, the interplay between space technology and social sciences becomes more and more important. Many people are still not aware of the possibilities of space technology. The best way to let people know, is to expose them to the information and knowledge. (Weeks, Faiyetole, 2014).

### 4.1.1 ESA

ESA has its own division for science and exploration. The ESA's Directorate of Science and Robotic Exploration has several programmes for space science and human and robotic exploration. Space science focuses on the exploration of the solar system, whereas human and robotic exploration focuses on astronauts and their activities in outer space. ESA has currently 7 astronauts from different European countries. (ESA, 2022t).
Regarding space science, the missions are divided into different subject matters, such as the sun, solar system, astrophysics, and fundamental physics, which are further divided into operations, post-operations, and implementations. ESA has a cosmic vision 2015-2025, which presents ESA's long-term plan for scientific space missions. Such a long-term plan is essential for the stability of space projects, as they typically last for a few decades. It often takes more than two decades from first concepts to the presentation of scientific results. Several stakeholders, like scientists, technologists, national funding agencies, the space industry and international partner are involved in the different processes. Since 2007, ESA chose together with the European space science community several missions for their future development. (ESA, 2021, June 10). There are different types of missions, from small, medium to large missions as well as fast missions and missions of opportunity. Small missions allow member state agencies to lead the missions, medium missions are led by the ESA or in cooperation with international partners, large missions are European-led flagships. Fast missions are similar to medium missions, but they focus especially on innovative implementation and a fast development path. Although most missions need a medium to long-term development phase, the missions of opportunity are designed to be flexible and quick to react to emerging opportunities within the space community. (Policy for missions, 2022).
Within the cosmic vision 2015-2025, the different missions are grouped into main themes: Planets and Life, the Solar System, Fundamental Laws, the Universe, the Hot and Energetic

Universe and the Gravitational Universe. Those main themes have several goals, concepts and mission scenarios which are pursued by the ESA. (ESA, 2021h).
Beside the existing organisational structures, ESA plans with its Technology strategy 2019 to invest more into skills and tools for technology R&D at ESA. An European-wide technology development planning and coordination process is conducted by the ESA for all major stakeholders from all sectors, to minimize duplications, fill strategic gaps and highlight the complementary role of different stakeholders. Several technological developments and innovations, such as big data, artificial intelligence, and quantum technologies play an important role for future space missions. Additionally, the projects and programmes are more and more transformed to fully digital engineering processes with models and high-fidelity virtual environments to prototype, experiment and test several options and concepts and integrate new technologies faster than before. For this purpose, ESA will leverage downstream commercial technological developments, adapt existing standardisations, advance manufacturing, and expand the smart usage of commercial elements. (ESA, 2019c).
Within the ESA, space system developments have been moving from space system engineering to integrated system-of-system engineering with space being only one part of larger interconnected systems. Furthermore, ESA improves space system end-to-end development processes and tries to reduce engineering lead time and costs. A multidisciplinary approach is used to combine the in-depth expertise with experience across all the different phases of a space systems life cycle. (ESA, 2019c, p 20 et seq.). Scientific research at the Moon is a hugely cross disciplinary area and involves several experts from the science community. Scientific priorities to 2030 are to analyse new and diverse lunar samples, detect and characterize polar water ice, potential resources, and the biological sensitivity of the lunar environment, build a geophysics network, and to deploy radio astronomy receivers on the surface of the Moon. (ESA, 2019b). Another example for a multidisciplinary scientific engineering program is the MELiSSA (Micro-Ecological Life Support System Alternative) initiative, which is a programme with several partners from Europe and Canada and combines expertise from microbiology, chemistry, biotechnology, plan physiology and more. (ESA, 2022m).
International cooperation and coordinated activities are essential, for instance, for the scientific research at the Moon. Most programmes, ongoing steps and study reports of the different missions are published on ESAs website. Therefore, the scientific information about space is available for the public.

### 4.1.2 NASA

The Science Mission Directorate (SMD) of NASA determines its vision as follows: "To lead a globally interconnected program of scientific discovery that encourages innovation, positively impacts people's lives, and is a source of inspiration". NASAs science programs focus on three different interdisciplinary objectives: Discovering the secrets of the universe, searching for life in the solar system and beyond and protecting and improving life on Earth. (NASA, 2020a, p 8) The thematic focus lies on the future flight missions as well as technological development.
The NASAs Science Mission Directorate has a Heliophysics Division, an Astrophysics Division, a Planetary Science Division, an Earth Science Division as well as a new Biological and Physical Science Division. Each division has own performance goals which are fulfilled by different missions and projects. Within all the performance goals, NASAs divisions demonstrated significant progress between 2020 and 2021. (NASA, 2021b, p 23 et seqq.).
The newest science strategy of the Science Mission Directorate for 2020-2024 has four priorities: Exploration and Scientific Discovery, Innovation, Interconnectivity and Partnerships and Inspiration. With its scientific and technological excellence, NASA wants to explore the Moon, lunar orbit, Mars and beyond. Exploration and scientific discovery projects include flight missions, research and analysis as well as technological developments and applications. The different divisions of SMD focus mainly on fundamental research. The results are used for further long-duration missions and other programs. There are "ongoing investments in fundamental research and science and technology payloads as well as support for commercial landers and lunar samples." (NASA, 2020a, p 15). The Directorate enhances interdisciplinary research and collaborations. Various synergies develop from the active cooperation of the different divisions and can lead to fundamental and applied advancements. An example for a cross-divisional collaboration is the Exoplanet Research Programme of the SMD. (NASA, 2020a).
NASA promotes innovation through different aspects: diversity in the workplace, a more inclusive environment, various experiments, and proactive communication as well as early investments in technology development and risk management. "For new risky ideas, the SMD established a Blue-Ribbon Panel, which re-examines high-risk or high-impact proposals, that didn't pass a standardized disciplinary peer review process." (NASA, 2022c, p 20). Several No Due-Date programmes were launched in Planetary Science, where individual researchers and small institutions get more flexibility in submitting proposals, without the necessity of advanced proposal support systems. Additionally, the SMD "catalyses the translation of

fundamental research into the commercial marketplace, and it provides researcher training in entrepreneurship skills.” (ibid, p 19). SMD also enhances collaborations with other government agencies and commercial companies by flexible mission design approaches. Commercial partnerships as well as public-private partnerships are becoming more and more important for the agency as they lead to more cost-effective approaches for their missions. (NASA, 2022c, p 18 et seqq.). Additionally, NASA extends its effective partnerships domestically and internationally. International, interagency, commercial, academic, and other cooperation can help to achieve better scientific results. The SMD has about 350 active international partnerships, that involve around 140 countries. NASA wants to benefit from the different partners and therefore also actively engages in learning communities by publishing free and open access scientific data through multiple channels and by creating a citizen-based science. (NASA, 2018, p 11 et seq., NASA, 2022c, p 23). An open science database can be useful for critical insights from different researchers and partners. NASAs data is also used for national needs, such as climate change, space weather prediction and planetary defence. (NASA, 2022c, p 9). Moreover, SMD wants to extend the accessibility and usage of SMD data for the users by further open science, a continuous evolution of data and computing system as well as new community and strategic partnerships for innovation. Citizens can directly contribute to the NASA by analysing data, participating in observations or other citizen science projects. Active participation of citizens is possible through community-based partnerships as well as the usage of digital tools, transdisciplinarity, and real-world experiences. For instance, during the James Webb Space Telescope launch, more than 600 events, such as star parties and hands-on arts and educational events, were organised by the NASA. Additionally, NASA is also a space agency that provides end-to-end research processes. (One year, 2022). “The SMD creates value by transforming taxpayer investments into knowledge.” (NASA, 2022c, p 28). The dissemination of various scientific results is used to create awareness and further understanding of Outer Space. (NASA, 2022c, p 18 et seqq.).

### 4.1.3 Comparison

Both space agencies focus on the topic of science in various ways. The science policy of NASA and technology policy of ESA show some similarities, but there are also a few distinctive differences. There are a few specifics that can be highlighted regarding the scientific divisions of the ESA and NASA. Some subdimensions can be compared:

*Scientific activities*

The ESA has a wide range of resources that addresses the whole range of space activities, especially in the field of science. Many European space missions have been successful and present a high level of capacity. (ESPI, 2019, p 6). The ESA has several different missions, focuses on innovative implementation and fast developments, a multidisciplinary approach and international cooperation. NASAs science discoveries depend on various elements: the scientific and technical foundation for space-based missions lies within Research and Development, the invention and usage of new space-based observing and sampling capabilities, the creation of a specific context and capabilities for the interpretation of data as well as the maximisation of the return on investment in the acquisition of data. (NASA, 2018, p 11 et seq.).

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*Research Methods and Outreach*

Both agencies focus primarily on fundamental research. Technological developments and new findings in outer space are the main focus of research results. Both agencies have end-to-end research processes. ESA and NASA adopt a multidisciplinary approach in the agency and in the different disciplines, but the missions seem to limit it only to natural sciences. None of the agencies emphasize in their strategic papers the importance to include social science into global research programs. This suggests, that both agencies value more the technological achievements in outer space, than the implications and effects on the society itself. Nevertheless, both agencies have some sort of knowledge management to involve the society into the outer space activities. Both agencies provide open access data regarding their research.

Research data can be easily found online on their websites. ESA publishes information about their missions, the ongoing developments, and the studies on their website. NASA went further and established a citizens-based science. American citizens can contribute to the existing research by analysing data. Furthermore, there are much more events regarding the space activities organized by the NASA for the American citizens, than by ESA for European citizens. NASA states, that it "creates value by transforming taxpayer investments into knowledge." (NASA, 2020a, p 24). The same statement cannot be given by the ESA, as it is not directly funded by the individual taxpayer, due to its organized structure.

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*Innovation*

The two agencies emphasize the importance of innovative ideas. Therefore, there are fast missions and missions of opportunity in the ESA, which focus on innovative implementation, a fast development path as well as flexible and quick opportunities. However, the proposal of the mission of opportunity can be submitted only by Member State Delegations or potential partners, not directly by the scientific community. (Policy for missions, 2022). NASA designed the Blue-Ribbon Panel, where rejected proposals are re-evaluated by a commission as well as the No Due-Date programs, where individual scientists and small institutions gets more flexibility regarding the submission of a proposal. Additionally, NASA provides researcher training in entrepreneurship skills.

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*Commercial participation*

A smart usage of commercial elements and partnerships can be found in both agencies. Both agencies cooperate with the space industry to reduce time and costs. Commercial partnerships are important as they lead to more cost-efficient approaches for the different missions. According to ESAs strategy paper, ESA focuses more on creating a coordination process with all stakeholders, minimizing duplications, and creating a European-wide technology process, whereas NASA enhances the cooperation with commercial actors by adopting flexible mission approaches. It seems, that NASA is more responding to the needs of the commercial space industry than the ESA. Nevertheless, both agencies underline the significance of international cooperation and partnerships, as they can lead to better scientific results.

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## 4.2 Military

Outer Space becomes more and more important as a geopolitical realm, where countries may wage wars and conduct diplomacy as it becomes the ultimate high ground that can be dominated by states. Several countries have already questioned the space dominance of the US. Most major space powers have adjusted their military doctrines related to outer space and reorganize their military. Especially dual-use assets, which are used for civil purposes as well as military purposes, anti-satellite technologies and cyber threats are developing fast. Such technology creates new threats and vulnerabilities. (ESPI, 2020a). There is no specific framework, which regulates the explicit weaponization of Outer Space. The Limited-Test-Ban Treaty from 1963 prohibits states to test nuclear explosions in the oceans, the atmosphere and in outer space. This was the first step to denuclearize Outer Space. Article IV of the Outer Space Treaty forbids nuclear weapons or any kind of weapons of mass destruction on celestial bodies. However, this implicitly permits other kind of weapons in Outer Space, such as intercontinental ballistic missiles. (Petras, 2002). Therefore, countries want to protect and defend themselves against possible threats.

Military space activities focus on two possible concepts regarding protection of Outer Space and Earth: Defence of Space and Space for Defence. (ESPI, 2020a). "The former emphasizes all means used by states to defend their space assets from space- or ground-based intentional threats whereas the latter stresses the use of space in support of terrestrial military operations (the so-called "militarization" of space), and its consequences (with space being considered as a "force multiplier" and even a "force enabler")." (ESPI, 2020a, p 3). Additionally, one can define security measures as active space defence, or passive space defence. For all the different strategies and actions states need surveillance measures. With the data from space surveillance, one creates a Space Situational Awareness, which is essential to react to any risk or threat. (ibid. p 5 et seqq.). Both space agencies play a different role when it comes to the question of national security.

### 4.2.1 ESA

The ESA itself was not established as a solely civilian agency, but rather for peaceful purposes. These peaceful programmes may also include some security components. (ESA, 2014, February 10). For a long time, European countries have restricted their space activities to purely civilian and scientific programmes at ESA. Nevertheless, European countries develop their own national military space programs individually or in cooperation. (Ayadi, 2019). At least four European countries have created their own military space commands for independent military space capabilities in the last few years. (Rome, 2021). Within the EU there are several key policies, beginning from 1993 with the Common Foreign and Security Policy (CFSP), which was established by the Maastricht treaty to support international security, peace and multilateralism, the Common Security and Defence Policy (CSDP), which is part of the CFSP, but sets the framework for EU political and military structures and military missions, in 2015 the Global Strategy for the European Union's Foreign and Security Policy (EUGS), which presents five strategic priorities for the EU external affairs, and in 2016 the European Defence Action Plan (EDAP), which focuses on a common development of technologies and better cooperation between the member states. (ESPI, 2020a, p 27 et seq.). Lately, ESA and the EU identified their goals to "strengthen the synergies between civil and security activities in the fields of navigation, communication and observation" and to "ensure European autonomy in accessing and using space in a safe and secure environment, and in particular consolidate and protect its infrastructures, including against cyber threats" (ESA, 2016). Military related space activities focus on Earth observation, Navigation, Space Situational Awareness, Surveillance, Tactical Communication Information System and Cyber defence. For the different military activities, ESA works together with other institutions, such as the European Defence Agency (EDA) as well as the European Commission. For instance, ESA and EDA have a joint project called "Cyber Defence for Space". The Governmental Satellite Communications (GOVSATCOM), a platform of dual use satellites, is also a collaborative project between the European Council, the EDA, various member states and the ESA. Furthermore, the ESA and EDA signed an implementing agreement regarding the cooperation of GOVSATCOM. There is also a close collaboration with the European Commission on this satellite program. ESA is also closely involved in a joint study with the EDA on dual use of Earth observation measures. (ESA, 2022d). Another important agency, the European Satellite Centre (SatCen), which was established by the CFSP, focuses on space and defence issues, on space situational awareness activities, space surveillance and tracking and provides high-level geospatial analyses to several actors, like the EU institutions, member states and other international organisations. Additionally, it engages with the ESA and the EDA in R&D activities, such as the usage of artificial intelligence and machine learning in the field of image analysis. (ESPI, 2020a, p 31 et seq.).

The Copernicus program, which was also developed by ESA in collaboration with the EU, has not only presented environmental data for global warming analysis, but also data for security purposes. It can monitor the European borders as well as conflict regions and areas, that are interesting for the EU. Such independent data is essential for any European country, without the necessity to rely upon foreign assets. The same applies to the Global Navigation Satellite System, in Europe Galileo. Galileo can be used for military purposes to coordinate and position armed forces as well as target specific objects. To protect the existing space assets from risks and threats, many European countries developed their space surveillance and tracking systems, such as radars and other dual use detection instruments. (Ayadi, 2019). For other threats, ESA has the Space safety programme, which works on topics regarding hazards from asteroids, space junk, space weather etc. With the Near-Earth Objects Coordination Centre, which is part of ESA's Planetary Defence Office, it contributes to the observation of small solar system bodies and evaluates the threat from these objects. (ESA, 2022o). ESAs Planetary Defence Office addresses the importance of Near-Earth Objects and their impact on Earth, develops methods to deflect any risky asteroids, and informs relevant parties, such as national emergency response agencies. (ESA, 2022a).

Nevertheless, the space activities in Europe started as a civilian activity and military space activities were always limited. (The ESA interview, 2014). Many European countries cooperated with ESA in exchange of capacities. They often promoted technologies to a point where they could adapt these inventions to their national needs. (Ayadi, 2019). Nowadays, the small scope of military space activities is the largest deficit of Europe compared to other space powers. (The ESA interview, 2014). Space policies and space defence are allocated on multiple levels within Europe, on the national, intergovernmental and supranational level. Besides the EU, NATO also recognized the importance of space defense and therefore cooperates with several states on different space projects. Still, states are the main actors on all three levels. Each level has an other degree of cooperation between the states and other institutions. While the strategic thinking, such as the development of security and defence strategies, remains as a domain for the individual states, the EU strengthens its cooperation with four flagship programmes. Regardless of the developments on the European level, states also develop their own national space programmes with the help of the ESA. (ESPI, 2020a, p 38 et seq.). The ESA works with the EU as well as with the individual countries. It is an institution that balances the different actors and their interests as well as guides and assists in the diverse space programs.

Additionally, ESA focuses on cybersecurity issues, as space systems, as well as interlinked ground systems and infrastructures, because they can be vulnerable to cyber-attacks. The public sector is as important as the private sector regarding the security aspects. It is anticipated, that as space activities are become more and more integrated in various sectors, cyber-attacks will

occur also in more and more sectors. Cybersecurity is a relevant topic for various sectors and therefore ESA plans to focus on several technological and engineering aspects, such as integrating security into the system engineering processes. (ESA, 2019c, p 20, 24).
Nevertheless, overall, "the military applications of space are still underdeveloped in Europe and more measures are necessary, that would interlink the civil and military space sector. Both sectors need each other to be commercially viable as well as affordable to the European institutions. Till now, the ESA was used more for the European space manufacturing sector, the EU for civil activities, while the military activities stayed on an individual national level." (ESPI, 2020a, p 45 et seq.). The ESA plays as a space organisation a relevant role regarding military activities, such as research and development, but is not the only one in charge of all military developments.

### 4.2.2 NASA

According to the 1958 National Aeronautics and Space Act 1958, NASA conducts civil space activities, whereas the Department of Defense (DOD) is responsible for military space activities. In the present day, national security space programs are divided between the DOD and the National Intelligence. (Spacepolicyonline, 2022b, September 7). Nevertheless, the Space Act also states, that the US space activities shall be used for peaceful purposes, but also contribute to the national defense. Till the 1980s, the development and usage of space technologies for civil and military purposes occurred simultaneously through the different civil and military agencies. (Petras, 2002). NASA also worked closely with the Central Intelligence Agency, for instance for analysing intelligence on foreign aeronautical and space programmes or using classified cameras in lunar probes. (David, 2015).
The military space activities were for a long time part of the Air Force, in the Air Force Space Command (AFSPC). The AFSPC was established in 1982 with its' main mission was to "provide resilient and affordable space capabilities for the Air Force, Joint Force and the Nation". Space operations vary from missile warning, launch operations, satellite control as well as space surveillance. During various military actions, AFSPC supported other military divisions with space-based activities regarding communication, positioning, navigation, timing, and meteorology. (Air Force Space Command (Archived), n.d.). In 2019 the US Space Force (USSF) was established and the AFSPC was redesignated and incorporated into it. In the same year, AFSPC held a Space Futures workshop with participants from the DoD, NASA, NATO, industry and academia to discuss the future of space in 2060. They came to the conclusion, that "space will be a major engine on a political, economic and military level for

those states, who can use the best potential of Outer Space.” (Air Force Space Command, 2019, p 4). There is a growing competition for the leadership in space and therefore, the US needs to defend its leading position. Would the US lose its leading position, then the US national power would be at risk. (Air Force Space Command, 2019). Due to the growing importance of space, the US recognized the necessity to have a military service, which “solely focuses on pursuing superiority in the space domain”. The main mission of “the USSF is responsible for organizing, training and equipping Guardians to conduct global space operations that enhance the way our joint and coalition forces fight, while also offering decision makers military options to achieve national objectives.” (USSF, 2022c). The USSF highlights the great benefits of space activities for the military as well as for their citizens. Military operations are faster, better connected, better informed and more precise due to space activities, whereas people are better connected with synchronized cell phone networks, can better monitor weather pattern, use the GPS and so on. Additionally, the USSF emphasized the existing threats in space, especially regarding the access to space and the freedom to operate in space. The connection to space is for the USSF a national security issue and is also important for the economic prosperity. (USSF, 2022b) “The USSF will secure the peaceful use of space, free for any who seek to expand their understanding of the universe, by organizing, training and equipping forces to protect US and allied interests in space.” (USSF, 2022d). The main space operations of USSF are designed to “generate, present and sustain combat-ready intelligence, cyber, space and combat support forces for the US and the Allies.” (Space Operations Command, 2022, p 6). From determining and mitigating adversary counterspace capabilities, evolving threat-based trainings, operationalizing new intelligence accesses and creating awareness in a contested environment, continuously developing, integrating and growing defense cyber operations, as well as enhancing and improving the institutional space systems sustainment and resilience readiness, to developing and deepening existing or new partnerships, the space activities of the USSF varies. The USSF also advances its digital services by continuously adapting and improving the digital transformation and designs data-driven decision-making tools and processes. Innovative approaches are essential to evolve space capabilities of the US. (Space Operations Command, 2022).

NASA has a strong partnership with the Department of Defense, had previously an agreement with the AFSPC and is now in a broad collaboration with the USSF. Since the beginning of the space age, NASA collaborated with the military. The cooperation with the AFSPC lead to a two-sided exchange of research and development information, reduction of duplication of system developments and the assistance of developing each institutions space guidelines. The

agreement with the USSF continue with the collaboration in the various areas, such as US space policy, human spaceflight, space transportation, best practices for safe space activities, research results and planetary defense. (USSF News, 2020, September 22). For instance, the USSF supported NASAs launch of the OSIRIS Rex spacecraft in 2016. (USSF, 2022a). In 2016 NASA also established a planetary defense coordination office (PDCO) for terrestrial impact hazard from Near-Earth objects. Through the Near-Earth Object Observation programme, the PDCO wants to find, track and characterize potentially hazardous objects, such as asteroids or comets, that come too close to Earth's orbit. Accurate detection and timely warning and predictable and proper calculated information to the government, media, the public is essential. The PDCO has several missions, which addresses new developments, technologies and techniques to deflect an asteroid off its direct course to Earth. Strategies are studied how to mitigate potentially hazardous objects and their impact on Earth. (NASA, 2019, March 14).
Additionally, beside the different interlinkages between NASA and the military regarding their space mission and research activities, NASA promotes the support for military veterans and their families by hiring them. Astronauts like Neil Armstrong, Buzz Aldrin or John Glenn had a military background. Veterans and military spouses can deliver specific expertise and skills in various subjects, such as information technology, transportation logistics or public relations. Job opportunities can be found in the aerospace, aviation, electronics engineering, cyber security, security administration and program management. They can find work in all various sectors of NASA. From aerospace, aviation, electronic engineering, cyber security, and project management. (NASA, 2022, August 29).

### 4.2.3 Comparison

ESA and NASA play a different role when it comes to military space activities. Both institutions were not designed to primarily concentrate on military topics. Therefore, there are no space policies that focus on military space activities. Nevertheless, there are different linkages between the two institutions and the military, which can be presented in the different subdimensions:

*Main idea of the space agency*

The main idea of the establishment of both institutions vary. The ESA was created for peaceful purposes, whereas the NASA has to contribute to national security. Although peaceful purposes can include some military aspects for security reasons, national security is a broader definition, that includes much more military activities. It is noteworthy, that even the international definition of the usage of space for peaceful purposes is interpreted by the European countries and the US differently. Whereas European countries understand the peaceful purposes to be nonmilitary, the US understand it as nonaggressive. Even though the two definitions still remain, no country has ever protested against the US definition of "peaceful" purposes in the context of outer space activities. (Petras, 2002, p 169 et seqq.). So, if there are different understandings of the main idea, what kind of space activities should be carried out, it is not surprising that the scope of military activities varies.

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*Narrative*

One of the most striking differences is the narrative, why military space activities are essential for the institution. ESA and especially the EU, need the collaboration between the different national militaries to develop an autonomous system for themselves and be independent from other providers, such as the US. Additionally, the EU noticed the growing importance of the space sector and wants to be an active partner within. NASA already has it well developed space system, but with the growing importance of the space sector and the additional threats from numerous new actors in space, the US sees a threat in the superiority of its position. Therefore, the space activities are oriented to protect US leading position in Outer Space as a national power, maintain the access to space, the freedom of exploration as well as protect their economy. Especially Russia and China are seen as a threat to the US. (Space Operations Command, 2022).

ESA

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*Organisational structure*

Additionally, the ESA is an independent institution, that works in collaboration with other states, institutions and companies regarding military activities. The military funding in space activities is quite small and the interlinkages between the civil and military space activities are weak. (ESPI, 2020a). Military topics are very fragmented and divided on multiple levels within Europe. On the EU-Level there are several space policies that address military issues and each country has its own policies. Military activities are divided on different European and national institutions. ESA plays only a small part within all the different military developments. There are several coordination issues between so many different institutions at various levels and possible duplications of projects and developments. Due to the fact, that in most cases, states develop their own military projects, it is difficult to trace the different military space developments in Europe. The ESA was never seen as an essential part for military space activities per se, but rather for the European space manufacturing sector. The strategic military thinking remains at the competence of states. Nevertheless, now the institution is more and more also a coordination partner for several national, European and international military space programmes.

By contrast, NASA is a national institution that works closely with one government and several other governmental institutions. Funding is available and the cooperation between the NASA and the military has a long history. Due to the fact, that the main cooperation between NASA and the military is on an institutional and national level, and the (military) space strategy come from one country, it is easier to coordinate work and avoid duplications. Due to the long lasting partnership between the NASA and other governmental institutions, especially the military, the collaboration is often smooth and effective. The interaction and exchange seem to be more well-functioning, especially because NASA signed in the 1980s an agreement to avoid duplications with the AFSPC, whereas ESA focuses on this issue since 2016.

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*Space activities*

NASA and ESA have similar military space activities, such as navigation, communication, cyber security and Earth observation. Both institutions have a Near-Earth Observation facility. Space situation awareness is one of the most important aspects of security. NASA, together with the USSF has a better developed space situation awareness system, due to the global network of radar and sensors. None of the European countries possess such a system. The European countries try to become more independent from the US system. Nevertheless, due to the fact, that the construction of such a system takes years, the European military and ESA cooperates with the US. The European military applications are still underdeveloped. European militaries can contribute to the US space security by adding information, capabilities, infrastructure as well as expertise. (Rome, 2021).

Both institutions use their satellites and other instruments often for dual use purposes. With the minimizing duplications in developments, both institutions work more and more closely with the military to get better results.
ESA and NASA use their gathered information for a two-sided R&D information exchange. Between the USSF and NASA there is also an exchange of best practices for safe space activities. An important aspect for the military is the combat-ready intelligence information and threat-based trainings in the USSF. It is possible that European national militaries do have similar trainings, but it is unknown whether ESA takes part in it.
NASA also engages in supporting veterans and their families. ESA doesn't have such a program because it is not indirectly linked to a European military.

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## 4.3 Economy

From commercial spaceflights, manufacturing of satellites and equipment, satellite services like radio, internet, telecommunication and navigation as well as space tourism, the economic activities in outer space are growing every year. The space sector is more and more interlinked between the governments and the private actors and needs therefore various innovative systems and policies. There is an ongoing global trend to interconnect different industries. (Robinson, Mazzucato, 2019). During the 1960s, the space sector was a public-sector centralized model, where governments coordinated the markets structure by governmental purchases from aerospace firms. Few decades later, the shift from public to private priorities began. Such a decentralization of space activities, where companies and entrepreneurs can access to space is seen as a "New Space" era. Active commercialization in space is done on several levels: there are companies that launch payloads and people into space, companies that provide images, satellite data and analytics, companies that provide facilities for manufacturing and research as well as some companies that start to invest in space tourism. (Weinzierl, 2018). Other non-space companies can use space data and other space assets for other commercial purposes.

Competition between the different companies leads to new developments and increased research results. One of the most important potential developments of space activities of private actors is the reduces launch costs. The costs to launch a satellite into space has decreased over the last few years. The invention of CubeSats, nanosatellites with a mass of approximately 1 to 10kg, expanded the possibility to access space. Such small satellites are used not only by the government and their military, but also by companies, universities and schools. (Zubrin, 2019). Due to the commercialization of space activities, new inventions were created more efficiently, such as reusable rockets. Human spaceflight technologies are developing rapidly by private actors, like SpaceX or Blue Origin. Responsibilities and risks are shifted from governmental agencies to private actors. The economic developments opened a new market with various chances but also some challenges. Legal aspects about various topics are still not determined. For instance, current international treaties do not deal with topics related to the space economy. Especially the private usage of resources is not regulated on international level. (Weinzierl, 2018). Article VI of Outer Space Treaty declares that "states have the international responsibility for national activities, whether they are carried out by governmental or non-governmental entities." (OST, 1967). Apart from that, there are no explicit legal regulation for all the new space activities, such as space tourism, which is carried out by commercial actors. Nevertheless, commercial space activities and their developments are promising and lead to innovations in various areas. Especially, the entrepreneurial mindset, an ethos of mass manufacture, business models with high production rate and low costs, as well as the existing governmental infrastructure pushes the new developments in the space sector. (Robinson, Mazzucato, 2019).

### 4.3.1 ESA

Article VII of the ESA Convention 1975 states, that European space programmes need to be cost-effective, and the industrial policies should "improve the worldwide competitiveness of European industry by maintaining and developing space technology and by encouraging the rationalization and development of an industrial structure approach to market requirements, making use in the first place of the existing industrial potential of all Member states." (Article VII of the ESA Convention). From the beginning, ESA mission was to create a competitive European industry by supporting research and developments as well as external contractors and build a new space network, establish various techno-economic processes and create a new competitive space market. (Robinson, Mazzucato, 2019).

The existing "New Space" market is an essential part of the global space economy and therefore pressures the European space agencies to have a competitive position on the global market. In 2016, ESA presented its new mission, that it will focus on "interconnecting science, industry, politics and society" in new ways. They presented a vision of Space 4.0, where industry and agencies get new roles, the supply chains and services are being interlinked, and a downstream value creation is essential. There is a need for new arrangements between the countries, the public sector and private sector, as well as interactions between different industries and the space sector and society itself. (ibid).

ESA enters in dialogue with the industry and the academia regarding technological developments. When the technology developments are in its baby shoes, most development is done by academia, whereas more advanced technologies are further developed within the industry sector. These partnerships are essential for the development of game-changing innovations as well as the competitiveness of Europe in Outer Space. (ESA, 2019c). According to the ESA and the Luxembourg government such partnerships and exchanging knowledge will lead to industrial clustering as well as the development of new standards, which will create new benefits for the social and environmental issues. (ESA, 2019a, Luxembourg Space Agency, 2018). ESA has several public-private partnerships, which are a large part of the ESAs Advances Research in Telecommunication Systems programme. Companies cooperate closely with the ESA on projects that use satellite technology. For instance, Airbus develops, owns, operates and co-finances the systems infrastructure. Additionally, Airbus also provides data transmission services. ESA is responsible for the funding of the infrastructure development. With public-private partnerships ESA bears the risks which are related to the innovative developments and would be too risky either technically or commercially for a single company. In this way, new innovative solutions are presented to the commercial space market. (ESA, 2022r, ESA, 2022q).

The space agency has several partnerships and pilot projects with non-space actors, such as European SMEs in technology sectors for virtual, augmented and enriched reality, smart glasses or integrated scanners, to broader the perspective of the space industry and create new innovative developments. (ESA, 2019c, p 22).

ESA actively promotes on their website the cooperation with various industries. It wants to interlink new businesses and the space agency with a market-driven approach and provide technical expertise and programmatic support to the companies. ESA lists all kind of industries, which can cooperate with the agency, from data platforms, education, energy, finance, agriculture, health, maritime, to safety, technologies, tourism, transportation etc. New commercial space activities should be developed by a collaboration of the ESA and the industry, academia or public organisations. (ESA, 2022h).

The ESA established Business Incubator Centre networks in various countries, where entrepreneurs are supported in their space-based business ideas. Entrepreneurs and start-ups can create products which use space systems, such as satellites navigation or communication, apply space-technologies in other industries or create new innovative products for the space industry. ESA provides technical support, legal advice, business coaching, fundings and opens the access to other business partners. A broad network within Europe provides a good support system, which connects the different businesses. The different centres can be found in 19 different countries across Europe[1]. (ESA, 2022g). Not all European countries participate in this initiative, there are almost no east-European countries involved in this program. Nevertheless, the Business Incubator Centres initiates the growth of space-related start-ups and other companies across Europe.

Commercialization is becoming a priority at the ESA and it focuses now more on downstream applications, products and services in various space-based value chains, rather than the supply

[1] Namely in Germany, France, UK, Ireland, Belgium, Netherlands, Italy, Spain, Portugal, Austria, Hungary, Switzerland, Czech Republic, Greece, Sweden, Norway, Denmark, Estonia, and Finland.

of satellites, infrastructure and technology itself. ESA also encourage upstream, midstream and downstream elements of diverse space value chains to create new markets. Products and services should be for consumers and public goods should address societal challenges. This presents a shift in the European space policies. (Robinson, Mazzucato, 2019).

This change can be seen in the European Earth Observation programmes. First, earth observation satellites and their technology were funded by the public sector, especially by the military for security reasons. For instance, the SPOT Series, an ESA mission, where high resolution and wide-area optical imagery are done by satellites. The first five satellites, launched from 1986 to 2015, were publicly funded, whereas the latest satellites, SPOT 6 and SPOT 7 are commercial satellites of Airbus Defense and Space. (ESA, 2022u). For the first five satellites, the public sector took all the risk, whereas for the last two one, the private company took all the risk. The Copernicus programme also created a constellation of Earth observation satellites. The satellites provide data on environmental and security aspects. All the data is accessible from ESA free of charge, but one need specific algorithms to add value to the images. Various business sectors can benefit from high resolution imagery, as it can be used, for instance, for urban planning or digital agriculture. This free and high-quality imagery can be used to create value added services and products around the world. (Robinson, Mazzucato, 2019). The "Future Earth observation" is an ESA programme which focuses on the further development and new innovations for Earth observation. It combines input from the scientific community, national, regional and international public institutions as well as private actors. Partners should be from Europe and ESA provide its partners technical expertise, financial support and robust programmatic support as well as the ESA facilities and network. (ESA, 2022p).

### 4.3.2 NASA

At the beginning of the space race, NASA was focusing on international prestige, national security, and research. For a long time, NASA and the US military were the only one in the USA that could launch a rocket or satellite into space. Under the centralized model, the USA was, together with NASA, the leading space power. (Weinzierl, 2018). Nevertheless, companies were often contractors to produce the necessary space launch equipment. Already in the 1960s a public-private partnership was established. The different commercial space activities have become interlinked to the NASA and the US military. (Highfill et al. 2019). COMSAT was a private cooperation between various stakeholders and telecommunication

companies, which created the start of the private communication satellite industry. NASA was responsible for the technological know-how and the COMSAT launches. This public-private partnership led to a substantial distribution of satellites into the orbit, that are nowadays used for public and private purposes. Within the centralized model, companies that worked with NASA had cost-plus contracts and were therefore insured against high risks and could only participate a little bit in the benefits of a commercial space market. (Weinzierl, 2018).
After the Apollo mission in 1972, NASA didn't have any clear goals. The goal to surpass the Soviet Union in the Space Race was fulfilled and new directions were missing. Additionally, the direction and the fundings of NASA depends strongly on the political will, but the budget was regularly cut. There were several revisions of various policymakers and therefore it was challenging to define goals for NASA. First decentralizations and the involvement of private actors came with the Commercial Space Launch Act in 1984 and the creation of the Office of Commercial Programs at NASA as well as the Office of Commercial Space Transportation in the Department of Transportation. With the new programme, NASA became a customer and partner and not a supervisor anymore. NASA provides insights and companies get their freedom to design their own products and possess their intellectual property. Such change shifted the risks of the companies, reduced the need of intensive monitoring of NASA and encouraged innovation. (ibid).
In the 1990s, four companies got licenses from the Federal Aviation Administration to build commercial spaceports. In 2012 SpaceX Dragon was the first commercial spacecraft that delivered cargo to the ISS. The commercial launch has reduced the cost to the ISS by a factor of 4. Other launches to space were reduced by the factor of 20. (Jones, 2018). Additionally, since 2011, the Centre for the Advancement of Science in Space (CASIS) manages 50% of launches and 50% of scientific and operational activities of the national lab. NASA delegated its control over ISS to the intermediary organisation and CASIS is now like a broker between the NASA and potential commercial companies. NASA focuses more on their role to support the right foundation for new emerging markets. They want to create a new market, which focuses on a sustainable LEO economy. To catalyse private investments, NASA created new procurement procedures to enhance the commercial market. With the various changes within the space programmes, a transformation of NASA occurred, from controlling to delegating and guiding into the right direction. Private companies are increasingly responsible for the direction of technology development and therefore an active private space sector is created in the US. (Robinson, Mazzucato, 2019).

In 2017, the Commercial Smallsat Data Acquisition programme was established by NASAs Earth Science Division. With this programme, Earth observation data from commercial small-satellites are identified, evaluated and acquired, which contributes to NASAs Earth science research. Satellite providers like Planet, Spire, Maxar, Teledyne Brown Engineering, Inc., deliver commercial datasets. NASAs research can be augmented and complemented with this cost-effective way of acquiring new data. This programme established data management processes and systems for rapid evaluations and for long-term preservation of data. A continuous usage of these datasets is possible by disseminating the information to the NASA scientific community. Data is available for national researchers and when data is relevant for NASAs research, it will be purchased by the space agency. (NASA, 2021, February 12). This space program is an example, that shows the delegation of competences from NASAs research regarding earth observation to commercial actors.

According to the Strategic Plan 2018, NASA has more than 1,200 domestic agreements with US industry and other private sector entities, which support NASAs missions in various ways. Private actors are incorporated into NASAs core mission because the agency needs its capabilities, and it is an opportunity to support the US economy and competitiveness. Additionally, "NASA has over 900 active interagency agreements with the US government departments and other agencies as well as more than 800 active international agreements." (NASA, 2018, p 33). After a final agreement, the partnership is being assessed, to determine how beneficial the agreement was to obtaining NASAs goals. (NASA, 2018, p 32 et seq.).

NASA also highlights the importance of the commercialization within their Science Strategy 2020-2024. Commercial and international cooperation is necessary for the scientific exploration of the Moon and the future missions to Mars. NASA intends to displace fundamental research to the commercial market with various programmes. For example, the Science Mission Directorate hosts science instruments on commercial satellites and have therefore lower-cost access to space. Earth science has also engaged with non-traditional partners like NGOs or others in the industry, like the Conservation International, Google, Microsoft etc. NASA works in tandem with private actors from various sectors. (NASA, 2022c).

### 4.3.3 Comparison

Several companies have discovered the possibilities of outer space and are therefore engaging increasing in this industrial sector. Commercial space companies have a widely shared goal of a large-scale, largely self-sufficient and developed space economy. (Weinzierl, 2019, p 174).

Nevertheless, to achieve such advanced stage of space economy, various developments and technical advantages are necessary.

The potential of commercial activities has been recognised by both space agencies. Due to the fact, that NASA is an older agency, it has a leading advantage, regarding the cooperation with commercial partners. Additionally, one must remember, that the biggest private space companies are located in the US. Nevertheless, both companies support as well as benefit from commercial space activities in different ways, which are compared in the following subcreteria:

*Objective and policies*

To support the commercial actors, ESA and NASA set different objectives and policies.

At the beginning of the space agencies, both agencies focus on developing space technology and launch satellites by themselves. With time, their changed their approaches. ESA has the goal to become a competitive actor in the global space sector, whereas NASA has the goal to support and guide the emerging market into the right direction. The numerous cooperation of NASA and the US private companies enhance the US economy and their competitiveness. Due to their different objectives, the policies of the space agencies also vary. NASA has more market-driven innovation policies, whereas ESA has a challenge-driven innovation policy (Robinson, Mazzucato, 2019).

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*Collaboration*

ESA and NASA are connecting and interlinking with academia as well as the industrial sector. They recognised the importance to combine the different input from science and economy. For example, scientific instruments can be found on commercial satellites.

Both agencies have established public-private partnerships in which they bear the risks of the projects and support the companies with their technical know-how. These kind of partnerships are often used for large-scale programmes and innovative developments, which would be too risky for individual companies.

Furthermore, the space agencies support companies from different industrial sectors in various ways. The ESA assists and encourages many European companies by creating the networks, funding possibilities, legal advice, business coaching etc. ESA is actively engaging with the European space industry to build an interconnected space market in Europe. NASA also supports companies, but delegates more its services to private companies and becomes a customer. Instead of providing services itself, it focuses more on guiding the whole US space market into a specific direction with definite programmes and missions. For instance, NASA delegated its control over the ISS to CASIS. The two approaches are quite different, as ESA engages actively into the space economy, whereas NASA guides more the space economy.

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*Shift of risks*

Nevertheless, in both agencies one can see a shift of risks from the space agencies to the private actors. Private actors have more freedom to include their innovative ideas into the new supporting structure of the ESA and NASA, than few decades before. They are now more responsible for their technological developments.

It can be assumed, that ESA and NASA act similar, due to the fact, that the space industry is a global market and that private actors do not differ so much from each other. Minor variations can be found only at the organisational level of the agencies. For instance, ESA and NASA focus on their own regions – ESA on the European private companies whereas NASA focus on the US private companies. Nevertheless, it can be assumed, that when NASA is only a customer and not a partner itself, the freedom of the private actors is greater, than in the different ESA partnerships. Therefore, the risks are shifted more in the US space economy.

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*Data accessibility*

Other small differences can be found in the degree of open data access of satellite data. Earth observation data which is acquired by ESA is open access to anyone on the planet, whereas data, which is acquired by NASA is free to use for NASA-funded researchers and all US Government-funded researchers. This difference could be possibly explained by the different organisational structure of the agencies, as NASA is a national space agency, whereas ESA is not part of one single country and therefore doesn't limit the access to the datasets of the Earth observation satellites to researchers from certain countries.

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## 4.4 Environment

For a long time, environmental aspects were not considered important, as technological development, research and strategic superiority were in the forefront. With the expanding space activities, the environment on Earth and in Outer Space becomes more and more relevant.
The construction of launch sites, spaceports or other space infrastructure affects environmentally the ground and the surrounding. During launches, thousands of tonnes of $CO_2$ and other emissions, such as discharge fuel, are released into the air and into the ground or the oceans. With the decreased launching costs, more satellites can be found in the LEO. The high number of satellites increases the possibility of collisions between those satellites, which would cause space debris. Such a space debris has a high velocity and is therefore a realistic threat for any other space object in LEO. Such orbital debris is not only dangerous for existing space objects, but also hinders the access to space. (Klinger, 2019). All the different actors, space agencies, international and regional organizations, private companies, need to find a sustainable approach as they all use the same environment. Long-term sustainability is necessary for the safety and security of future space activities as well as for Outer Space itself. (Brachet, 2012).
Outer Space has a unique environment, which differs extremely from the environment on Earth. It is extreme, because it has no atmosphere, no gravity, high and low temperatures, high pressure and many other dangers. Additionally, it is also very fragile, as is doesn't have a self-sustaining ecosystem and renewable resources. Increasing human space activities will impact the existing space environment. (Fabrykowska, 2020, Mendenhall, 2018). Space activities affect various areas of the space environment. Nowadays, orbits from planets and moons are used by satellites, whereas robots collect scientific samples from the surface of the celestial bodies. Future plans envision a permanent moon base (a long-term goal of the Artemis program) (NASA, 2022a), possibilities to benefit from various resources, such as mining minerals, collecting solar power from the sun, to space tourism and space hotels (Zubrin, 2019). It can be assumed, that the scope and the perspective of space resources will advance quickly in the next few years. (ESA, 2019a, p 4).
Till now, the technological developments are not feasible for the futuristic ideas, but with the increasing progress from international, national and private actors, it is imaginable, that with time, these goals will be achieved. With the ongoing developments and new achievements, one should not only think about the benefits for humans and profit for companies, but also think about the existing environment. The space environment should not be overlooked, as it should

not have the same destiny as the Earths environment. It is essential to tackle the current problems in the early stages, and not when it is too late.

### 4.4.1 ESA

ESA declares itself as “a socially responsible organisation as it takes into maximum consideration the needs of future generations with respect to the sustainability of its activities towards the environment, economy, and society.” (ESA, 2022k). The Corporate Social Responsibility principles of ESA influence the programmes and space activities through specific sustainable measures and creates therefore a more sustainable and responsible space sector. ESA focuses on sustainable developments as they want to create a low-carbon and climate resilient space economy in Europe. ESA-led space projects and missions are ethical and beneficial to society and expands the possibilities of technology and knowledge. (ibid). Beside the CSR principles, ESA also established an ESA Green Agenda (EGA), which supports the objectives of ESAs Agenda 2025. The goals to reduce greenhouse gas emissions, preserve biodiversity, human health and resource scarcity are incorporated into the EGA. The space agency wants to increase its sustainable development and reduce its environmental footprint through various activities in the different areas: sustainable strategies for projects, life cycle assessments and Eco-Designs, facility and asset management, procurement and supply chain and culture and ways of working. (ESA, 2022i).
ESA was one of the first, who introduced sustainable plans for space activities, especially for the long-term activities. The sustainable usage of resources and orbits has become a prime concern of several economic actors, such as earth observation and navigation businesses as well as telecommunication businesses. Additionally, the technological advancements should lead to a clean space environment. For this reason, with the Greensat programme, space missions are undergoing life cycle assessments for the reason to understand better the environmental impacts of launch vehicles or the ecological footprints of satellites. With the eco-design of each space mission, ESA can identify environmental challenges and create new innovative and greener solutions for the environmental problems. More environmentally friendly missions will be created with greener materials and processes for the production of spacecrafts as well as greener ways to manage the missions’ operations. The focus of Greensat lies on the Earth impact, as other programmes focus on protecting other parts of outer space. (ESA, 2017, February 28).

Additionally, ESA has a materiality matrix, where it identifies the principal sustainability aspects and environmental concerns of space missions, as well as environmental impact of sites and infrastructure. It also includes the contribution to environment monitoring and protection. (ESA, 2022j).
One of the most important challenges that is highlighted by the ESA, is space debris. Through various measures, such as end-of-life disposal orbits, passivation and design for demise, ESA wants to mitigate space debris. Since the mid-1990s ESA has to perform collision avoidance manoeuvres for European satellites in the LEO, approximately 12 manoeuvres a year. For the conjunction predictions, ESA uses its own data as well as the data from the US Joint Space Operation Center. (ESA, 2022n, ESA, 2022s).
With the Cleansat initiative, ESA wants to mitigate space debris. Future components of satellites, hardware and other space objects have to conform with the Design for demise, when they de-orbit after their final utilisation. Satellite structures and hardware parts, such as batteries need to completely burn up during their reentry into atmosphere. (ROOM, 2016). Furthermore, more sustainable ways are necessary for the removal for old satellites. For this reason, ESA plans the Clearspace-1 mission, which is the first mission, that will remove a 112 kg inactive rocket piece of space debris from its orbit. It is planned to be launched in 2026. (ESA, 2022b). With such measures, ESA wants to actively clean up the space environment, especially the LEO. It also focuses on advancing technologies for image processing, proximity guidance, navigation, etc. for future active debris removal. The focus on space debris is important for future space activities and the management of space-related traffic. (ESA, 2019c, p 23, p 38). Additionally, the European Commission supports an EU approach for space traffic management to preserve the safety and security for orbital traffic and space sustainability for the Member States. (EC, 2022).
Furthermore, ESA has other projects, that helps to clean up other places on Earth, such as the oceans. With the ESA Glob Current project, satellite data can provide information about the oceans surface and the existing litter. (ESA, 2017, February 9). Through other projects, like the Climate Change Initiative, ESA provides satellite data with several components of the dynamic climate system. (ESA, 2022l)
Sustainable developments are not only important for science missions, but also for the three main exploration missions regarding LEO, Moon and Mars. Technologies, such as propulsion, life support, navigation, energy, and in-situ resource utilizations, need innovative and sustainable concepts for future space missions. (ESA, 2019c, p 37). Overall, within the technology strategy 2019, ESA had the goal that by 2020 all ESA missions will be

environmentally neutral, so they don't produce debris larger than 1 mm in orbit, by 2024 there will be developed technologies for active removal of space debris and by 2030, all ESA missions will be risk neutral. (ESA, 2019c, p 26 et seq). Till now, there is no update regarding these envisioned goals.

Beside the environmental issues, ESA also understands the importance of the short-, medium and long term utilisation of resources in space. Due to the expanding resource scarcity on Earth, a sustainable approach regarding the resources in Outer Space becomes more and more important as the cost of access decreases. A multidisciplinary approach is necessary for space and non-space, science and industry, public and private actors with diverging interests on its own.

New approaches how to use resources sustainable and technological innovation can lead to better management of the resources on Earth. ESA wants to use for space exploration the In Situ Resource Utilisation (ISRU) approach. This practice intends to use the existing resources on space objects to manufacture objects for living and working in space. For example, ESA uses solar radiation for the production of power for their space activities. The advancement of the ISRU on the Moon is prioritised by ESA. They assume, that the local resources at the Moon can be used for propellants, life support consumables, metals and materials for in situ manufacturing and in the long-term for extraction of specific metals for economic reasons. Space resources should be used for future missions and their missions architecture. (ESA, 2019a).

ESAs endeavours to be more sustainable and have sustainable activities and developments can also be seen on an international level. ESA has several measures that are specifically related to the international Sustainable Development Goals (SDGs). For each of these 17 SDGs, ESA has from two to ten different projects and programmes that realize the international goals. (ESA, 2022f). Additionally, ESA also cooperates with other space agencies and economic partners on a broader and international level, for better results. This approach is fundamental, as many climate issues are global and can be best solved in collaboration. Another international project that can be used as an example and where ESA is a partner, is the global exploration roadmap, which focus on a sustainable strategy for human exploration with the cooperation of different space agencies. (Laurini, Gerstenmaier, 2014).

### 4.4.2 NASA

In 1969 the National Environmental Policy Act (NEPA) was enacted. Federal agencies need to consider environmental factors during their decision processes, involve the affected into the environmental-analysis process and minimize environmental damages during their activities. All agencies of the Federal Government are obliged to make their decisions through a systematic and multi-disciplinary approach by using natural and social sciences and environmental design arts to review projects. (NASA, 2020, July 2). In regard to NEPA, NASA conducts several analyses of their space activities and future projects, such as Environmental Assessments or Environmental Impact Statements. These measurements integrate environmental consideration at an early stage, review and analyse alternative ways, ensure, that environmental, technical, and economical considerations are weighed during any decision making process, and that the public is aware of the environmental consequences. Additionally, beside the federal law, NASA implemented an Environmental Management System (EMS), and it verifies compliances through Environmental Functional Reviews (EFR) each agency centre every 3 years. The EMS is an overall agency approach to manage environmental activities and improve NASAs environmental performance and maintain a good compliance with environmental regulations. The EFR supports NASAs environmental compliance as a management tool for NASAs Centers. These procedures are important for the measurement of an effective implementation of NASAs environmental goals. (NASA, 2019, September 6).

NASA has an Environmental Management Division (EMD), which is responsible for the leadership and guidance on environmental issues at NASA. It oversees the institutional and programmatic requirements for environmental and sustainable developments and establishes policies regarding environmental planning, restoration, pollution prevention, energy and water conservation as well as natural, cultural and historic resource preservation. (NASA, 2019a, July 24).

NASA has a sustainability policy, which tries "to execute NASAs missions without compromising the planets resources so that future generation can meet their needs". NASA has 13 sustainability objectives, which focus on energy efficiency and renewable energy, reduction of greenhouse gas emissions, protection of water resources, elimination of waste and prevention of pollution, support of sustainable technologies and markets growth, creation and operation of sustainable buildings, improvement of the power management, as well as mitigation of climate change risks. With this long-term sustainability goals, NASA uses public funds efficiently and effectively. (NASA, 2019b, July 24).

In 2018, President Trump signed an Executive Order[2], which stated, that all Federal agencies have to provide a report how their implement and achieve their sustainability goals. NASA provided 2020 a Sustainability Report and Implementation Plan. (NASA, 2020, November 18). NASAs report focused closely to their sustainability objectives, mainly facility energy efficiency, renewable energy, water efficiency, high performance sustainable buildings, waste management, transportation as well as electronic management and reduction of greenhouse emissions. For instance, solar photovoltaic panels were incorporated into the different space agencies buildings to have a better energy efficiency as well as renewable energy. (NASA, 2020c). Additionally, President Biden signed in 2021 an Executive Order[3], that Federal agencies must provide climate action plans (CAP). Within these CAPs the agencies have to outline their efforts and actions to reduce the climate change effects. The CAPs should also address climate vulnerabilities and create climate-resilient facilities and supply chains. (NASA, 2022b). With this CAP, NASA revised and modified its space activities in regard to the climate change effects. For instance, NASA has to nourish beaches at their facility, especially near their launch sites, to maintain access to space. Rising sea levels due to climate change and higher water levels during storms affect NASAs facilities. Around 80 percent of NASAs infrastructure is more than 40 years old and not prepared for climate changes. NASA tries to become less vulnerable to climate changes and develops new climate models and new climate risk management tools to access climate change better. (NASA, 2021a).
Beside the different plans for sustainable developments, NASA already has several areas and projects that focus on sustainability. NASA has a greenhouse gas programme, which analyses and evaluates the greenhouse gas emissions at NASAs sites. Greenhouse gas emissions are being reduced by a lower energy usage and more renewable energy usage. Over the last 10 years, the emissions declined 37,6%. NASA also protects natural resources and wildlife on Earth through different partnerships and projects. For instance, NASA provides its land for the preservation of an endangered chicken species. As NASAs sites are located in diverse ecosystems, from deserts to coasts, it also protects endangered and threatened plants and animal species. (NASA, 2021, December 3). Additionally, NASA has a clean-up and restoration programme, which cleans up chemicals, such as trichloroethylene (TCE) that have been released into the environment during space activities.  NASA also focus on developing

[2] Executive Order 13834.
[3] Executive Order 14008.

innovative technologies, such as chemical substitutes, alternative primers and coatings as well as improve lead-free solder for the usage in future space missions. (NASA, 2021, February 4). For their space activities, especially for the return to the Moon, NASA also plans to generate products with local materials and therefore using the practice of in-situ resource utilization. NASA focuses on sustainable infrastructure, as ISRU will become increasingly important for any future space mission. For the development of ISRU technology, NASA uses not only in-house engineering skills, but also engages with industry and academia through various opportunities, such as public-private partnerships, fellowships etc. (NASA, 2020, April 3).

Regarding space debris, NASA and the US Department of Defense created a detailed catalogue of objects in Earth orbits. Furthermore, NASA established a conjunction assessment with debris avoidance manoeuvres as well as a collision avoidance process for human spaceflight. The US Space Force works together with NASA to perform these conjunction assessments for all NASA space assets. NASA is responsible for the decision when and where a collision manoeuvre is necessary. (NASA, 2021, May 26). This can be seen as a space traffic awareness, where debris is detected. If this debris belongs to another country, NASA or the Space Force have to report the possible collision, but have no authority to prevent the collision. NASA doesn't have its own space traffic management system, there are only concepts about a possible system in the future. (Foust, 2021).

NASA commits to a global environmental stewardship and therefore collaborates on different international projects. For example, NASA and ESA study the dense African tropical forest in Gabon. Data collected from the forest can be used for several space activities and future space missions and it can help to inform policy makers about possible climate mitigation and forest conservation policies. (Vinas, 2016). Additionally, NASA is also partner of the global exploration roadmap and it reflects NASAs commitment to work collaboratively with other space agency partners on a sustainable and implementable strategy for human exploration. (Laurini, Gerstenmaier, 2014).

### 4.4.3 Comparison

Both space agencies are looking for more sustainable ways for their space activities. At the first glance, both space agencies want to enhance more sustainable space activities, but on a closer look, one can find various differences, with this following subdimensions:

*Environmental vision*

ESA focuses on more sustainable activities in space and tries to help with space activities, such as satellite data, to improve the environment on Earth. Space activities are developed to be more sustainable, and the environmental footprint is being reduced by a more sustainable facility and asset management. The space agency wants to act responsible towards the environment, economy and society. It focuses on innovative and green ideas to increase sustainable developments. ESA has Corporate Social Responsibility principles and a Green Agenda, which support the existing ESA Agenda. Since 2016, ESA publishes voluntarily an annual Space Environment Report, which provides an overview of the global space activities and the space debris mitigation measures. (ESA Space Debris, 2022).

NASA doesn't want to compromise the planets resources and needs therefore sustainable measures. It seems as if many of their sustainable measure focus more on NASAs facilities and launch sites, than on the space activities themselves. For example, NASA highlights the improvement in their energy management through solar panels or the protection of wildlife at their sites. For their sustainable developments, they also focus on innovative and green ideas. With the different Sustainability plans and Climate action plans NASA has to justify their fundings as a federal agency.

ESA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | O | X | O | O |

NASA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | X | O | O | O |

*Measures and cooperation*

Both space agencies use similar measures and processes to evaluate sustainable actions. Environmental assessments, life cycle assessments and eco-designs for the different space activities can be found at ESA and NASA. Additionally, both agencies cooperate with the economy and academia to create innovative and sustainable solutions through various projects and programmes. With their investment in the economy through various collaborations, they want to establish a greener space economy. ESA and NASA also created a new strategic partnership between them to better understand climate change. Nevertheless, ESA and NASA already collaborated on several missions regarding environmental issues. (ESA, 2021 July 13). Furthermore, international cooperation is essential for both space agencies. Both are partners in the global exploration roadmap, which focuses on the sustainable development of the future space missions. Although both space agencies fulfill several international SDGs, only ESA has presented coherently all their programmes that correspond to the 17 SDGs.

ESA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | O | X | O | O |

NASA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | X | O | O | O |

*Sustainable activities*

Space exploration, usage of resources as well as climate change are the main activities that are compared in this thesis. Regarding climate change, both agencies try to become more resilient to the changes of the climate. It seems, that the climate changes impact the different Centers of NASA more. The reason could be, that NASA has more launching sites and Centres than ESA or the requirement of NASA to present a Climate Action Plan. Additionally, NASA has more old buildings than ESA and needs to enhance them to be more climate neutral. ESA doesn’t

focus their main climate change activities on their facilities. Nevertheless, both agencies use their satellites to provide data about the climate system. NASA sustainability activities focus more often on their facilities and the surrounding than on the space activities in space itself. ESA emphasize their sustainability activities more on the space activities and their programmes.
The understanding of the usage of resources is similar. Both space agencies want to use their resources responsible and develop sustainable exploration through sustainable infrastructure, especially through In-situ resource utilization.

ESA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | O | X | O | O |

NASA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | X | O | O | O |

*Space debris*

One of the main differences can be seen in the approach regarding space debris. Both space agencies highlight the importance and danger of space debris. ESA and NASA have debris avoidance systems. For NASA, conjunction predictions and avoidance manoeuvres are sufficient to mitigate space debris. ESA goes a step further and wants to start actively removing space debris from the orbits. The Cleansat-1 mission is one of its kind and is a new approach towards the problem of space debris. The approach of Design of demise is rarely used by NASA, rather by ESA. A space traffic management is supported in the EU and ESA. ESA emphasized the importance of such a management system. NASA also highlights the importance and there are already discussions about it, but till now, in both agencies, this idea is in its early stage.

ESA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | O | O | X | O |

NASA

| Does not apply (0) | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | Does fully apply (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| O | O | O | O | O | O | O | X | O | O | O |

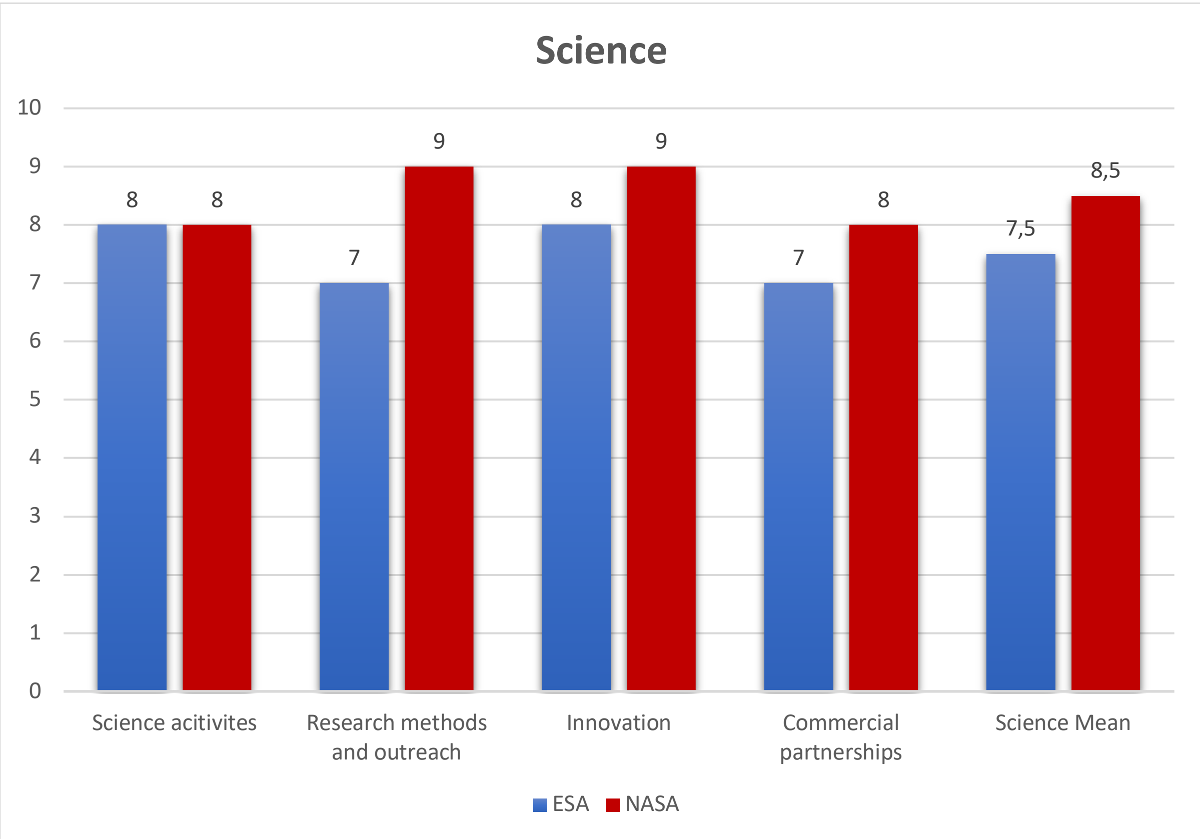
# 5 Assessment of the ESA and NASA in relation to the four dimensions

The previous section presented an in-depth analysis of four different aspects, namely Science, Military, Economy and Environment. These four dimensions are essential, as they represent the political self-understanding of the two space agencies and impact therefore the policies of the ESA and NASA. This section demonstrates the outcomes of the analysis, divided into the four dimensions and further subdimensions and interpret the results.

## 5.1 Science

In the section science, several subdimensions were analysed during the analysis: the existing kind of science activities in the two space agencies, which kind of research methods are primarily used for research and development, how scientists and the community is engaged in space activities, how important are innovative ideas for both space agencies as well as how much do commercial actors cooperate in scientific activities at ESA and NASA. Figure 2 presents the summarized results of the analysis of the scientific dimension:

*Figure 2: Comparison of the scientific dimension of ESA and NASA*



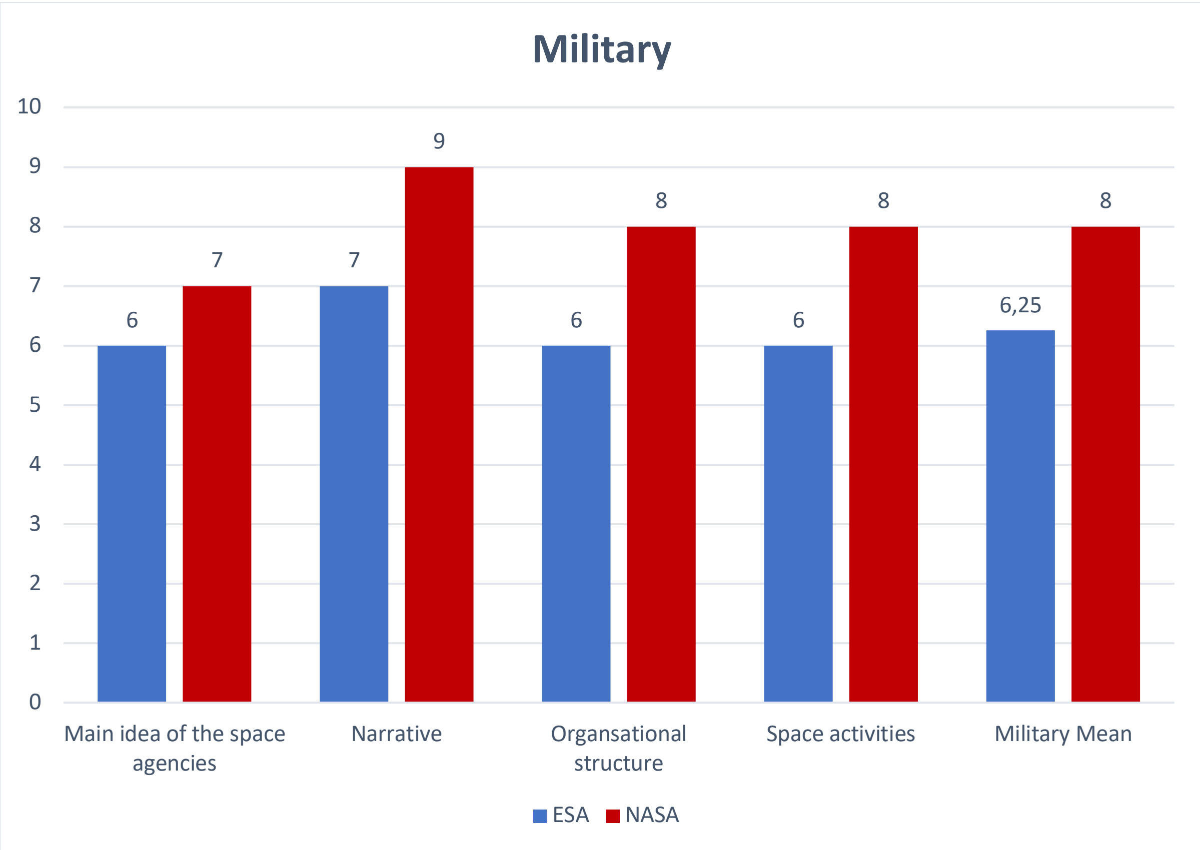

*Source: own analysis.*

Regarding the first hypothesis (*H1: NASA focus their future projects more on research development than ESA*), it is now clear, after analysing the different strategy papers of the ESA and NASA, that both agencies focus strongly on science and research, but NASA has more possibilities regarding their scientific research.

## 5.2 Military

In the section military, the subdimensions regarding the main idea of the creation of the space agencies, the narrative, if and how military activities are important and interconnected to the space agencies, as well as the organizational structure of the different space agencies and current military space activities were analysed. Figure 3 presents the summarized results of the analysis of the military dimension:

*Figure 3: Comparison of the military dimension of ESA and NASA*



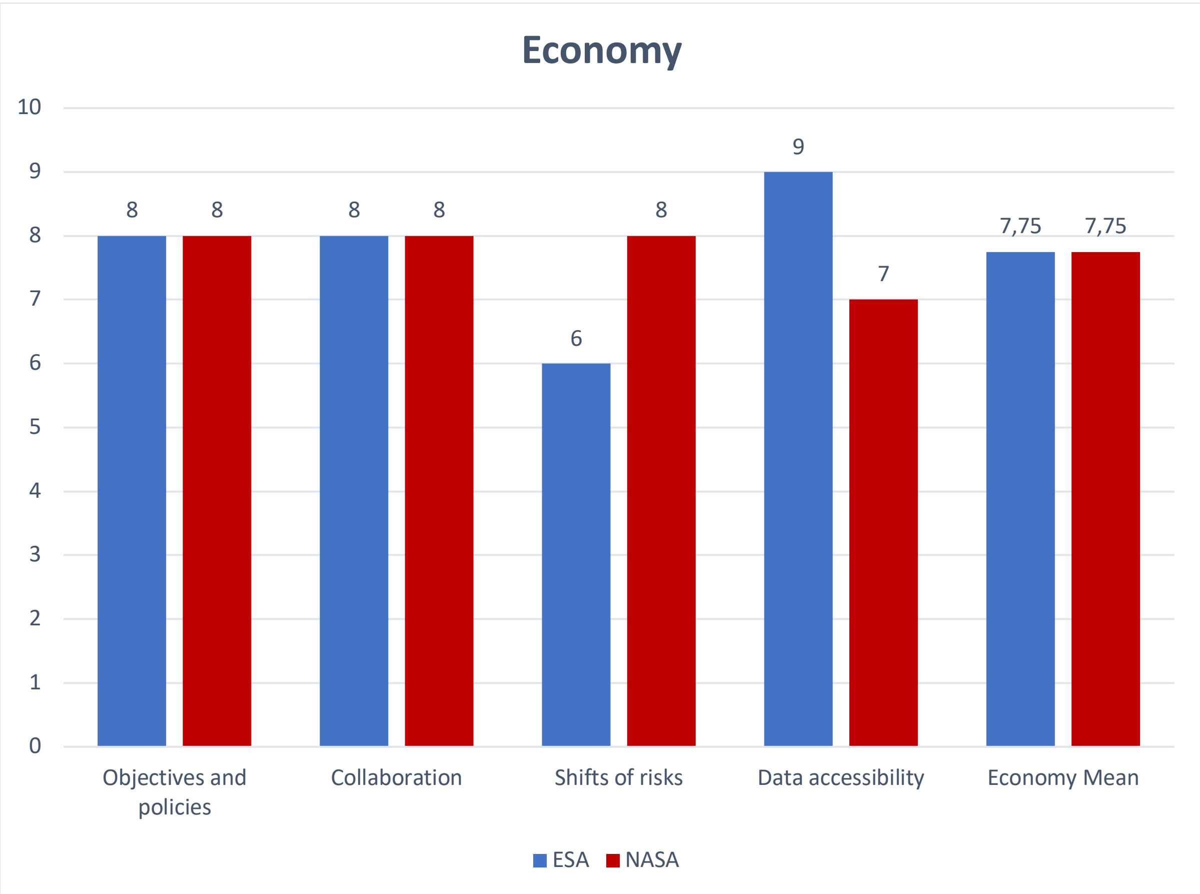

*Source: own analysis.*

Regarding the second hypothesis (*H2: NASAs strategies focus more in strategic/military projects than the ESA*.), it can be stated, that there are no main strategies of NASA and ESA regarding military activities, but mainly due to the organisational structure and the narrative, NASA is focusing more on military activities than the ESA.

## 5.3 Economy

In the section economy, the subdimensions regarding the space agencies objectives and policies regarding the economic partners were analysed, as well as the ongoing collaborations, programmes and projects with commercial companies. Additionally, it was also analysed the existing shift of risks from the space agencies to the commercial companies as well as the accessibility of datasets, which can be used for other commercial purposes. Figure 4 presents the following results of the analysis of the economical dimension:

*Figure 4: Comparison of the economical dimension of ESA and NASA*



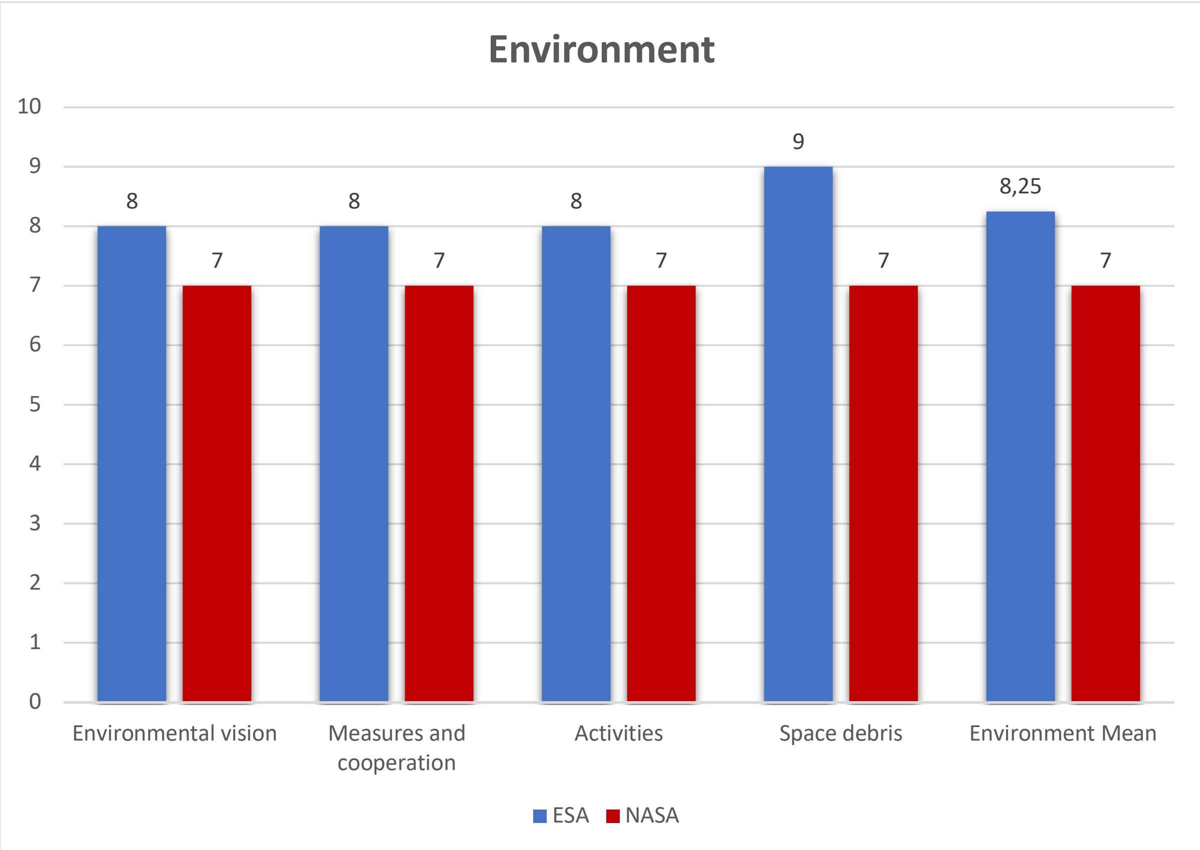

*Source: own analysis.*

Regarding the third hypothesis (*H3: NASA is more economically oriented and works more active with private companies than the ESA.*), it can be stated, that both space agencies are oriented towards a commercialisation of space, even though there are minor differences in the realization and fulfillment of the commercialisation of outer space.

## 5.4 Environment

In the section ecology, ESA and NASA were analysed regarding their environmental vision in their current policies as well as the existing legal binding and non-binding environmental measures and possible cooperation with commercial partners. Additionally different sustainable activities and especially space debris were analysed and compared. Figure 5 presents the following results of the analysis of the environmental dimension:

*Figure 5: Comparison of the environmental dimension of ESA and NASA*




*Source: own analysis.*

Regarding the fourth hypothesis (*H4: NASA is less cautious when it comes to the environmental impacts of space activities than ESA.*) it is now clear, that both space agencies focus on environmental and sustainable space activities. Nevertheless, ESA has a more proactive approach regarding their space activities than NASA, for example in regard to the space debris problem.

# 6 Discussion of the four hypotheses in relation to the four dimensions and the future directions of NASA and ESA

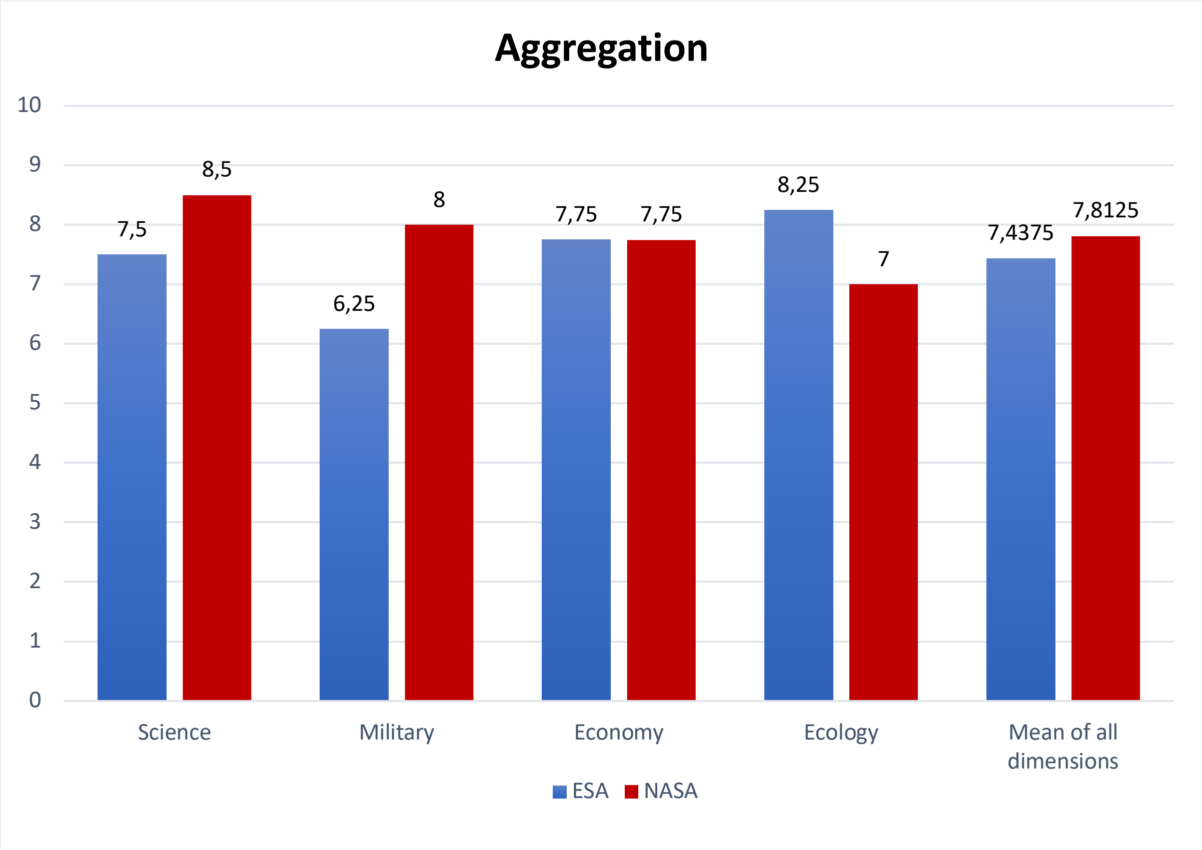
ESA and NASA are two space agencies, one situated in Europe, the other one in the United States of America. On the first glance, one could say, that both space agencies are the same, as they both focus on space activities. Nevertheless, when one look closer, one can see various differences as well as similarities. The comparison of these two space agencies shows how different institutions can be established although they have similar activities and interlinked operations.

## 6.1 Aggregation of the four dimensions

The four dimensions with its subdimensions show just a small part of the space activities of the ESA and NASA. Its noteworthy, that this master thesis could only present an overview as well as only a few details, which were highlighted by the space agencies themselves in their recent policy papers and on their websites. This comparison can't be seen as an all-inclusive comparison, as too many space programmes and details were intentionally left out, because it would go beyond the scope of this thesis. Nevertheless, through the aggregation, some basic assumptions were possible to conclude. Interlinkages between commercial actors and science, environment and military are visible. To summarize the different dimensions, an overview of the comparison is helpful for future in-depth research.

Figure 6 presents the aggregation of the four dimensions and the overall comparison of the ESA and NASA. It is understandable, that ESA has totally less points than NASA, as it is a younger space agency, and it doesn't have the same advantages of NASA. NASA has long experience in space activities, longer cooperation and is better established within the space sector. It also has the advantage of the space market, as most recent developments such as SpaceX reusage rockets were created in the US. Nevertheless, the ESA is not far behind, as it has similar activities.

*Figure 6: Aggregation  of the four dimensions of ESA and NASA*




*Source: own analysis.*

This aggregation can be used to answer the main research question: *"To what extent do the two space agencies, National Aeronautics and Space Administration (NASA) and European Space Agency (ESA), differ or are the same regarding their current space policies in reference to the following four dimensions: science, military, economy and environment?".* It presents the comparison of the four dimensions and leads to the following outcome: NASA has better policies, developments and space activities in the field of science and military, whereas ESA has better policies and developments in the field of sustainability and environmental understanding. Economic aspects seem to be equally strong developed in both space agencies. ESA and NASA focus their policies similarly on the development of the space economy, even though their approaches differ. Interlinkages of the commercial actors can be found in both space agencies. They include commercial companies in all four dimensions. Through the analysis of the different policies and other documents, it can be stated, that ESA and NASA have similar goals, as both space agencies cover all four dimensions, but the strategies and approaches may differ in several aspects, which lead to fine differences. Nevertheless, the divergences are not widely apart. The reason for this varies from the historical developments, organizational structures, political influence and other attributes.

## 6.2 Science

The first hypothesis focuses on the field of science, research and development: H1: NASA focus their future projects more on research development than ESA.

Both agencies present science as one of the most important topics as it is directly or indirectly mentioned in their overall mission. ESA and NASA have a similar overall mission: ESA wants to deliver benefits to the citizen of Europe and the world, whereas NASA wants to discover and expand knowledge for the benefit of humanity. Benefits can be delivered through science by knowledge production and knowledge application. ESA refers to science indirectly, whereas NASA states explicitly in their mission, that they want to expand knowledge.

It is interesting, that both space agencies have a broad and global point of view in their missions as they both mentions humanity and the world. Nevertheless, in more detail, each space agency focuses on their own locations – ESA on citizens in Europe, and NASA on their citizens in the US.

The differences within the organizational structure should not be overlooked. NASA is an institution of the American government, whereas ESA is an independent organization. This structure presents several advantages and disadvantages. NASA has easier access to other federal institutions, their data and the public. Collaborations are well developed, duplications are minimized, knowledge exchange happens on a daily basis. However, NASA is strictly bound to the yearly reporting and must justify their funds. Fundings as well as visions where NASA should go next depend on political decision. Innovative developments can be cut due to a political decision. Over the last few decades, the budget of NASA decreased steadily, and the goals changed depending on the President and its directives.

ESA has several financing sources, even though it is far less than the NASA gets. There are also ongoing problems with duplications of developments and research, as there are many different space actors in Europe. Appropriate funding, possible collaborations and correct project management without duplications are essential for any research project, especially in the space sector, as it is very cost-intensive.

From this comparison, it seems that NASA has a better outreach to the public than ESA, as they create more events for the public and established a citizens-based science.

It can be assumed, that ESA will focus in the future on a smoothly and fluently coordination of the different space actors and that this multidimensional approach will influence the scientific outcomes of the space agency. NASAs future science projects will depend on the political will and budget.

## 6.3 Military

The second hypothesis focuses on the topic of military and security issues: H2: NASAs strategies focus more in strategic/military projects than the ESA. The main idea of the creation of the space agencies as well as the narrative play an important role within the military dimension. NASA needs to be a leader within the space sector as it is also part of their national security. NASAs success affects not only the US national security and military, but also the US economy. This can be linked to the classical geopolitical theory, where states were the only actors in space, and they needed to show their power in space. NASA executes the political will of the US and through NASA the US can expand its power to Outer Space.

ESA acts differently, because it wants, in cooperation with the EU and the member states, become more independent, as it has less capabilities than NASA. NASA had many years to establish and improve their leading position in the space sector, whereas ESA is slowly growing over the last few decades. The ESA can't have a classical geopolitical understanding, as it doesn't represent one single country, but rather multiple interests. The European space power comes from a collaboration and combination from various entities, the EU, the member states, the ESA itself. The ESA want to be part of the space sector and not the leading part. ESA focuses on their space activities to create European autonomy, which should be independent from other systems of other countries. Nevertheless, this is not easily achieved, as there is a mixture of different space strategies and interests from various parties.

National space agencies, the EU, the ESA and other organization collaborate but not evenly.

A good management of the different collaborations is essential in Europe. Each organization and agency have its own visions and interests and it can be hard to combine them together as one. ESA has to identify the strength and weaknesses of each stakeholder and fill strategic gaps in order to get the best results. The harmonization of the different interests and establishing compromises is time-consuming and influences the internal bureaucratic system within the ESA. The vision of ESA is clear, even though it is difficult to achieve, as there are many interests from other parties involved. A common vision among the different parties is missing in Europe. This missing common vision is one of the greatest deficiencies of the ESA. The ESA is not impacted by the political decision of one Government, but many, as there are different members within the ESA. This difference was mainly illustrated in the dimension of science and military. It can be concluded that ESA will focus in the nearest future on their differences within the various political levels, whereas NASA will try to expand their power in space and present it as their achievement and therefore try to remain undisputable the only leader in Outer Space.

## 6.4 Economy

The third hypothesis focuses on the field of economy, commercial support and the development of the space economy: H3: NASA is more economically oriented and works more active with private companies than the ESA. Both space agencies have recognized the importance of the space economy. Commercial partners are becoming more and more important for both space agencies. ESA collaborates with several commercial partners and actively supports the commercial space market through various opportunities and support systems, such as specific networks or fundings. It wants to invest in the space economy and grow together with it. NASA goes a step further and doesn't only support commercial companies and include them into their space activities, but also acts as a customer. It wants to lead the US space economy into the right direction. It seems that NASA has more a leading role, whereas ESA has more of a supportive role.

Due to the ongoing technological developments and the enhanced involvement of commercial companies, the responsibilities also changed. ESA as well as NASA present through their activities a shift of risks, where companies become more and more reliable for their products and activities in space. This similarity is relevant, as is shows a development which seems to be typical for the space sector. Both space agency focuses their policies on the space economy, as they can benefit from the commercial developments. Interlinkages between the space economy and other fields can be found in the different dimensions. In all four dimensions, commercial partnerships are essential for the development of the ESA and NASA. There is no dimension, where the space agencies don't want to cooperate with commercial actors.

With the shift or risks, commercial companies get more and more influence within the space sector. With their influence the current existing power relation, especially when it comes to space-based technologies and satellite-based data, may change. Due to the separation of the different space activities between the space agencies and the commercial companies, it could be, that future inequalities will be distributed on other areas. Further economic developments may change the existing inequalities. For both space agencies, the LEO is an important area. NASA wants to maintain a constant human presence in LEO and enhance the commercial market. As the space economy focuses mainly on LEO, it is also important for the ESA. Nevertheless, it is also important from an environmental perspective.

From this analysis, it can be assumed, that both space agencies will continue their involvement into the commercial space economy in the future, even though they have different approaches and understanding how to cooperate with commercial actors.

## 6.5 Environment

The fourth hypothesis addresses the topic of environment and sustainability: H4: NASA is less cautious when it comes to the environmental impacts of space activities than ESA. Several information about environmental activities had to be looked up separately. Environmental interlinkages can be found in several policy papers, as it is a topic that overlaps several fields, such as science or economy. Both space agencies incorporate environmental and sustainable activities throughout their different space activities at ground or in space.

NASA is the oldest space agency on Earth, and this can be seen in this comparison. For example, within the environmental dimension, NASA focuses on their facility management and improves it to be more sustainable. The reason for this can be that NASA has several old buildings as well as much more facilities than the ESA.

ESA also understands the importance of the environment and the space economy. Therefore, it is possible that the ESA have a more environmental-friendly and economy-based theoretical understanding of astropolitcs. Nevertheless, ESA and NASA have recognized the importance of environmental aspects. Similar to the theory of global political ecology, both space agencies interlink nature with economy. Various technological developments are interconnected with environmental issues. With their focus on sustainable space activities the space agencies create incentives for a greener space economy. Within the global political ecology, it was highlighted that such incentives led to the creation of markets for more sustainable goods and that these new practices and standards were adopted by the industries. NASA and ESA have therefore an impact on the developing space market conditions. Environmental problems, such as climate change are also presented to the public through various dissemination activities.

It is interesting to see, that ESA has a more active approach regarding space debris than NASA. Both space agencies have conjunction prediction and avoidance manoeuvres, but only ESA actively wants to clean up the LEO. Within its policies and documents NASA focuses more on the environment on Earth and how to create a more sustainable way of living at Earth, like the cleaning of oceans, whereas ESA focuses in their policies more on space activities itself. Maybe there is a correlation to the way how environmental issues are presented. There is no single policy that focuses explicitly on environmental aspects. NASA is obliged to present

yearly reports about their Climate Action Plan or earlier their Sustainability Plan, whereas ESA has no obligation and presents optional environmental reports regarding space debris.
As environmental issues are becoming more and more important, it can be expected, that both space agencies will concentrate their efforts in the future on this topic through various ways.
An essential element, that runs through all four dimensions are the existing international cooperations between the agencies or other actors. International cooperation is important to interconnect and interlink the different activities on Earth and in Space, regardless if it considers science, military, economy or the environment. As NASA and ESA states it in their vision: their work is for humanity and the world.

## 6.6 Limitations and suggestions for further research

This research has several boundaries and limitations. The research question focuses strongly on the four different hypotheses. Other fields and cases could present other outcomes, for instance the relation of the space agencies to foreign politics or specific space programmes. It is possible that specific space programmes have other focuses than the four hypotheses. Nevertheless, the four hypotheses present a basic overview of the most relevant topics for NASA and ESA in their current space policies in 2022.
Additionally, this analysis was tested experimentally, and the methods were mixed with an innovative approach. There is a probability, that the outcomes would differ, when for instance further expert interviews would be conducted. It is also possible, that the researcher interpreted a policy paper in another way than it was intended by the space agencies.
There is also a chance that the space policy papers of the space agency do not present the reality, but rather the desirable goals of ESA and NASA. Therefore, the expert interviews could present a broader overview and deeper insights into the actual work of the space agencies.
A further research could focus on a deeper analysis of the four hypotheses by conducting expert interviews from NASA and ESA. It would present a more adequate picture of both agencies, as it would analyse not only the policy papers but also the actual implementation of it.
The research could be expended on further stakeholders – as commercial companies become more and more important within the space sector, it would be interesting to analyse their perspective on the two agencies and their perception. Innovative approach from the commercial sector could be included into further space activities. With an indepth analysis, the different interlinkages between the various stakeholders could be studied and used for further development of the space agencies.

# 7 Conclusion

As Outer Space becomes increasingly crowded, space politics gains in significance. Space activities are not only conducted by states but also other independent actors such as commercial firms. With the growth of the space activities, different interlinkages to these activities became visible. Outer space is not only used for science and military purposes but also for economic and environmental goals by the different space agencies.

For this reason, this master thesis analysed these four different dimensions with the following research question: "To what extent do the two space agencies, NASA and ESA, differ or are the same regarding their current space policies in reference to the following four dimensions: science, military, economy and environment?" with the corresponding four hypotheses:

- H1: NASA focus their future projects more on research development than ESA.
- H2: NASAs strategies focus more in strategic/military projects than the ESA.
- H3: NASA is more economically oriented and works more active with private companies than the ESA.
- H4: NASA is less cautious when it comes to the environmental impacts of space activities than ESA.

For the analysis of this research question, the conceptional framework presents several relevant political theories, such as knowledge democracy and different geopolitical theories. Classical, critical as well as environmental theories are essential to understand the development of space activities. The methods of this research are explorative and innovative. Beside a literature research and literature review, a comparison is done based on the four dimensions. Furthermore, the results of the literature analysis are rated to obtain a descriptive comparison.

The overall analysis starts with the introduction of both space agencies, their historical background, and their future directions, which are stated in several policy papers. Further on, the analysis goes into detail and analysis the different strategy papers and space programmes of both space agencies in relation on the four different dimensions, science, military, economy and environment. The assessment of the four dimensions shows the following results:

Science and Military are better developed at NASA, whereas ESA has more innovative approaches regarding environmental issues, such as space debris removal. Both space agencies focus strongly on economic aspects and although there are different approaches towards companies, the development and cooperation with commercial actors is equally important for NASA and ESA. International cooperation between the two space agencies as well as other space agencies, states or associations is also equally important for NASA and ESA. The subtle difference can be explained by the different organisational structure, the historical background, the main ideas, narratives as well as the unique setting of both space agencies. The geopolitical theories were interlinked to the different approaches of NASA and ESA.

Overall, NASA scores more points than ESA in the aggregation of all dimensions. This is not really surprising as NASA has a great advantage before ESA, as it conducts way longer space activities and is the leading space agency. Nevertheless, it was interesting that ESA scored more in the environmental topics, as ESA presented new innovative solutions for environmental problems in outer space.

With this research, the different approaches of NASA and ESA regarding the four dimensions were analysed. It also presented several challenges that these space agencies have to deal with. These distinctive approaches, various space programmes and projects as well es the existing challenges within the space agencies were used to present possible future plans of NASA and ESA. Innovation and cooperation are the key for future developments. In the long run, both space agencies reach out for the stars and want to create a better future with their space activities.

# Fazit

Der Weltraum wird zunehmend überfüllt und Weltraumpolitik gewinnt an Wichtigkeit. Weltraumaktivitäten werden nicht nur von Staaten, aber auch von anderen unabhängigen Akteuren, wie kommerzielle Unternehmen, durchgeführt. Mit dem Anstieg der Weltraumaktivitäten, verschiedene Verflechtungen dieser Aktivitäten werden sichtbar. Der Weltraum wird nicht mehr nur für Forschungs- und Militärzwecke verwendet, sondern auch für ökonomische und umweltpolitische Zwecke der verschiedenen Weltraumagenturen.

Aus diesem Grund analysiert die Masterarbeit diese vier verschiedenen Dimensionen mit der folgenden Forschungsfrage: „In welchem Umfang sind die zwei Weltraumagenturen NASA und ESA unterschiedlich oder gleich in deren derzeitigen Weltraum Policies bezugnehmend auf die folgenden vier Dimensionen: Wissenschaft, Militär, Ökonomie, Umwelt?" mit den dazugehörigen vier Hypothesen:

- H1: NASA fokussiert deren zukünftige Projekte mehr auf Forschungsentwicklung als die ESA.
- H2: NASAs Strategien fokussieren mehr auf strategische/militärische Projekte als die ESA.
- H3: NASA ist ökonomisch mehr orientiert und arbeitet aktiver mit den privaten Unternehmen als die ESA.
- H4: NASA ist weniger achtsam wenn es um die Umweltauswirkungen geht als die ESA.

Für die Analyse der Forschungsfrage präsentiert der konzeptionelle Rahmen mehrere relevante politische Theorien, wie die Wissensdemokratie und verschiedene geopolitische Theorien. Klassische, kritische als auch umweltpolitische Theorien sind essentiell, um die Entwicklung der Weltraumaktivitäten zu verstehen. Die Methoden der Forschung sind untersuchend und innovativ. Neben einer Literaturrecherche und einer Aufarbeitung der Fachliteratur, wurde ein Vergleich, basierend auf den vier Dimensionen, durchgeführt. Weiters wurden die Ergebnisse der Literaturanalyse bewertet, um einen beschreibenden Vergleich zu erhalten.

Die Gesamtanalyse beginnt mit einer Einführung der beiden Weltraumagenturen, deren geschichtlicher Hintergrund und deren zukünftige Ausrichtung, welche in mehreren Policy Papers genannt werden. Weiters, die Analyse geht ins Detail und analysier die verschiedenen Strategiepapiere und Weltraumprogramme der beiden Weltraumagenturen im Bezug auf die vier verschiedenen Dimensionen Wissenschaft, Militär, Ökonomie und Umwelt.

Die Bewertung der vier Dimensionen zeigen folgende Ergebnisse:

Wissenschaft und Militär sind besser entwickelt bei NASA, während ESA einen innovativeren Ansatz hat bezüglich umweltpolitischer Themen, wie zB bei der Entsorgung des Weltraummülls. Beide Weltraumagenturen fokussieren sich stark auf die ökonomischen Aspekte und obwohl man unterschiedliche Ansätze feststellen kann gegenüber den Unternehmen, ist die Entwicklung und die Zusammenarbeit mit den kommerziellen Akteuren gleich wichtig bei der NASA und ESA. Internationale Kooperation zwischen den zwei Weltraumagenturen, als auch weiteren Weltraumagenturen, Staaten oder Vereinigungen ist ebenso gleich wichtig bei NASA und ESA. Die feinen Unterschiede können durch die unterschiedliche Organisationsstruktur, geschichtlicher Hintergrund, die Hauptideen, das Narrative als auch das einzigartige Setting beider Weltraumagenturen erklärt werden. Die geopolitischen Theorien werden zu den unterschiedlichen Ansätzen der NASA und ESA verbunden.

Insgesamt erlangt NASA mehr Punkte als ESA in der Zusammenführung aller Dimensionen. Das ist nicht wirklich verwunderlich, da NASA einen großen Vorteil gegenüber der ESA hat, da sie schon länger Weltraumaktivitäten durchführt und die führende Weltraumagentur ist. Nichtsdestotrotz ist es interessant, dass ESA mehr Punkte im Bereich der umweltpolitischen Themen erlangt hat, da ESA neue innovative Lösungen für Umweltprobleme im Weltraum präsentiert hat.

Mit dieser Forschungsarbeit konnten die verschiedenen Ansätze der NASA und ESA bezüglich der vier Dimensionen analysiert werden. Es präsentiert auch mehrere Schwierigkeiten, mit welchen die Weltraumagenturen zu kämpfen haben. Die distinktiven Vorgehensweisen, die verschiedenen Weltraumprogramme und Projekte als auch die bestehenden Schwierigkeiten in den Weltraumagenturen wurden dafür benutzt, um die zukünftigen Pläne der NASA und ESA zu präsentieren. Innovation und Kooperation sind der Schlüssel für zukünftige Entwicklungen. Langfristig gesehen, greifen beide Weltraumagenturen zu den Sternen und wollen mit ihren Weltraumaktivitäten eine bessere Zukunft gestalten.

# Literature


Air Force Space Command (Archived). (n.d.) Air Force Space Command History. https://www.afspc.af.mil/About-Us/AFSPC-History/. (accessed on 08.09.2022).

Air Force Space Command. (2019). The Future of Space 2060 & implications for U.S. strategy: Report on the space futures workshop. Technical Report. Air Force Space Command, Colorado Springs. 1-36.

Al-Rodhan, N. (2012). Meta-Geopolitics of Outer Space: An Analysis of Space Power, Security and Governance, St. Antony's Series (STANTS). Palrgave Macmillan, London.

Anderson, F. W. (1981). Orders of Magnitude, A history of NACA and NASA 1915-1980, The NASA History Series, NASA SP-4403, National Aeronautics and Space Administration, Washington D.C.

Ayadi, J. (2019). 42nd Round Table on current issues of international humanitarian law on the 70th anniversary of the Geneva Convention: Military implications of the use of outer space: European perspective, International Institute of Humanitarian Law. https://iihl.org/wp-content/uploads/2019/10/Ayadi.pdf. (accessed on 16.02.2022).

Brachet G. (2012). The origins of the "long-term sustainability of outer space activities" initiative at UN COPUOS. Space Policy. 2012, 28 (3) 161–165. https://doi.org/10.1016/j.spacepol.2012.06.007.

Brand, U., Wissen, M., (2013). Crisis and continuity of capitalist society-nature relationships: The imperial mode of living and the limits to environmental governance, Review of International Political Economy, 20,4, 687-711.

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., Neville, A. (2014). The use of triangulation in qualitative research. In Oncology nursing forum, 41, 5, 545-547. https://onf.ons.org/onf/41/5/use-triangulation-qualitative-research.

David, J. E. (2015). NASA's Secret Relationships with U.S. Defense and Intelligence Agencies: Declassified Records Trace the many hidden interactions between the U.S. Civilian data, and National Security Space Programs. National Security Archive Electronic Briefing Book No. 509. https://nsarchive2.gwu.edu/NSAEBB/NSAEBB509/.

Denk, T. (2010). Comparative multilevel analysis: proposal for a methodology, International Journal of Social Research Methodology, 13:1, 29-39, https://doi.org/10.1080/13645570802583779.

Dolman, E. C., (1999). Geostrategy in the space age: An astropolitical analysis, The Journal of strategic studies, 22, 83-106. https://doi.org/10.1080/01402399908437755.

EC. (2022). Joint Communication: An EU Approach for Space traffic Management – An EU contribution addressing a global challenge. European Commission. https://ec.europa.eu/info/files/joint-communication-eu-approach-space-traffic-management-eu-contribution-addressing-global-challenge_en. (accessed on 29.09.2022).

ESA. (2014, February 10). The European Space Agency director general – in interview. European Space Agency. https://www.esa.int/About_Us/Jean-Jacques_Dordain/The_European_Space_Agency_director_general_in_interview. (accessed on 03.02.2022).

ESA. (2016). Joint Statement of shared vision and goals for the future of Europe in Space. European Space Agency. https://www.esa.int/About_Us/Corporate_news/Joint_statement_on_shared_vision_and_goals_for_the_future_of_Europe_in_space_by_the_EU_and_ESA.

ESA. (2017, February 28). Greensat: one step closer to an environmentally friendly space mission. European Space Agency. https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Greensat_one_step_closer_to_an_environmentally_friendly_space_mission. (accessed on 18.03.2022).

ESA. (2017, February 9). Cleaning up our oceans. European Space Agency. https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/Cleaning_up_our_oceans. (accessed on 28.09.2022).

ESA. (2019a). ESA Space Resource Strategy. European Space Agency. https://exploration.esa.int/web/moon/-/61369-esa-space-resources-strategy. (accessed on 23.03.2022).

ESA. (2019b). ESA Strategy for Science at the Moon. European Space Agency. https://exploration.esa.int/web/moon/-/61371-esa-strategy-for-science-at-the-moon. (accessed on 19.03.2022).

ESA. (2019c). ESA Technology Strategy 2019 https://www.esa.int/Enabling_Support/Space_Engineering_Technology/ESA_s_Technology_Strategy_for_Space19. (accessed 18.03.2022).

ESA. (2020). This is ESA. European Space Agency. https://esamultimedia.esa.int/docs/corporate/This_is_ESA_EN_LR.pdf.

ESA. (2021, July 13). ESA and NASA join forces to understand climate change. European SpaceAgency.https://www.esa.int/Applications/Observing_the_Earth/ESA_and_NASA_join_forces_to_understand_climate_change. (accessed on 28.09.2022).

ESA. (2021, June 10). Cosmic Vision. European Space Agency. https://sci.esa.int/web/cosmic-vision/-/46510-cosmic-vision. (accessed on 12.09.2021).

ESA. (2022, June 8). Policy for missions of opportunity in the ESA science directorate. European Space Agency. https://sci.esa.int/web/cosmic-vision/-/59977-missions-of-opportunity. (accessed on 15.09.2021).

ESA. (2021a). A European vision. European Space Agency https://www.esa.int/About_Us/Corporate_news/A_European_vision. (accessed on 19.03.2021).

ESA. (2021b). Building the International Space Station. European Space Agency. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station/Building_the_International_Space_Station3. (accessed on 25.04.2021).

ESA. (2021c). Electromagnetics and Space Environment. European Space Agency. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Electromagnetics_and_Space_Environment. (accessed on 15.04.2021).

ESA. (2021d). ESA and the EU. European Space Agency. https://www.esa.int/About_Us/Corporate_news/ESA_and_the_EU. (accessed on 25.04.2021).

ESA. (2021e). ESA's purpose. European Space Agency. https://www.esa.int/About_Us/Corporate_news/ESA_s_Purpose. (accessed on 25.04.2021).

ESA. (2021f). European Milestones. European Space Agency. https://www.esa.int/About_Us/Corporate_news/European_milestones. (accessed on 19.03.2021).

ESA. (2021g). Member states and cooperating states. European Space Agency. https://www.esa.int/About_Us/Corporate_news/Member_States_Cooperating_States. (accessed on 20.03.2021).

ESA. (2021h). Science & Technology. European Space Agency. https://sci.esa.int. (accessed on 16.09.2021).

ESA. (2021i). Surviving extreme conditions in space. European Space Agency. https://www.esa.int/Science_Exploration/Space_Science/Extreme_space/Surviving_extreme_conditions_in_space. (accessed 15.04.2021).

ESA. (2021j). The weightlessness environment: what are the advantages? European Space Agency. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/European_ISS_Business_Club/The_weightlessness_environment_what_are_the_advantages. (accessed on 15.04.2021).

ESA. (2022a). About asteroids and Planetary Defence. European Space Agency https://www.esa.int/Space_Safety/About_asteroids_and_Planetary_Defence. (accessed on 08.09.2022).

ESA. (2022b). Clearspace-1. European Space Agency. https://www.esa.int/Space_Safety/ClearSpace-1. (accessed on 22.09.2022).

ESA. (2022c). Convention of the establishment of a European Space Agency, December 31, 1975. https://www.esa.int/About_Us/Law_at_ESA/ESA_Convention.

ESA. (2022d). EDA Space. European Defence Agency. https://eda.europa.eu/docs/default-source/documents/eda-information-sheet-on-space.pdf. (accessed on 15.02.2022).

ESA. (2022e). ESA Agenda 2025. European Space Agency. http://www.esa.int/About_Us/Introducing_ESA_Agenda_2025.

ESA. (2022f). ESA and the Sustainable Development Goals. European Space Agency. https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/ESA_and_the_Sustainable_Development_Goals. (accessed on 22.09.2022).

ESA. (2022g). ESA Business Incubation Centres (BIC). European Space Agency. https://commercialisation.esa.int/bic/. (accessed on 13.09.2022).

ESA. (2022h). ESA Commercialisation Gateway. European Space Agency. https://commercialisation.esa.int. (accessed on 14.09.2022).

ESA. (2022i). ESA Green Agenda. European Space Agency. https://www.esa.int/About_Us/Responsibility_Sustainability/ESA_Green_Agenda. (accessed on 22.09.2022).

ESA. (2022j). ESA Materiality Matrix. European Space Agency. https://www.esa.int/About_Us/Responsibility_Sustainability/ESA_Materiality_Matrix. (accessed on 22.09.2022).

ESA. (2022k). ESA Sustainability Principles. European Space Agency. https://www.esa.int/About_Us/Responsibility_Sustainability/ESA_Sustainability_Principles. (accessed on 22.09.2022).

ESA. (2022l). ESA's Climate Change Initiative. European Space Agency. https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/ESA_s_Climate_Change_Initiative. (accessed on 29.09.2022).

ESA. (2022m). MELiSSA life support project, an innovation network in support to space exploration. European Space Agency. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/MELiSSA_life_support_project_an_innovation_network_in_support_to_space_exploration. (accessed on 18.03.2022).

ESA. (2022n). Mitigating space debris generation. European Space Agency. https://www.esa.int/Space_Safety/Space_Debris/Mitigating_space_debris_generation. (accessed on 28.09.2022).

ESA. (2022o). Near-Earth Object Coordination Centre (NEOCC). European Space Agency. https://neo.ssa.esa.int/about-neocc. (accessed on 08.09.2022).

ESA. (2022p). Opportunities. European Space Agency. https://commercialisation.esa.int/business-opportunities/. (accessed on 14.09.2022).

ESA. (2022q). Partnership projects. European Space Agency. https://www.esa.int/Applications/Telecommunications_Integrated_Applications/Partnership_Projects. (accessed on 17.09.2022).

ESA. (2022r). Partnership. European Space Agency. https://www.esa.int/Applications/Telecommunications_Integrated_Applications/EDRS/Partnership. (accessed on 17.09.2022).

ESA. (2022s). Reentry and collision avoidance. European Space Agency. https://www.esa.int/Space_Safety/Space_Debris/Reentry_and_collision_avoidance. (accessed on 28.09.2022).

ESA. (2022t). Science & Exploration. European Space Agency. https://www.esa.int/Science_Exploration. (accessed on 10.07.2022).

ESA. (2022u). SPOT. European Space Agency. https://earth.esa.int/eogateway/missions/spot. (accessed on 14.09.2022).

ESPI. (2019) Measuring Space Power: A theoretical and investigation on Europe – Executive Summery. European Space Policy Institute. https://www.espi.or.at/reports/executive-summary-measuring-space-power/.

ESPI. (2020a). ESPI Report 72, Europe, Space and Defence – Full Report, 2, 2020, European Space Policy Institute, https://espi.or.at/publications/espi-public-reports.

ESPI. (2020b). ESPI Report 75, European Space Strategy in a Global Context – Executive Summary, 11, 2020, European Space Policy Institute, https://espi.or.at/publications/espi-public-reports.

ESPI. (2021). Executive Briefs, Perspectives on ESA Agenda 2025, European Space Policy Institute, No 50, April 2021, https://espi.or.at/publications/espi-executive-briefs.

European Space Conference. (2021). Meeting minutes from the 13th European Space Conference Space Embracing a Changing World: Green, Digital, Resilience & Security, https://www.europlanet-society.org/13th-european-space-conference-space-embracing-a-changing-world-green-digital-resilience-security/. (accessed on 24.05.2021).

FAA. (2018). The Space Environment 4.1.2. Advanced Aerospace Medicine Online, Section III – Space Operations. 1-26. Federal Aviation Administration. Washington, DC. https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/cami/library/online_libraries/aerospace_medicine/tutorial/section3/spacecraft_design. (accessed on 15.04.2021).

Fabrykowska, A. (2020). Empty Spaces in Space. In Carayannis E. (eds) Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship. New York, NY: Springer New York. https://doi.org/10.1007/978-1-4614-6616-1_200095-1.

Flick, U. (1991). Triangulation. In U. Flick, E. v. Kardoff, H. Keupp, L. v. Rosenstiel, & S. Wolff (Hrsg.), Handbuch qualitative Sozialforschung : Grundlagen, Konzepte, Methoden und Anwendungen. Beltz - Psychologie Verlag Union, München. 432-434. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-37324.

Flick, U., (2006). An introduction to qualitative research, SAGE Publications Inc, California.
Foust, J. (2021, October 21). From space traffic awareness to space traffic management. SpaceNews. https://spacenews.com/from-space-traffic-awareness-to-space-traffic-management/. (accessed on 28.09.2022).

Gal, G. (2004). Some Remarks to General Clauses of Treaty Space Law, Miskolc Journal of International Law, Vol 1, 2004, Nr 1, p 1-8.

Görg, C., (2010). Vom Klimaschutz zur Anpassung: gesellschaftliche Naturverhältnisse im Klimawandel, In Der Klimawandel, VS Verlag für Sozialwissenschaften, 347-362.

Görlich, P. (2019, March 27). Paragrafen auf der Umlaufbahn – Wie ein Vertrag dafür sorgt, dass der Weltraum zum Wohle aller genutzt wird. Universität Potsdam. https://www.uni-potsdam.de/de/nachrichten/detail/2019-03-27-paragrafen-auf-der-umlaufbahn-wie-ein-vertrag-dafuer-sorgt-dass-der-weltraum-zum-wohle-. (accessed 18.03.2021).

Haverluk, T. Beauchemin, K., Mueller, B. (2014). The Three Critical Flaws of Critical Geopolitics: Towards a Neo-Classical Geopolitics; Geopolitics, 19:1, 19-39, https://doi.org/10.1080/14650045.2013.803192.

Highfill, T., Georgi, P., Dubria, D. (2019). Measuring the Value of the U.S. Space Economy. SCB, Survey of Current Business. The Journal of the US Bureau of Economic Analysis (BEA), 99, 12. https://apps.bea.gov/scb/2019/12-december/1219-commercial-space.htm.

In'tveld, R. (2010). Knowledge Democracy. Consequences for Science, Politics, and Media. Springer-Verlag Berlin Heidelberg.

Jones, H. (2018). The recent large reduction in space launch cost. 48th International Conference on Environmental Systems.

Klinger, J. M. (2019). Environmental Geopolitics and outer space, Geopolitics, https://doi.org/10.1080/14650045.2019.1590340.

Laurini, K. C., Gerstenmaier, W. H. (2014). The Global Exploration Roadmap and its significance for NASA. Space Policy. 30 (3), 149-155. https://doi.org/10.1016/j.spacepol.2014.08.004.

Lauth, H., Pickel, G. and Pickel S. (2009). Methoden der vergleichenden Politikwissenschaft: Eine Einführung. VS Verlag. Wiesbaden.

Luke, T. W. (2003). Towards a green geopolitics: Politicizing ecology at the Worldwatch institute; In Dodds., K., Atkinson, D. Geopolitical traditions: a century of geopolitical thoughts, Routledge, London and New York.

Luxembourg Space Agency. (2018). Opportunities for space resource utilization, future markets and value chains. https://gouvernement.lu/dam-assets/documents/actualites/2018/12-decembre/20-Study-Summary-of-the-Space-Resources-Value-Chain-Study.pdf, accessed on 23.03.2022.

MacDonald, F. (2007) Anti-Astropolitik – outer space and the orbit of geography, Progress in Human Geography 31, 5, 592-615, SAGE Publications, California. https://doi.org/10.1177/0309132507081492.

Mayring, P. (2000). Qualitative content analysis. Forum: Qualitative Sozial Research Sozialforschung, Vol 1, No. 2, Art. 20, 2000.

McCall, S. M. (2020). Challenges to the US in Space. Congressional Research Service, IF10337, 1-3.

Mendenhall, E. (2018). Treating Outer Space Like a Place: A Case for Rejecting Other Demain Analogies, Astropolitics, 16:2, 97-118, https://doi.org/10.1080/14777622.2018.1484650.

Moisio, S. (2015). Geopolitics/Critical Geopolitics, The Wiley Blackwell Companion to Political Geography, First Edition, John Wiley & Sons, Ltd.

Mooney, H. A., Duraiappah, A., Larigauderie, A. (2012). Evolution of natural and social science interactions in global change research programs, Proceedings of the national Academy of Sciences of the United States of America, 2013, vol. 110, 3665-3672.

NASA. (2018, April 2). NASA History Overview. National Aeronautics and Space Administration. https://www.nasa.gov/content/nasa-history-overview. (accessed on 25.04.2021).

NASA. (2018). NASA Strategic Plan 2018. National Aeronautics and Space Administration, Washington DC.

NASA. (2019a, July 24). EMD Purpose. National Aeronautics and Space Administration. https://www.nasa.gov/emd. (accessed on 27.09.2022).

NASA. (2019b, July 24). Sustainability 101. National Aeronautics and Space Administration. https://www.nasa.gov/emd/sustainability-101. (accessed on 27.09.2022).

NASA. (2019, March 14). Planetary Defense Coordination Office. National Aeronautics and Space Administration. https://www.nasa.gov/planetarydefense/overview. (accessed on 08.09.2022).

NASA. (2019, September 6). NEPA Fundamentals. National Aeronautics and Space Administration. https://www.nasa.gov/emd/nepa-fundamentals. (accessed on 27.09.2022).

NASA. (2020, April 3). Overview: In-Situ Resource Utilization. National Aeronautics and Space Administration. https://www.nasa.gov/isru/overview. (accessed on 28.09.2022).

NASA. (2020, July 2). National Environmental Policy Act. John F. Kennedy Space Center, National Aeronautics and Space Administration. https://environmental.ksc.nasa.gov/EnvironmentalPlanning/NEPA/NEPA%20Overview. (accessed on 27.09.2022).

NASA. (2020a). Explore Science 2020-2024. National Aeronautics and Space Administration. Washington, DC.

NASA. (2020b). NASA Fiscal Year 2020 Volume of Integrated Performance, National Aeronautics and Space Administration, Washington DC.

NASA. (2020c). Sustainability Report and Implementation Plan. National Aeronautics and Space Administration, Washington DC.

NASA. (2020, November 18). Sustainability Report and Implementation Plan (SRIP). National Aeronautics and Space Administration. https://www.nasa.gov/emd/srip. (accessed on 27.09.2022).

NASA. (2021, December 3). Natural Resource Management. National Aeronautics and Space Administration. https://www.nasa.gov/emd/nrm. (accessed on 28.09.2022).

NASA. (2021, February 4). Environmental Cleanup / Restoration. National Aeronautics and Space Administration. https://www.nasa.gov/emd/ecr. (accessed on 28.09.2022).

NASA. (2021, May 26). Space Debris and Human Spacecraft. National Aeronautics and Space Administration. https://www.nasa.gov/mission_pages/station/news/orbital_debris.html. (accessed on 28.09.2022).

NASA. (2021, February 12). Commercial Smallsat Data Acquisition (CSDA) Program. NASA Earth Observation Data. https://www.earthdata.nasa.gov/esds/csda. (accessed on 12.09.2022).

NASA. (2021a). Climate Action Plan. National Aeronautics and Space Administration, Washington DC.

NASA. (2021b). NASA Fiscal Year 2021 Volume of Integrated Performance, National Aeronautics and Space Administration, Washington DC.

NASA. (2021c). The Future. National Aeronautics and Space Agency. https://www.nasa.gov/specials/60counting/future.html. (accessed on 26.09.2021).

NASA. (2022, August 29). Veterans and Military Spouses. National Aeronautics and Space Administration. https://www.nasa.gov/careers/veterans. (accessed on 08.09.2022).

NASA. (2022, January 9). One year into the Biden Administration, NASA Looks to Future. National Aeronautics and Space Administration. https://www.nasa.gov/press-release/one-year-into-the-biden-administration-nasa-looks-to-future. (accessed on 31.01.2022, 08.07.2022).

NASA. (2022a). Artemis. National Aeronautics and Space Administration, Washington DC. https://www.nasa.gov/specials/artemis/. (accessed on 20.09.2022).

NASA. (2022b). Climate Action Plan and Sustainability Plans. National Aeronautics and Space Administration.https://www.nasa.gov/sites/default/files/atoms/files/cap_sspp_announcement_a_0.pdf. (accessed on 27.09.2022).

NASA. (2022c). Explore Science 2020-2024 Update. National Aeronautics and Space Administration. Washington, DC.

Nucera G. G. (2019). International geopolitics and space regulation. In: Oxford research encyclopedia of planetary science. Oxford, Oxford University Press. 2019. https://doi.org/ 10.1093/acrefore/9780190647926.013.40.

Palmberger, M., Gingrich, A. (2014). Qualitative comparative practices: Dimensions, Cases and Strategies, Qualitative Data Analysis, SAGE Publications, California.

Peet, R., Robbins, P. Watts, M. (2010). Global Political Ecology, 1st edition, Routledge. https://doi.org/10.4324/9780203842249.

Petras, C. M. (2002). Space Force Alpha – Military Use of the International Space Station and the Concept of peaceful purposes. ALWD, 53 A.F. L. Rev. 135-182.

Ritchie, J., Lewis, J. (2006), Qualitative research practice: a guide for social science students and researchers, SAGE Publications, California.

Robbins, P. (2004). Political Ecology: a critical introduction. The Wiley Blackwell Publishing Ltd, Malden, MA.

Robinson, D.K.R., Mazzucato, M. (2019). The evolution of mission-oriented policies: Exploring changing market creating policies in the US and European space sector. Research Policy 48 (4), 936-948.

Rome, N. (2014). European Militaries join the U.S. in Space (2021, April 7). Georgetown Security Studies Review. https://georgetownsecuritystudiesreview.org/2021/04/07/european-militaries-join-the-u-s-in-space/. (accessed on 24.07.2022).

ROOM. (2016, September 23). ESA launch CleanSat initiative to clean up space debris. ROOM, Space Journal of Asgardia. https://room.eu.com/news/esa-launch-cleansat-initiative-to-clean-up-space-debris. (accessed on 17.03.2022).

Rumerman, J. (n.d.). The National Advisory Committee for Aeronautics (NACA). U.S. Centennial of Flight Commission. https://www.centennialofflight.net/essay/Evolution_of_Technology/NACA/Tech1.htm. (accessed on 22.04.2021).

Space Operations Command (2022). Commander's Strategic Plan 2022. Space Operations Command, Colorado.

Spacepolicyonline. (2022a, September 7). Brief Introduction: US Government Civil Space Agencies. Spacepolicyonline.com. https://spacepolicyonline.com/topics/civil/. (accessed on 24.04.2021).

Spacepolicyonline. (2022b, September 7). Military/National Security Space Activities Spacepolicyonline.com. https://spacepolicyonline.com/topics/militarynational-security-space-activities/. (accessed on 24.07.2022).

Spector S, Higham JE, Doering A. (2017). Beyond the biosphere: tourism, outer space, and sustainability. Taylor Francis Online. Tourism Recreation Research. 2017, 42 (3), 273–283.

The Planetary Society. (n.d.). Your Guide to NASA's Budget. The Planetary Society. https://www.planetary.org/space-policy/nasa-budget. (accessed on 01.05.2021).

The White House. (2017, December 11). Presidential Memorandum on Reinvigorating America's Human Space Exploration Program. https://trumpwhitehouse.archives.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/. (accessed on 07.11.2022).

United Nations Office for Outer Space Affairs, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), January 27, 1967. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

USSF News. (2020, September 22). NASA, US Space Force establish Foundation for Broad Collaboration. United States Space Force. https://www.spaceforce.mil/News/Article/2356032/nasa-us-space-force-establish-foundation-for-broad-collaboration/. (accessed on 08.09.2022).

USSF. (2022a). Supporting NASA. United States Space Force, Colorado. https://www.spaceforce.mil/Multimedia/Photos/igphoto/2002226824/. (accessed on 08.09.2022).

USSF. (2022b). USSF History. United States Space Force, Colorado. https://www.spaceforce.mil/About-Us/About-Space-Force/History/. (accessed on 08.09.2022).

USSF. (2022c). USSF Mission. United States Space Force, Colorado. https://www.spaceforce.mil/About-Us/About-Space-Force/Mission/. (accessed on 08.09.2022).

USSF. (2022d). USSF News. United States Space Force, Colorado. https://www.spaceforce.mil/News/Article/2356032/nasa-us-space-force-establish-foundation-for-broad-collaboration/. (accessed on 08.09.2022).

Vinas, M-J. (2016, February 24). NASA, partner space agencies measure forest in Gabon. National Aeronautics and Space Administration, Global Climate Change. https://climate.nasa.gov/news/2405/nasa-partner-space-agencies-measure-forests-in-gabon/. (accessed on 28.09.2022).

Way, T. A. (2018). The Space Gap, Access to Technology, and the Perpetuation of Poverty, International Research Scape Journal, Vol 5, Nr 1, 2018, 1-20, https://scholarworks.bgsu.edu/irj/vol5/iss1/7.

Weeks, E. E., Faiyetole, A. A. (2014). Science, technology and imaginable social and behavioral impacts as outer space develops, Acta Astronautica 95, 2014, 166-173.

Weinzierl, M. (2018). Space, the final economic frontier. Journal of Economic Perspectives, 32(2), 173-192.

Wolfson, D. (2010). Dreaming about a properly informed democracy. Knowledge Democracy. Consequences for Science, Politics, and Media. Springer-Verlag Berlin Heidelberg, 37 – 49.

Zubrin R. (2019). The case for space. How the revolution in spaceflight opens up a future of limitless possibility. Amherst: Prometheus Books.