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Opportunities and Challenges facing the Commercialisation of Outer Space

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The space industry is rapidly expanding, and the potential market is estimated to be worth $1 trillion by 2040. With the emergence of private actors in space enabled by innovations such as re-usable rocket technology, the industry is poised for significant growth. Increased privatisation of the commercial space industry will free up funds of national space agencies for exploration and scientific research for the betterment of humankind. However, there are issues that need to be addressed before space can be accessible to all, including monopolisation, the creation and monitoring of space junk, and the lack of policy regarding the use, ownership, and maintenance of outer space and its resources. A legal framework needs to be implemented to prevent the creation of debris and to prevent accidental or purposeful collisions in outer space and to be able to govern the safe use of space for everyone. The ambiguity surrounding the possibility of private entities to own resources found in outer space needs to be clarified by the international community, and a legislative framework must be constructed to ensure the orderly development of space operations to prevent international disputes. If the international community were to take a proactive approach towards space policy, actors operating in the space industry would be protected from having to deal with inconsistent national laws.

Keywords	Space Industry, Outer Space, Space Policy, New Space, Space Commercialisation

Contents

1 Introduction

1.1 Background & relevance

The space industry is an important topic as activities in space create value to the global economy and the whole of society, as it brings employment, as well as contributes to the development of science and technology. There are also many other benefits to investing in space, such as innovation, environmental, and socio-economic (International Space Exploration Coordination Group, 2013).

Investing in the space industry has led to numerous innovations in the past, from solar panels, advanced computing, light-weight materials, cancer therapy, and mobile technologies, such as GPS and satellite imagery like Google Earth, to name a few, all of which have benefitted and improved the quality of life. The space industry and space exploration will continue to be an essential driver for opening new domains of science and technology (International Space Exploration Coordination Group, 2013).

> Since the dawn of the space program, there have been more than 2,000 examples of space-developed technologies that have since found beneficial uses on Earth, including cordless power tools, freeze-dried food, flame-resistant firefighter gear, the integrated circuit, lightweight insulation, improvements to kidney dialysis, lightning detection, and automated credit card transactions (Greenblatt and Anzaldua, 2019).

Since the first human activities in space, society has seen profound impacts on the development of humankind as it has expanded our views about the limits of human travel and as well as our place in the Universe. Stephen Hawking said, 'to confine our attention to terrestrial matters would be to limit the human spirit' (Krauss and Hawking, 1997).

The impact of human activity on the natural environment of the Earth is undeniable. Deforestation, desertification, soil degradation, ozone layer depletion, and climate change are all effects of human activity. However, many space-based technologies have improved our understanding of the water cycle, air quality,

forests, and other facets of the natural world. These technologies for surveying and monitoring ecosystem health offer important data on the condition of ecosystems, which offers significant support for conservation and sustainable resource management (United Nations, 2018).

These environmental benefits include utilising satellites to help with sustainability by, for example, the monitoring of greenhouse gasses and CO2 emissions, and observation of other environmental impacts such as deforestation, mining, oil spills and industrial operations, as well as helping to identify and prevent any illegal activities associated with them. Satellites can also help with food security, by monitoring fishing, farming, and looking at weather and temperature patterns to help optimise agricultural yields and help farmers improve efficiency (Morgan Stanley, 2020).

Space also has the potential to help the economy by rebalancing the supply and demand that we face on Earth as demand for resources is expected to rise due to population growth, greater longevity due to better health care, and increasing consumption caused by economic development in developing countries (Gerland et al., 2014). Over time demand could be shifted away from our home planet with the help of space colonies. Moreover, the cosmos is vast and the capacity it has could provide solutions for habitation, energy, capacity, plant and food production, industry and manufacturing and waste solutions. When it comes to resources, space has an almost infinite supply such as phosphorus, zinc, platinum, cobalt, gold, and helium, to name some. These resources could be extracted from asteroids, moons, or planets to replace scarce and dwindling supplies on Earth.

This paper aims to investigate the commercial space industry, how it was born and has developed over time, the current economic situation of the market, what its outlook is and what opportunities the commercial space industry presents, as well as identifying and outlining the challenges facing the industry and what needs to be done to address these. This thesis will also discuss the importance of policy in outer space, why it is needed for the space industry, and investigate ways how to best implement it.

2 Theory

2.1 Research Purpose

Academic research is usually undertaken with the purpose of systematically discovering something, such as studying an unfamiliar phenomenon, generating a precise representation of an existing event, or elucidating and describing links between variables (Kothari, 2004). In other words, depending on the reasons behind the study initiation, the research may have descriptive, exploratory, or explanatory purposes. In particular cases, investigators may adopt more than one purpose, for instance, to pursue descripto-explanatory research, as well as changing the initial aim as the investigation progresses (Saunders, Lewis, and Thornhill, 2009).

2.2 Exploratory Research

Exploratory research is a means of finding out "what is happening; to seek new ideas and insights; to ask questions and to assess phenomena in a new light" (Robson, 2005). According to Saunders et al (2009), the three principal ways of conducting exploratory research are searching for literature, interviews with 'experts' in the subject, and focus group interviews. Exploratory research is flexible and adaptable to change, and the emphasis is on the discovery of ideas and insights.

One of the features that differentiates exploratory research is the flexibility of its nature, when compared to descriptive and explanatory research. This allows for many different dimensions of problems to be considered as and when they may arise and allows a broad definition of a problem to be narrowed down to become more precise and focused.

The research that is being conducted in this thesis is exploratory by nature, as the concept of the commercialisation and privatisation of space has only recently started to become an actuality. Because of this, there has been very few studies conducted into this topic, thus, to conduct this research it has been necessary to study relevant literature.

2.3 Research Approach

According to Durrheim (2006), "A research design is a strategic framework for action that serves as a bridge between research questions and the execution or implementation of the research." In other words, research design refers to the general plan for conducting the investigation and acts as a framework for the researcher, helping them define every stage of the research process.

For this research, an induction approach was taken, since there was not enough initial information available about the research subject, it was not viable to start with a theory. Induction refers to a collection of methodological procedures that aim to methodically develop theories based on observations of the empirical world. and refers to "the processes by which observers reflect upon their experience of social phenomena and then attempt to formulate explanations that may be used to form an abstract rule, or guiding principle, which can be extrapolated to explain and predict new or similar experiences" (Kolb et al., 1979). The primary purpose of inductive research to derive concepts, themes, or a model through raw data and interpretations made by the researcher (Thomas, 2006). Induction emphasises on the collection of qualitative data and is more flexible in structure, which allows for the adaptation of the research emphasis as research progresses (Saunders, Lewis and Thornhill, 2009).

2.4 Research Strategy

Documentary secondary data was the main source of data used in this research in the form of written documents such as books, journals, reports, online articles, and websites (Saunders, Lewis, and Thornhill, 2009). The reason secondary data was used was the due to the difficulty of acquiring primary data on this topic, as primary data refers to real-time information collected by the researcher through observations, experiments, interviews, and questionnaires. Due to the nature of the topic and the fact that it is still new, trying to find experts on the topic to interview or survey proved to be too difficult to achieve.

Archival research, which makes use of administrative records and documents, as the principal source of data, was another strategy used in this paper, as parts of this paper focused on the past and the changes that have happened over time. Much care and analysis were used when looking at administrative records and documents, as the data for these was originally collected for a different purpose, the administration of the organisation.

Apart from the difficulty of acquiring primary data, collecting secondary data was advantageous as there was a vast amount of it available, and was more cost and time effective. Secondary data is characterised by its permanence, meaning that the data available is typically permanent and available in format that can be checked easily by others, meaning findings are more open to public scrutiny and thus, ideally, more accurate in nature.

However, there are disadvantages to this, such as despite the permanence of secondary data, there is no tangible way to control the quality of it, outside sources such a government institutions and data archives. Another issue is that of access, as it may be difficult or costly to access reports that are not in the public domain, available to libraries, or available online for free. How data is presented is also a crucial factor, particularly in publications, as authors have the ability to select what they deem to be the most important points and place undue emphasis on them, at the expense of supporting data. (Saunders, Lewis, and Thornhill, 2009).

When using secondary data careful analysis and evaluation on part of the researcher must be exercised. The reliability and validity of the data is of key importance, and it is important for the researcher to assess the authority or reputation of the source. Measurement validity is one of the most important criteria for the suitability of any data set as if the data is not valid, then it will fail to provide the information that is needed to answer research questions or meet the set objectives.

When collecting data for this research, special care was taken when checking the reliability and validity of secondary data. One way in which this was done was by thoroughly checking the source of the data that was used. "Dochartaigh (2002)

and others refer to this as assessing the authority or reputation of the source" (quoted in Saunders, Lewis, and Thornhill, 2009).

3 Literature Review

3.1 History of Space Exploration

Space, the final frontier. 50 years ago, outer space was reserved for the wealthiest and most powerful nations, but today there is an ongoing democratisation of space. Commercial and private industry is bringing us closer than ever to the cosmos.

In 1957 the Soviet Union launched Sputnik into space, the first human made object to go into orbit around the earth. For America, and the rest of the world, this came as a great shock as space was seen to be the next frontier of exploration and for the West it was important not to lose face, or ground, to the Soviets.

> This had a "Pearl Harbor" effect on American public opinion, creating an illusion of a technological gap and provided the impetus for increased spending for aerospace endeavours, technical and scientific educational programs, and the chartering of new federal agencies to manage air and space research and development (Garber and Lanius, 2019).

This event ushered in the beginning of the Space Race.

In 1958 the United States launched its own rocket, Explorer 1, into space, which was designed by the U.S Army. The same year, then U.S President, Dwight D. Eisenhower created the National Aeronautics and Space Administration (NASA), a federal agency dedicated to space exploration (Tillman, 2017).

In 1959 the Soviets once again paved the way by launching the first space probe to hit the moon, Luna 2. Then, in April 1962, Yuri Gagarin made history by becoming the first person to orbit around the Earth. America soon followed by sending up Alan Shepard in May 1962 (History.com Editors, 2010).

Twenty days after Alan Shepard became the first American in space, then President John F. Kennedy boldly announced "I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the moon and

returning him safely to Earth" (Tillman, 2017). This came as a direct response to Soviet successes in space, and NASA set up Project Apollo, later known as the Apollo Programme, as a high-profile undertaking to display the United States' scientific and technological supremacy over its Cold War rival to the global audience.

Seven years after Kennedy's famous speech, Neil Armstrong and Buzz Aldrin became the first humans to land and set foot on the Moon's surface, effectively bringing the decades long space race to an end. However, this by no means signalled the end of space exploration and innovation, with the Soviets instead shifting their focus to building a space station. In June 1971, showing that space exploration would and could continue, the Soyuz 11 spacecraft successfully docked with the Salyut 1 space laboratory and completed a 22-day stay. A year later, in 1972, a negotiation easing hostile relations was agreed upon by the Soviet Union and the US, thus leading to a new age of cooperation between the two nations and their endeavours to explore space (Royal Museums Greenwich, 2021).

Building upon this new cooperation, in 1975 the US and NASA collaborated with the Soviet Union and achieved the first international space flight, with both countries launching their own spacecraft from their respective countries. The Apollo and Soyuz crews rendezvoused in space and conducted experiments in space for two days (Garber and Lanius, 2019).

After a gap of six years, during which various famous missions were launched, such as Voyager, Viking, Pioneer, and Helios, in 1981 NASA returned to human spaceflight with the introduction of the Space Shuttle, the first reusable spacecraft. The Space Shuttle was designed to be able to carry people and large payloads to and from orbit and showed the world that a re-usable spacecraft was feasible. However, due to two major disasters, the Challenger in 1986 and the Columbia in 2003, and other factors such as high cost, slow turnaround, few customers and an unsafe vehicle, the space shuttle program was discontinued in 2011 (Adler, 2020).

During the period that the Space Shuttle was still in operation, work began on what would become the International Space Station (ISS). While the construction was started by the United States, today the ISS is an international collaboration, with

a number of different partners and nations contributing to its design, construction, maintenance, and operation. Its main function is that of a low orbit research laboratory. Since 2001 the ISS has been continuously occupied by a variety of astronauts, cosmonauts, and space tourists from nineteen different nations (Garcia, 2016).

The ISS has been serviced by a multitude of different nations, namely Russia, the United States, Japan, and the European Space Agency (ESA). However, Japan's and the ESA's vehicles have been retired, meaning the responsibility now falls to NASA and Russia's Roscosmos. Following Russia's invasion of Ukraine in February 2022, this collaboration is now under threat, with demands for a coordinated response from Western scientists (Stone 2022). Russia had already announced its withdrawal from the ISS by 2025 (Foy 2021; Cookson and Foy 2021), with the aim of developing its own space station by 2030. The deteriorating security aspects of space travel and exploration are a matter of increasing concern to scientists (Mecklin 2022).

Private sector initiatives, however, continue to flourish, as discussed in the following section. Already in 2012 history was made as a commercial spacecraft, SpaceX's Dragon, visited the space station for the very first time (Howell, 2018).

Space launch systems have been designed to send vehicles into outer space to reduce costs, improve reliability, safety, and dependability. While in the past these have been designed, built, and operated by government agencies, in the past few years there has been strong competition from private companies and the commercial market to launch the next generation of launch systems (Aerospace, 2019).

3.2 Rise of the Private Space Sector

The private sector is defined as "business and industries that are not owned or controlled by the government" (Cambridge Dictionary, 2019). The private sector consists of privately owned, for-profit businesses which tend to seek to maximise profits and tends to make up the larger share of the economy in free markets (Sloman and Garratt, 2019, p.22).

The first big step towards the rise of private space companies was in 1982 when the United States received the first request from a private company, a Texan corporation, Space Services Incorporated of America, to launch a commercial space vehicle. At the time there was no mechanism in place to be able to handle such a request and thus companies requesting clearance were faced with a multitude of complicated administrative and bureaucratic procedures that caused delays and expenses.

However, in 1984 President Reagan signed the Commercial Space Launch Act (Space Act of 1984), after predicting that space was the next area of expansion for the United States private sector. This order granted the private sector the right to operate expendable launch vehicles, which are non-reusable launch systems that can deliver payloads into Earth's orbit. In creating this Act, the US made it clear that it was committed to aiding the private sector in space development (Filiato, 1986).

Following the retirement of the Space shuttle program in 2011, an opportunity opened for commercial actors in both the public and private space sectors. "The failure of NASA to find a replacement for the shuttle for 30 years shattered the idea of NASA being in charge … When the shuttle was retired, it created this void that allowed NASA to look to the commercial sector" (Weinzierl and Acocella 2016).

Over the past decade, what has emerged are more and more decentralised and private space companies, which are generally given the name of 'New Space'. These companies tend to thrive upon innovations in technology and business models that usually permit a significant reduction in cost, the provision of new products and services and a broadening of the customer base, as well as providing increased returns for companies and investors (de Concini and Toth, 2019).

Different categories can typically be used to group these companies. Companies focused on "Beyond low Earth orbit" have a diverse range of objectives, including space manufacturing, asteroid mining, and colonising the Moon and Mars, with SpaceX being a well-known example. "Space access" firms specialise in launching individuals and cargo into space. "Remote sensing" enterprises, like the Finnish company ICEYE, offer Earth images and have a close association with "satellite

data and analytics" firms that cater to a broad range of clients. Lastly, "habitats and space stations" companies aim to create and maintain secure facilities for research, manufacturing, and even tourism in low Earth orbit, such as Virgin Galactic. (Weinzierl, 2018).

Figure 1 below shows a more detailed outline of the different spectrum of space business services according to their level of maturity. We can see from this that in the 'New Space' section, there are sixteen industries in total, double that of 'Traditional Space'; however, almost half of these are still in the 'Emerging' phase, meaning that they haven't yet been implemented. Nevertheless, there are several industries that have been implemented and started, such as ISS Servicing and Space Tourism, which companies such as SpaceX and Virgin Galactic, respectively, have commenced upon.

All of this shows us that while 'Traditional Space' is an established industry, with a few commercial activities, there are a lot more opportunities for companies in the 'New Space' section, especially commercial, with a lot of possibilities to engage in started and emerging activities.

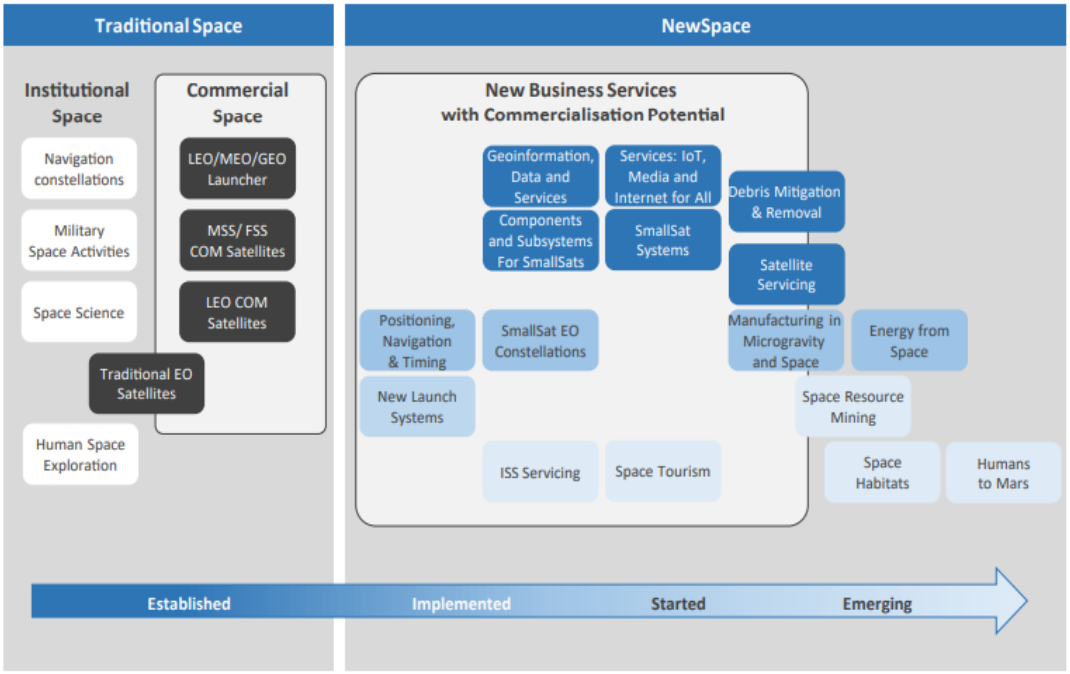

Figure 1. Existing and new business services in the space sector (de Concini and Toth, 2019)

According to Bryce Space and Technology, a leading space industry analyst, in 2020, $7.6 billion was invested into start-up space companies, $1.9 billion more than 2019 (BryceTech, 2021). This tells us that, at least in 2020, there was an increased interest to invest into the start up space industry, meaning that investors see the future potential that the space industry could have.

3.3 Development of a Space Economy

According to Sommariva, (2020), over the course of the 20th and 21st centuries the space economy has been defined by three phases which have been influenced by different public and private actors. The first phase, from 1950 - 1969, the Cold War and the following Space Race was mainly characterised by government run space programs, which helped contribute to the innovation of space technologies and helped space captivate the global masses. However, other actors during this period included the launch of Telstar 1, the world's first communications satellite, which was developed by the American Telephone and Telegraph Company (AT&T), a private company (Smithsonian, n.d.).

The second phase, from 1970-2000, was marked with the gradual entry of private actors, such as Arianespace that was founded as the first commercial space

transportation company in 1980, and Space Adventures, a space tourism company founded in 1998. The dawn of the digital era and the development of the modern-day computer and microchips and the industry surrounding these enabled the growth and production of satellite infrastructure allowing for their commercialisation. In the 1970's the United States issued the 'Open Skies' policy, which allowed any company, provided they had the resources, to launch a communication satellite, which facilitated the quick growth of private telecommunications.

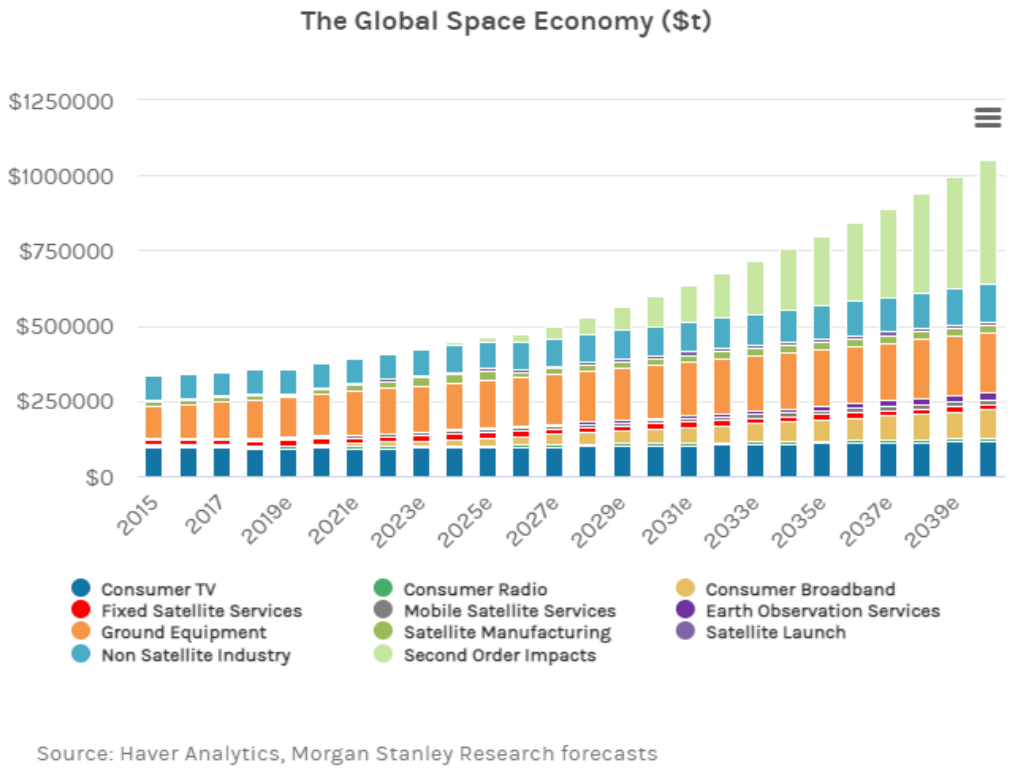

Figure 2. Estimated value of the Global Space Economy (Morgan Stanley, 2019)

The third phase, from 2000 up until the present day, has seen a steadily higher activity of private actors conducting space activities. Morgan Stanley estimates (see Figure 2) that the global space industry has the potential to surpass $1 trillion in revenue by 2040, marking a significant increase from the $446.9 billion generated in 2020 (Morgan Stanley, 2019).

As well as private actors, national and international agencies have also started to realise the benefits of space commercialisation. The European Space Agency (ESA) announced in November 2022, that they would pledge €117.6 million to encourage

entrepreneurship and commercialisation in the European space sector in the hopes of increasing the competitiveness and economic autonomy of Europe's space economy (European Space Agency, 2022). Using this money, the ESA plans to assist the development of businesses though incubation, acceleration, intellectual property, technology transfer, and by helping businesses scaleup their products on new markets.

In 2017, the US Government signed the NASA Transition and Authorization Act, in which policymakers decided to allow commercial providers to carry out missions, such as payloads of supplies and equipment, as well as crew to the International Space Station, allowing NASA to focus more resources on space exploration and basic science and allowing a greater portion of activities in low Earth orbit to be undertaken by private actors providing commercial activities. The signing of this policy means that economic development of space has been largely left to the private sector (Weinzierl, 2018).

However, this presents its own problem, as due to the rapid rise of commercialisation in space, a lot of frameworks and policies have yet to be updated to allow the space economy to stay competitive. Hollinger and Cookson (2021) argue that one such example of this is Elon Musk's Starlink, which as of May 2021, launched 1,730 satellites into low earth orbit (Mann, 2021). The US has already granted Musk approval to launch more than 30,000 satellites, while Germany has applied to grant Starlink space to launch 40,000 satellites. The head of the European Space Agency, Josef Aschbacher stated, "You have one person owning half of the active satellites in the world. That's quite amazing. De facto, he is making the rules" (Hollinger and Cookson, 2021).

Another problem that may arise in the future space economy is that of possible monopolisation of the commercial satellite industry, which in turn can lead to a loss of innovation, little to no competition, and can lead to an increase in prices due to inelastic demand. However, monopolisation can also lead to advantages such as economies of scale that can lead to lower average costs from increased scale, more resources to allocate to research and development, and the ability for governments to regulate more easily. There is also the possibility of oligopoly, which is in some ways similar to a monopoly. However, oligopoly occurs when

there are just a few firms that between them share a substantial portion of the market (Sloman and Garratt, 2019, pp.127–141). Tacit collusion, product differentiation, and higher prices are some characteristics of an oligopoly.

Accountability also comes into question, as currently the only party holding Elon Musk accountable seems to be Elon Musk. This was highlighted in May 2021 when Tesla, electric car manufacturer owned by Musk, suddenly announced that they would no longer accept vehicle purchases using Bitcoin after announcing it would be a possibility earlier that year in March (Hoskins, 2021). This brings about the issue as to whether it is wise to entrust an individual with so much power.

> Society needs successful businesses, but today business is taking over society. It is as if an over-indulged child had taken more and more liberties until it is entirely out of control. Everyone wants the child to do well, no boundaries are set, and before you know it the family is under the thumb of a teenager gone wild (Plesch and Blankenburg, 2008).

China has complained about the proliferation of SpaceX satellites and debris endangering its own space station, while European space experts have expressed concern about the way in which the design of rules for space seems to have been delegated to Musk in practice (McMorrow 2021).

Regarding the subject of space policy, because countries are in practice not at all eager to hand out orbital slots to private individuals such as Elon Musk, there must be policies set in place to govern these individuals and their companies so that space remains a resource usable and accessible to all. Given the current security climate, this is going to be a challenge.

3.4 Commercial Activities

3.4.1 Space Stations

Currently, the International Space Station takes up a third of NASA's budget and costs roughly $3 billion a year to operate and is planned to be deorbited in 2030. NASA has started a competition to fund and had out contracts to privately owned companies to design replacements for the ISS. These companies include Blue

Origin, Sierra Space, Northrop Grumman, Axiom Space, Lockheed Martin and Nanoracks who are competing to be selected in 2025 and expected to be operational in 2028. These companies are competing for an estimated $1 billion in annual revenues from NASA to deliver space station services and ideally become the go-to platform for the rapidly emerging space economy. Research manufacturing, tourism, and entertainment are all services that such an orbital platform could provide (Hollinger, Cookson and Bott, 2022).

Although NASA is promoting replacements for the ISS, it is worried that the market won't be big enough to sustain private stations as the current industry is still maturing. A granular study (Crane et al., 2017) of five potential markets for commercial space stations has estimated that the market would between $455 million and $1.2 billion in annualised revenues by 2025. However, investment bank Citi has estimated that the annual sales for commercial space stations is estimated to be $8 billion, and comprised of services such as research, industrial activities, and astronaut training. Axiom Space has claimed to have already made $2 billion in revenues through private missions to the ISS, private research projects, and is looking to target nations with ambitions in space, who have not easily been able to realise these ambitions. This provides companies and nations and with no space programs or infrastructure capable of launching a vehicle into orbit the possibility to access this lucrative market in the future.

Any emerging space nation will gain access to services in low Earth orbit that we could not afford before, because programmes such as the ISS required a lot of continuous upfront investment," says Sarah Al Amiri, chair of the United Arab Emirates Space Agency. "Now countries such as the UAE will be able to tap into the services that we need" (quoted in Hollinger, Cookson and Bott, 2022).

While the freeing up of funds for government agencies allows them focus on other pursuits, such as landing on the moon (NASA, 2019), the possibility of providing private companies with ease of access to outer space, while no policy or policing is in place is an unsettling concept.

3.4.2 Mining

Mining in outer space is another activity that has gained popularity in recent years, with the vast amounts of resources in outer space offering the possibility to provide vital resources for civilisation. There are currently two sources where resources from outer space could realistically come from, asteroids or the Earth's Moon. On Earth itself, resources such as precious metals and fossil fuels are finite, meaning that once they are used up, they will no longer be available. This will have an impact as the depletion of resources will lead to higher prices of goods, possible regional conflicts for control of resources and environmental damage from soil degradation, damage to ecosystems and pollution (Ross, 2001).

Asteroid mining is a concept where a spacecraft would be used to extract resources such as gold, nickel, iron, and platinum to be used for commodities, and also water, which could be used in as a fuel source or as a usable water supply. Near-Earth asteroids (NEAs) are the most accessible and attractive of these, due to their close trajectories to Earth, meaning that it could potentially require less energy that travelling to the Moon (Cain, 2015).

In 2017, the market value of space mining activities was estimated at $712 million and is forecast to increase to $3.9 billion in 2025 (Statista, 2022). Asterank, a scientific and economic database of over 600,000 asteroids has calculated that the most cost-effective asteroid to mine, named Ryugu, would be worth an estimated $30 billion in profit alone (Webster, 2012).

Currently, the biggest limiting factor is that of technology, with no way of transporting enough materials cost-efficiently to earth to make a profit, or the mining technology to be able to extract metals in the zero-gravity vacuum of space. The estimates of how much such commercial asteroid mining missions would cost is uncertain. However, similarities can be drawn from NASA's OSIRIS-REx mission, which has travelled to a near-Earth asteroid in 2016 and is currently on track to return to Earth in 2023 (NASA, 2016). The spacecraft has room to collect between 60-2000 grams of samples (NASA, n.d.) and has cost over $1 billion (Dreier, n.d.).

The potential value that asteroid mining can bring has also attracted a lot of investment, further highlighting the potential for the future. Luxembourg set aside €200 million in 2016 to fund space mining initiatives (Statista, 2022).

3.5 Space Debris

An issue that is becoming more relevant as more launches are made and more objects are placed in orbit is that of space debris or space junk. The US Department of Defense tracks and catalogues these objects, and as of May 2021, there are more than 27,000 pieces of orbital debris in the near-Earth space environment, equating to roughly 9,000 metric tonnes (London and York, 2022), with many more existing which are too small to be tracked. These debris travel at speeds over 25,000km per hour and are fast enough to cause damage or even destroy spacecraft or satellites. Even a fleck of paint can cause damage when travelling at these speeds, as was seen with the space shuttle in 1983, when a 0.2-millimetre fleck of paint impacted the window (NASA, 2008), causing the windows to have to be replaced due to damage caused (Garcia, 2021).

The build-up of space debris can also lead to another problem, where a collision can start a chain reaction, giving rise to more and more debris to be created, leading to more collisions and so forth. This is known as the Kessler Syndrome (Kessler and Cour-Palais, 1978), which is named after NASA scientist Donald Kessler who observed that once the number of space debris goes past a certain critical mass, the total amount of space debris will keep increasing. An example of this was in February 2009 when a defunct Russian satellite crashed into an operational communications satellite, the result of which produced nearly 2,000 pieces of debris larger than 10 centimetres wide (Wall, 2021). This and other events pose an issue as it increases the risk of satellites being destroyed, astronauts being injured or killed onboard the ISS and also makes reaching or escaping orbit more difficult as it would mean avoiding an increased amount of debris.

In November 2021 Russia unexpectedly launched an anti-satellite missile at a defunct Russian satellite and as a result hundreds of thousands of new fragments were launched into orbit around the Earth (Hollinger, 2021). As well as potentially

endangering the lives of astronauts onboard the ISS, this action also has the potential to hit currently orbiting satellites and cause a chain reaction of collisions. Most of the debris that resulted from this test will probably decay within five years, meaning that they will fall down to Earth and burn up in the atmosphere, and perhaps a fifth will endure for a decade, but some debris from the satellite exploded by Russia might even go as high as 2,000km and take closer to 15 years to decay (Manson and Seddon, 2021).

In 2020 the Satellite Industry Association estimated that there could be more that 100,000 commercial spacecraft in orbit by 2030 (Hollinger and Learner, 2022). However, this figure may be an underestimation, as just three private companies, SpaceX operated Starlink, Kuiper Systems and OneWeb, have registered interest in launching close to 60,000 satellites between them (Hollinger, 2021). Presently, the space sector has only established loose guidelines for the implementation of best practices in order to minimize the generation of debris. These include deorbiting a satellite within 25 years of completing its mission or ejecting any remaining fuel to decrease the risk of potential explosions. Even so, it has taken years for even these basic conventions to win support at the United Nations, and they are still not legally binding and now appear to be insufficient to keep up with speed of progress and activity in low Earth orbit (Hollinger and Learner, 2022).

One of these companies, Starlink, which is operated by SpaceX, has been in the centre of much media attention over the past years since their first launces in 2019. Starlink is a constellation of satellites in low Earth orbit that aims to provide high-end broadband to much of the globe (Starlink, n.d.). According to Hugh Lewis, the head of the Astronautics Research Group at the University of Southampton, Starlink satellites are involved in about 1,600 close encounters every week, where spacecraft pass within 1 kilometre of one another, which accounts for 50% of all incidents. With Starlink aiming to launch 12,000 satellites as part of its first-generation constellation, Lewis predicts that the number of close encounter incidents caused by Starlink satellites could rise to 90% from 50% (Pultarova, 2021).

However, with the global space economy forecasted to be worth up to $3 trillion in coming decades and expected to grow by 74 per cent by 2030 (Hollinger and

Learner, 2022), some companies have spotted an opportunity to profit from space debris.

One of these companies, Astroscale, a Japanese start-up founded in 2013, is one example. "Astroscale is developing innovative and scalable solutions across the spectrum of on-orbit servicing, including life extension, *in situ* space situational awareness, end of life, and active debris removal, to create sustainable space systems and mitigate the growing and hazardous build-up of debris in space" (Astroscale website, n.d.).

Northern Sky Research estimates that the market for in-orbit services, which Astroscale's offering falls under, is going to generate $14.3 billion in revenue by 2031. The ESA and the UK Space Agency are funding its first mission, planned for 2024. The aim of these services, apart from clean-up, are to avert the creation of new debris by preventing satellite collisions, as well as extending satellite lifetime through inspections and maintenance. There are also concerns that until technology to clear up space debris is functional, that it will be difficult to enforce rules for sustainable space use and how to try keep it free of debris. "If there is no solution, people won't know how to regulate…. Currently, technology is the bottleneck" (Toru Yamamoto, quoted in Inagaki, 2022). Without the technology in place to show to what capacity and limitations it presents, governments and agencies can only speculate and plan as to what policy and best practices to implement, whereas reality might be different (Inagaki, 2022).

However, with currently no rules or legislation in place to clear up space debris, or to prevent agencies or companies from creating more, such as Russia destroying one of their satellites, there is no reason that companies would be willing to pay millions to get satellites and other debris removed from orbit. Because of this lack of action, the threat of Kessler syndrome and low Earth orbit becoming polluted with junk, much like the Earth's oceans, increases with each new launch.

"Near Earth, space is a finite resource. If everyone gets to launch what they want, where they want, when they want, without coordination then... space becomes unusable." (Moriba Jah, quoted in Hollinger and Learner, 2022)

3.6 Space Policy

Global space governance has been in place since the early phase of the Cold War when in 1958, one year after the launch of Sputnik, the U.N. Office for Outer Space Affairs (UNOOSA) was established, for legal, technical, and political infrastructure to be established and to aid governments with support in these matters. The UNOOSA also created and has maintained a Register of Objects Launched into Outer Space, which is still in use to this day, with 89% of all objects launched into Earth orbit or beyond having been registered (UN Office of Outer Space Affairs, n.d.).

The same year that UNOOSA was created, the U.N. formed the ad hoc Committee on the Peaceful Uses of Outer Space (COPUOS), which was made permanent in 1959. The Committee was created "to govern the exploration and use of space for the benefit of all humanity: for peace, security and development" (quoted in Goguichvili, Lindenberger and Gillette, 2021) and was responsible for the creation and implementation of five UN space treaties.

In 1960, the then President of the United States, Dwight D. Eisenhower, proposed to the UN General Assembly that the Antarctic Treaty be applied to outer space and celestial bodies (U.S Department of State, n.d.). The Antarctic Treaty was created and signed in 1959 and is still adhered by over sixty years later. Some of the provisions of this treaty include, "Antarctica shall be used for peaceful purposes only", "Freedom of scientific investigation in Antarctica and cooperation toward that end… shall continue" (quoted in Secretariat of the Antarctic Treaty, 2020). These five UN space treaties have been adopted by the U.N. General Assembly (UNGA) follow many of the same principles of the Antarctic Treaty and are the basis that have been used to form the foundation for space governance.

Of these treaties, the one that is most notable is the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space including the Moon and Other Celestial Bodies", otherwise known as the Outer Space Treaty (OST) and was signed and entered into force in 1967 (United Nations Office for Outer Space Affairs, 2019). The Outer Space Treaty provides a basic framework for international space law and composed of the following articles:

> The exploration and use of outer space for peaceful purposes by all States for the benefit of mankind (Art. I); the outlaw of national appropriation or claims of sovereignty of outer space or celestial objects (Art. II); a ban on the placement of weapons of mass destruction in orbit or on celestial bodies (Art. IV); that astronauts should be regarded as the envoys of mankind (Art. V); and that States are required to supervise the activities of their national entities (Art. VI) (quoted in Goguichvili, Lindenberger and Gillette, 2021).

In Article I, the OST creates a framework for cooperation based on ideas like "mankind" and the shared interests of all States. Article II prohibits countries or states from claiming or appropriating celestial bodies such as planets, moons, or asteroids for themselves. On July 31, 1969, Herbert Reis, the United States representative to the U.N. Committee on the Peaceful Uses of Outer Space, explained the reasoning behind the non-appropriation principle:

> The negotiating history of the [Outer Space] Treaty shows that the purpose of this provision [Article II] was to prohibit a repetition of the race for the acquisition of national sovereignty over overseas territories that developed in the sixteenth, seventeenth, eighteenth and nineteenth centuries. The Treaty makes clear that no user of space may lay claim to, or seek to establish, national sovereignty over outer space or a celestial body (Valters, 1970).

If celestial bodies and outer space are indeed the 'province of all mankind' and not under the jurisdiction of any State, then it could be theoretically possible to exploit and own the resources of outer space. The ability to grant exploitation and property rights over natural resources is typically associated with a State's sovereign jurisdiction over the territory in question (Blanchette-Séguin, 2016). Unfortunately, the Outer Space Treaty makes no explicit mention of resource exploitation or property rights as the treaty was created during the Cold War, when only the US and the Soviet Union had spacefaring capabilities, didn't consider the possibility of space becoming easily accessible to all, or for the possibility of technologies such as asteroid mining. Currently, as of October 2022, the treaty is ratified by 112 nations (United Nations Office for Disarmament Affairs, n.d.). While the treaty offers principles to guide the activity of nations, these are broad in nature and are vague, which means that they can be interpreted by different actors as they see fit and are inadequate for today's standards.

There have been attempts to implement policies in recent years, such as in 2015, when the Obama administration signed the U.S Commercial Space Launch Competitiveness Act, also known as the Space Act, which allows US citizens to engage in commercial exploration and exploitation of 'space resources', which covers everything in space that isn't living (Orphanides, 2015). The Space Act of 2015 built upon its predecessor, the Space Act of 1984, which stated:

> Commercial Space Launch Act - Prohibits persons from launching a launch vehicle or operating a launch site within the United States (or, in the case of U.S. citizens, from outside the United States and outside the territory of a foreign nation) unless they are properly licensed; and (2) in the case of a license holder, launching a payload (an object placed in space) unless such payload complies with all requirements of Federal law (Akaka, 1984).

This legislation helped pave the way for the beginning of the commercialisation of space, at least in the United States, by allowing the private sector to develop by establishing a legal framework for private individuals to develop, launch and operate space vehicles: "A United States citizen engaged in commercial recovery of . . . a space resource . . . shall be entitled to any . . . space resource obtained, including to possess, own, transport, use, and sell the . . . space resource obtained in accordance with applicable law, including the international obligations of the United States" (U.S. Commercial Space Launch Competitiveness Act).

The 2015 Space Act allows U.S citizens to engage in the commercial recovery of space resources. The notion that resources in outer space can be owned by private individuals, but states are barred from claiming control over the territory where they are found contradicts itself as the exploitation of resources on Earth is subject to the sovereignty of the state in which the resources are located (Blanchette-Séguin, 2016). Mineral resources located in Antarctica, which are subject to a distinct legal framework, are an exception to this general premise. However, resources located in Antarctica do not give rise to the same concerns that apply to resources in outer space since Article 7 of the Protocol on Environmental Protection to the Antarctic Treaty provides that "any activity relating to mineral resources, other than scientific research, shall be prohibited" (Protocol On Environmental Protection To The Antarctic Treaty).

In 2017, Luxembourg created and passed a legal framework that allows private operators rights to the resources they extract in space, with Article 1 stating that "Space resources are capable of being owned" (quoted in Luxembourg Space Agency, 2017). This is a huge step in space policy and, as of 2022, Luxembourg is the first European country and the second worldwide, after the USA, to pass into law a framework that allows the ownership and use of space resources.

In 2020, the Trump administration proposed the Artemis Accords, an industry-friendly set of bilateral agreements, signed by twelve countries, that further attempts to push the case for granting companies property rights to space (The Artemis Accords, 2020). The Accords highlight principles on Peaceful Purposes, focusing on international cooperation and peaceful relationships between nations; Transparency, which requires nations to publicly describe policies and plans regarding space exploration; Interoperability, which requires nations to utilise international standards, and develop new ones if and when necessary; Registration of Space Objects; and Orbital Debris and Spacecraft Disposal, with partner nations agreeing to mitigate the number of debris created (NASA, n.d). However, while the Accords have been signed by 12 countries, two major players in outer space, China and Russia, have not signed, and without the involvement of the United Nations, or any international institution, the countries which have not signed the Accords, are outside of international law (Skibba, 2021). This of course was further highlighted by the Russian destruction of one of their satellites, and there being no way to make them accountable for their actions.

While the Artemis Accords are a good foundation to update space policy and to bring it into the twenty-first century, a lot of work still needs to be done. For one, more countries should join the Accords, as this way they will have more weight behind them, and further speed up the standardisation of policy and norms, which can lead to them being ratified into modern international law. Using these as a foundation, a new space treaty could be created and would allow the preservation of space as a place for collaboration and exploration, rather than conflict and commercial gain. With it, steps could be taken to clean up debris affecting low earth orbit and limit traffic to avoid collisions. It could also take steps to limit the deployment and testing of weapons in the atmosphere.

On September 8th, 2022, the Federal Communications Commission (FCC), a United States federal agency proposed a set of guidelines called the 'Second Report and Order' designed to keep Kessler Syndrome at bay (Federal Communications Commission, 2022). Current NASA guidelines recommend that satellites be deorbited within 25 years of their decommission. The FCC wanted to change that and adopt a five-year rule that would require "space station operators planning disposal through uncontrolled re-entry into Earth's atmosphere to complete disposal as soon as practicable, and no more than five years following the end of mission" (quoted in Federal Communications Commission, 2022). Meaning that the time from the decommissioning to deorbiting would be reduced, lowering the risk of accidental collisions and creation of debris. The proposal only affects satellites that are US licenced and non-US licenced satellites that are seeking to access US markets, which would directly affect for example, SpaceX's Starlink satellites in the future. However, satellites that are already in space would be exempt from this proposal (Federal Communications Commission, 2022).

Another issue related to current satellites in space and in need of policing is the lack of rules for objects already in low Earth orbit and how to further prevent collisions. "For instance, rules exist about interfering with the broadcast frequencies of other satellites but there is no international system of space traffic control" (quoted in Hollinger, 2021). This fact was highlighted in 2019, when the European Space Agency had to move a satellite out of the way of one of SpaceX's Starlink satellites, when it became clear that SpaceX did not plan to alter the trajectory, despite warning of a collision (Hollinger, 2021).

Mark Dankberg, the founder chain and CEO of Via-sat, and American satellite company, also has concerns that without rules, space may become inaccessible. Because of mega-constellations crowding low-earth orbit, or LEO, there is a greater barrier to entry, as smaller companies, or even nations, might not potentially have the scale or technology to be able to safely occupy the same space within LEO. According to Dankberg, mega-constellations can also cause environmental harm in the future through increased amount of de-orbited spacecraft releasing particles and chemical compounds into the ozone layer. Light pollution caused by large numbers of satellites could also interfere with astronomy. Dankberg also goes on

to explain that if nothing is done, the number of satellites will continue, especially in mega-constellations and the limited natural resource of space will run out. This highlights the fact that there is need for policy regarding outer space to keep it accessible for all, and not just the wealthy or the first adopters, as well as keeping limiting the possible damage caused to the environment by constant launches of new satellites and the de-orbiting of old ones. However, as he stated, these possible damages have not been thoroughly researched, so the impact of these are not yet known as to how damaging they will be (Dankberg, 2022).

The development of policy in outer space has come a long way from the first policies set in 1958, when space was accessible only to the global superpowers of the era. The Outer Space Treaty was a good foundation for its time, but in today's world with space becoming rapidly accessible to all, new policy is needed. While treaties such as the Outer Space Treaty and the Artemis Accords are good frameworks for international policy, there is still no international law that has been signed by all nations, spacefaring or not. For policy in outer space, it is important that all nations adhere to it, and through them, private actors as well to prevent any conflicts or accidents from arising. Countries such as the USA and Luxembourg have both taken steps in the right direction by creating laws that state that private individuals can own space resources, allowing for private entities to access these without the fear of repercussions from these states. However, there is nothing currently stopping individuals from other countries from owning the same resources as individuals who have followed the laws of their countries, as there is no international law for them to currently break if this was the case.

Policy is also needed to address the looming issues of debris in outer space and any international treaties or policies should also address this by either agreeing upon a lifetime in which after satellites would need to be de-orbited in a safe and controlled manner, or some form of traffic control to ensure that no collisions take place. Also, laws preventing the deliberate destruction of property should also be created to prevent debris and even human fatalities from happening.

If scientists, non-government organisations and stakeholders all put pressure on governments and law makers, then the chance to kickstart space diplomacy and enable the new creation of modern, up-to-date laws and policies using existing

treaties such as the Outer Space Treaty and the Artemis Accords as foundations is possible. Developing these laws and policies further to suit the needs of the space industry would be an ongoing and evolving process as the industry continues to develop.

In February 2022, the Russian Federation invaded Ukraine, causing outcry in the international community and triggering a huge shift in geopolitics. During the invasion, it has been reported that Ukraine's defenders have been using Elon Musk's Starlink, possibly the first time a commercially available satellite communication device has been used in an active warzone, allowing Ukrainian citizens and armed forces to use telecommunication devices and access the internet in areas where communications infrastructure had been damaged, destroyed, or turned off. The benefits of Starlink being available have been great as it kept key civic and humanitarian infrastructure running in the country, such as hospitals and banks. It has also been utilised by the Ukrainian army in fighting in their campaign. However, Elon Musk had a change of heart in September of 2022, 'stating Starlink is for peaceful use only' (Elon Musk, quoted in Tett, 2022) and at the same time the systems stopped working in Russian annexed parts of Ukraine causing complications for the Ukrainian army. This once again leads to the question about how much power should an individual wield when it comes to outer space, and what is to stop them from exerting their influence, especially if it is in the extremes of life and death in an active conflict (Tett, 2022). In addition to this, the continuous use of commercial space systems may result in that they are treated no differently than military space systems, resulting in them being disabled or destroyed. This could in-turn explain why Musk did a U-turn on the use of his Starlink, but this is only speculation, as no official comments have been made.

With the ongoing conflict in Ukraine, private and national companies have chosen to shift their launch contacts to launch providers outside of Russia, putting additional strain on other agencies, which in turn means delays in launches (Grunert, 2022). Nearly 200 commercial and civil-space satellites that were meant to be launched in 2022 and 2023 have been delayed since Russia has faced sanctions from Western nations and decided to limit the use of their Soyuz rocket to these nations (Rainbow and Berger, 2022). All of this means that private

companies will look for other alternatives for launching their satellites, whether it be private organisations like SpaceX, or national ones in Europe and America.

4 Conclusion

Based on the research conducted in this paper, it is possible to draw a few conclusions regarding the space industry. While the industry is still in its infancy, there is a massive untapped potential market emerging that is estimated to be worth $1 trillion by 2040. Outer space is gradually being accessed and profited from by different private actors, by the enablement of innovations such as re-usable rocket technology, bringing down costs and enabling easier access. With this ease of access, the space industry also continues to gain investments with massive potential for growth in the future, with significant developments in technologies and new companies entering the market on the horizon.

Once the benefits of increased privatisation of the commercial space industry is that it will free up funds of national space agencies, which until recent decades were the only actors in space, allowing more resources to be potentially spent on exploration and scientific research for the betterment of humankind.

However, there are issues that need to be addressed before space can be accessible to all, including monopolisation, the creation and monitoring of space junk and the lack of policy regarding the use, ownership, and maintenance of outer space and its resources. The cleaning up of space junk will become of great importance in the close future if society wants to keep Low Earth Orbit and outer space accessible to all. Legal frameworks should be implemented to prevent the creation of debris and trying to prevent accidental, or purposeful, collisions in outer space.

Currently, the argument over ownership of resources in space is ongoing, but we are starting to see more developments in terms of space policy and state legislation. Before we see the first harvested resources, there are still a lot of scientific breakthroughs that need to take place. Materials like platinum-group metals, which are uncommon and exceedingly valuable on Earth, are abundant in outer space. It is vital that the legal ambiguity surrounding the possibility for private companies to hold space resources be clarified and that a legislative

framework ensuring the orderly development of space operations be constructed in to prevent international disputes.

If the international community were to take a proactive approach in regards of space policy, actors operating in the space industry would be protected from having to deal with inconsistent national laws that represent various States' potentially opposing views on current legal matters. There are enough old treaties, policies, and frameworks in place, such that it wouldn't take a lot of effort to modernise them and to be adopted by States' and governing bodies such as the United Nations Office for Outer Space Affairs.

Since the invasion of Ukraine in 2022, sanctions and lack of willingness to do business with Russia, private companies looking access outer space will go to other actors, such as SpaceX, Blue Origin and others, as well as nations with launch capabilities. These risks leaving Russia behind in the increasingly competitive commercial space industry, possibly permanently damaging their ability to re-enter the market at all. While the rewards are there for private companies, looking to make more profit from the exit of Russia from the market, causing more growth in other markets to fill up the demand, there is also the risk of Russia taking offensive action against any objects in orbit that it deems a security threat, including commercial satellites, especially if it feels like it has been backed into a corner (see Weichert 2017: 229; 2019).

During the writing of this paper, many external resources were used, primarily secondary data. While there was no lack of resources in the forms of articles, journals and papers, the validity of these was always a concern. While great care was taken to assure that the data was valid, because this paper was exploratory in nature, many changes could happen in the future such as advancements in technology, science, and the creation of policies regarding the use and ownership outer space and its resources. The current conflict in Ukraine is also a situation that has caused deterioration in global geopolitics, including that of the space industry, and at the time of writing this paper, no resolution to the conflict is in sight.

Although the ambition to commercialise space and its resources is not new, and many current and future challenges are still to be overcome, humankind has finally reached a point where it is very rapidly becoming reality.

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