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Environmental Sustainability in Space Tourism

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The commercial space industry has progressed rapidly during the past decade, and the operators have never been so close to success than now. The growing need for exciting and unique experiences has caused an increased demand for public space travel. The space industry has been moving towards a more accessible field with new players from both private and public sectors emerging to the field. The industry is experiencing a paradigm shift from government collaborations and large government investments to a new era of innovation, participation and commercialisation. Many operations of the growing commercial space industry are in conflict with the current trend of sustainable development and environmental protection. The operators of the commercial space tourism industry need to address this issue since they are starting to operate in an era of global environmental crisis.

The aim of this research is to gain an understanding of the current state of the space tourism industry, as well as understanding how environmental sustainability is included to this growing field. The research also addresses how environmental issues should be considered in the operations of space tourism. Since the industry is still in its development stage and regular commercial spaceflights have not yet started, the research mainly concentrates on the future prospects. The research was conducted without a commissioner.

The theoretical framework defines the concept of space tourism the history. It also introduces the most advanced operators of the field, as well as the different forms of commercial space activities. The theoretical framework presents the current laws and regulations of the space industry and discusses the possible future legislation framework for space tourism. It also defines the concepts of sustainability and sustainable development and discusses how these are connected to space activities on different levels.

The research problem was approached by qualitative research method. The research was conducted by gathering theory from literature and articles and collecting data with semi-structured interviews.

Due to the industry being still in its development stage and as there is no regular suborbital or orbital tourism yet, the knowledge of the environmental impacts of this future industry still remains limited. The environmental sustainability has currently only a small part in the operations of the space tourism operators, which results as a crucial need for developing sustainable practices for the industry and including sustainability into the business models. The current limited information about the practices of the operators sets a challenge to form a regulatory framework for the growing space tourism industry. The environmental issues of the industry are recognised in general, but the concrete large-scale actions are still waiting to be taken.

Keywords
Space tourism, sustainability, sustainable development, environment, tourism

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1 Introduction

Space tourism phenomenon is growing interest among the general public and professionals, while at the same time awareness towards environmental protection is increasing. The concept of futuristic tourism in space is very appealing with its ideas of space hotels and other activities, but the concern of outdated regulations, environmental impacts and ethical questions are at the same time causing dilemma. There are also many ethical questions needed to be considered when the field starts to become reality and possibly heading towards its mass phase.

The aim of the research was to gain an understanding of the current state of the space tourism industry, as well as understanding how environmental sustainability is included to the field. Furthermore, the research problem addressed how environmental issues should be considered in the operations of the field in the future. Since the industry is still in its development stage and regular flights have not yet started, the research concentrated mostly on the future prospects of the field. The research problem was approached by gathering theory from literature and articles, combined with gaining knowledge in the form of interviews.

The thesis consists of theoretical framework, empirical part, research findings, consideration of results and discussion. The theoretical framework of this research stars from chapter two, in which the definition of space tourism and its history are explained, and it also introduces the most advanced operators of the field and the different forms of space activities on Earth and in space. The research also presents the current laws and regulations of the space industry and discusses the possible future legislation framework. In chapter three, the theoretical framework continues with the definitions of sustainability and sustainable development. The chapter discusses how space technologies, sustainability and sustainable development can be combined together. The chapter is finalised with the explanation of Sustainable Future Planning Framework and how space tourism can be combined together with sustainability and sustainable development on five different levels. Since the research's focus is on the environmental sustainability, everything is centralised to this aspect.

The empirical part of this research starts in chapter four in which the research design and the data collection method of the thesis are explained and justified. The research was conducted using qualitative research method and the data was collected through semi-structured interviews. The methods are introduced in the chapter four, research design. The chapter five presents the research findings. The results are divided into three main

themes, which are space tourism practices, regulating space tourism and the future of space tourism. The final chapter of the empirical part, chapter six, focuses on the consideration of the results, which is a combination of analysis of the research findings and the used sources. It also includes suggestions for the further work and justifications of the reliability of this research. This was evaluated and justified through credibility and explained in more detail through reliability and validity. The research ends to an evaluation of the thesis process and one's own learning, in which the authors discuss the process, challenges and accomplishments of this work.

2 Space Tourism

Over the years, entrepreneurs, engineers, scientists and the general population have been gradually growing their interest towards space tourism. This can be seen from the growing numbers of publications and articles addressing the topics of spaceports, reusable launch vehicles and space habitats. Some research surveys show that the space tourism industry may in the near future turn into a multi-billion-dollar business due to its exclusivity and attractiveness. The start of the 2020's brought a lot of predictions of what the future may bring to the industry. Some believe that there will be a huge development caused by the increasing and expanding space activity, which could allow the commercial space industry and its operators to grow and increase their operations. The foundation for this change has been set with the SpaceX Falcon 9 rocket and its reusability. (Mäkinen 2020; Seedhouse 2008, 1.)

Space tourism can be defined as space related commercial activity that is a part of extra-terrestrial phenomena containing a variety of space-related tourism activities. It is a new sector of adventure tourism, and the growing need for exciting and unique experiences has caused an increased demand for public space travel. Space tourism can be divided into two categories. The first one is astrotourism, which is linked to visiting space, for example in the form of travelling to the International Space Station (ISS), a large spacecraft orbiting the Earth. The second category is terrestrial space tourism, which can take different forms from going stargazing, meteorite collecting, watching rocket launches, or travelling to space related destinations. In the future, the space tourism sector might not differ much from the current aviation industry, but before reaching the mass tourism phase in the astrotourism sector, it will most likely only offer limited and luxurious experiences for the wealthy elite. (Carter, Garrod & Low 2015, 457; Stimac 2020; Toivonen 2017, 22; Wild 2020.)

The growing commercial space industry is in conflict with the current trends of the tourism industry, in which the awareness of sustainable development and environmental protection is increasing. The future space operations will likely create new challenges on the Earth. Space exploration and space tourism may lead to environmental impacts that could harm both terrestrial and celestial environments. Also, the outdated regulation of the industry is creating challenges regarding the possible unequal access to space and usage of the resources it withholds, which could lead to potential inequality between countries, social classes, private corporations, and individuals. In theory, the growing space industry could also help to create the ultimate sustainable environment on Earth. If the industry reaches large scale, it could pass the limits of terrestrial environment by expanding to

space and therefore offer long-term possibilities for economic growth. This future scenario of using only space resources could protect the environment of Earth and preserve the civilized society through sufficient economy. The space industry will most likely grow along with orbital travel, which could help to create new space businesses and jobs, such as space manufacturing and orbital hotel maintenance. But before any of this can proceed, the industry needs to solve the operational obstacles such as the costs and safety. (Cohen & Spector 2019, 1-2; Toivonen 2017, 22; Toivonen 2021, 76-106.)

2.1 History of space tourism

The road to today's commercial space industry has been complicated and long. The foundation of space tourism begins with the start of space exploration in the 1950's during the Cold War era. The Space Race between the United States (the U.S.) and the Soviet Union (USSR) boosted technology to the point in which the current commercial space industry operators can take private citizens to space. (Stimac 2020.)

Figure 1. The history of space exploration begins

USSR took the lead of the competition after the victorious launch of satellite Sputnik 1 (figure 1). Soviet cosmonaut Yuri Gagarin became the first man in space in April 1961 by making a 108-minute orbital flight in space vehicle Vostok 1. On the same year, the U.S. Mercury program launched Alan Shepard as the first U.S. citizen to space. In 1969, the U.S. citizens Neil Armstrong, Buzz Aldrin and Michael Collins reached the lunar surface of the Moon as the first humans in history. As Armstrong was taking his first step on the surface, he said "That's one small step for a man, one giant leap for mankind", which became one of the most famous quotes in the history of space exploration. (NASA Administrator 2019; Stimac 2020.)

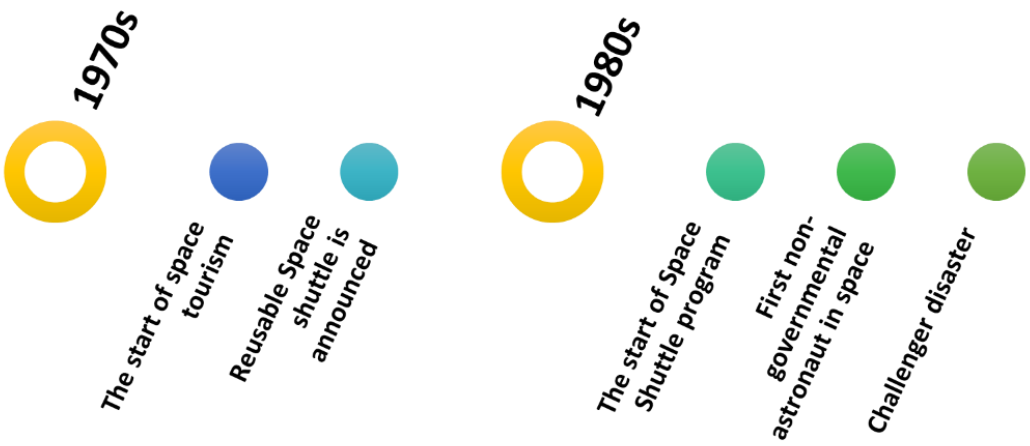

Figure 2. The start of space tourism

In the beginning of 1970s arose an idea of ordinary people traveling to space. This marks the start of space tourism history (figure 2). The new era of spaceflight began after President Richard Nixon revealed the idea of a reusable space shuttle that could carry payloads for space stations. The early concept also had a cabin for up to 74 passengers and it was the first large-scale idea for the space tourism industry. Even though the original plan was never conducted, the idea of space tourism continued to the 1980s, and the U.S. started discussing moon bases and lunar orbit. The focus shifted towards preparing and launching a more advanced spacecraft, the Space Shuttle, that would open new possibilities in orbit. This space shuttle program was also known as the Space Transportation System and the shuttle was launched for the first time in 1981. (Heiney 2012; Stimac 2020.)

National Aeronautics and Space Administration (NASA) gained confidence to launch Space Flight Participant program after the 1984 flight of Charles Walker, who is considered as the first non-governmental astronaut. The program was formed to inspire ordinary people without governmental or scientific roles to travel to space. One of the participants of the program was Christa McAuliffe who was meant to be the first teacher in space. In 1986 McAuliffe and six other astronauts were launched on a mission in the Challenger space shuttle. This launch reminded the world that spaceflights are never routine. The mission ended only 73 seconds after launch when a solid rocket booster failed, causing an explosion that destroyed the whole shuttle and took the lives of all seven crew members. After the disaster, the Space Flight Participant program retired. It took over two years for NASA to launch another space shuttle – Discovery was launched for the next mission in 1988. Overall, the Space Shuttle program was successfully run from 1981 to 2011, with a total of 135 missions launched and 355 people sent to space. (Heiney 2012; Stimac 2020.)

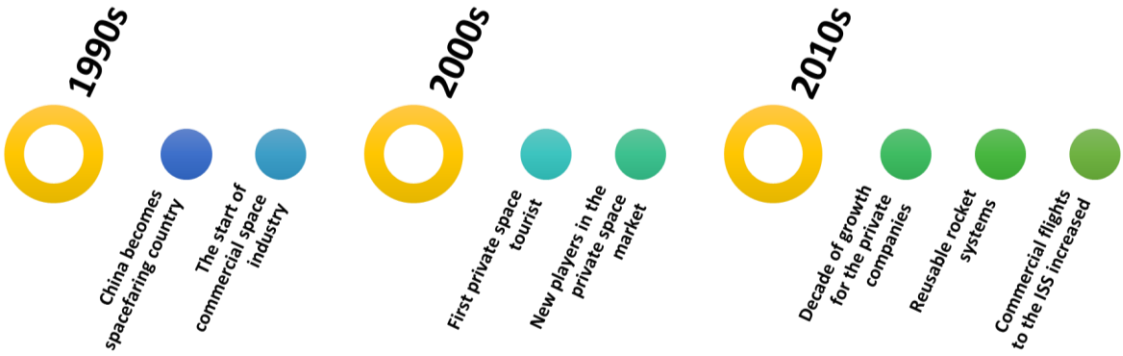

Figure 3. The start of commercial space tourism industry

During the next decade in the 1990s spaceflights and launches were conducted consistently by Russia and the U.S. as well as China, which also slowly proceeded to become a spacefaring country. A new wave of space tourism began (figure 3), and many private companies such as Space Adventures and Bigelow Aerospace were founded. Space Adventures was the first company working towards taking private citizens to space and Bigelow Aerospace had a plan of having a private space station in orbit. (Stimac 2020.)

In the 2000s the industry became a steady reality when Dennis Tito became the first private citizen to purchase a ticket to space in 2001. The ticket was purchased through Space Adventures and allowed Tito to spent eight days in the International Space Station. In the following years, six more civilians visited the ISS. Around the same time, more private companies were established to the field of space tourism. Blue Origin, founded by Jeff Bezos in 2000, SpaceX, founded by Elon Musk in 2002, Virgin Galactic, founded by Richard Branson in 2004, and Rocket Lab, founded by Peter Beck in 2006, became the new players in the space market. Space tourism remained limited from the early 2000s to the 2010s with the only possible destination being the ISS. (Rocket Lab USA 2020; Stimac 2020.)

The 2010s was the decade of growth for the private commercial spaceflight companies, as they started to develop products off Earth, transport supplies to the ISS, as well as reflying rockets. During the decade, the capabilities and diversity of the rocket technologies improved drastically. The private space industry has also made development in Earth observation, for example by using satellites for keeping an eye on missile and rocket programs. Since then, many companies have launched bigger constellation projects. Commercial flights to the ISS increased with new companies entering the market. Various factors have enabled the increased progress on the field. The drop in the cost of accessing

space and grown interest among private investors, has led to the increase of assets of private space companies. The field of human spaceflight has also faced challenges during the decade as many companies working towards commercial space tourism have been forced to postpone their plans due to launch errors, accidents, and development issues. As the companies keep working on overcoming these challenges, the hope in the space tourism industry remains strong. (Wall 2019.)

2.2 Space industry operators

Since the space industry has been moving towards more accessible and democratized field with the new players of both private and public companies and space countries emerging to the field, the control of the industry is no longer within the large industrial groups, corporations or superpowers. Right now, the industry is experiencing a paradigm shift from government collaborations and large government investments to age of participation, commercialisation and innovation. (Merhaba, Ainardi, Aebi & Khairat 2019.)

Figure 4. Most advanced private space companies

A new space race has begun, in which private companies are competing against each other and governmental agencies. Several private companies all around the world have been part of the satellite market for many years, and their input to the development of non-governmental space exploration has aided the new generation of entrepreneurs to start their operations in human spaceflight sector. It is possible that in the next few years space tourists do not need to travel to Central Asia to fly to space. Private companies especially in the US, such as SpaceX, Virgin Galactic and Blue Origin (figure 4) have been

most advanced in the development of reusable spacecrafts. Their main goal is to reduce the cost of access to space, so it would be available for private astronauts. Other companies, such as Space Adventures, has been doing their own part on the private sector by flying customers to the ISS from Baikonur spaceport in Kazakhstan, together with the State Space Corporation Roscosmos (Roscosmos). A company called Axiom Space is planning to fly customers to the ISS with NASA and is also building its own space station, the Axiom station. (Axiom Space 2021; Grady 2017; Minet 2020; Schaal 2016; Toivonen 2021, 88.)

Space Adventures is a private spaceflight company that was co-founded in 1998 by Peter Diamandis and Eric Andersson. The company headquarters is located in Virginia, U.S., and it also has an office in Moscow, Russia. It is the only private spaceflight company that has arranged and flown private astronauts to space, starting with the world's first space tourist Dennis Tito, who flew to the ISS in 2001. To this date Space Adventures has flown eight spaceflights for seven clients. Their vision is to open spaceflight to private citizens by developing new experiences that are safe and exciting with a lower price range in mind. For the future, the company wants to offer their clients a wider variety of choices, such as multiple vehicles and destinations. (Minet 2020; Space Adventures 2021a; Space Adventures 2021b; Space Adventures 2021g.)

Axiom Space is a private aerospace manufacturer and orbital spaceflight services company founded in 2016. The company is based in Houston, U.S. and was founded by Michael T. Suffredini and Doctor Kam Ghaffarian, who both have worked with NASA in the past. In the leadership positions of the company are several former astronauts and they have been involved with the missions of the ISS since the beginning of the program. Axiom provides crewed mission service for private and professional astronauts to the ISS. Other projects of the company are to build and launch the world's first free-flying commercial space station, the Axiom Segment. (Axiom Space 2021; Foust 2020; SpaceFund 2021.)

Blue Origin is a private spaceflight company founded by Jeff Bezos in 2000. It is based in Kent, Washington in U.S. where the company's business, engineering and manufacturing teams are located. Their launch location is in West Texas and it is the world's only privately operated and owned launch site. Bezos quietly established Blue Origin in 2000 keeping the company's plans hidden for years. His aim was to develop rockets that could vertically take-off and land while taking passengers into the suborbital space. The only information that came out at the start was through mandatory disclosures to NASA and FAA. After gaining needed approvals and funding, Bezos launched detailed website and

promotional materials for Blue Origin in the late 2000's. This created a big difference compared to other companies in the field who were still developing their marketing. (Blue Origin 2020b; Howell 2018a; Space.com 2020.)

During the early years, Blue Origin designed and developed prototypes of engines and spacecrafts. They made several tests launches between the years 2005 and 2010, but in 2011 the company had a setback, when a vehicle was destroyed during a test launch. During same year, the company received 22 million dollars from NASA's Commercial Crew Development program. The funding was used to develop their New Shepard rockets escape system and design. In 2012, Blue Origin achieved a key milestone on the development of a safe spacecraft for humans by conducting a successful rocket escape test. Originally the system was planned to be used on suborbital spaceflights, but the company is also intending to use its technology on orbital flights. Blue Origin made history with New Shepard in 2015 by launching and landing a reusable rocket for the first time in the world without any problems. After this the rocket has made several successful test flights and the company is planning on using a reusable first stage in all its orbital flights. In 2020, as a part of testing the technology of precision lunar landing for NASA, Blue Origin successfully launched the suborbital New Shepard rocket to the space and back. This mission was the 13th flight for the rocket since 2015 along with using the latest reusable booster for the seventh time. In the future, the company is planning on testing a few more flights before starting human spaceflights. (Clark 2020; Howell 2018a; Space.com 2020; Tarantola 2020.)

Blue Origin is currently working together with Dynetics and SpaceX to build a moon lander as a part of NASA's Artemis Program, in which astronauts will land on the moon surface in 2024. The company is also working on building a lunar lander called Blue Moon that will be used to deliver robotic cargo to the lunar surface. The Blue Moon technology is based on the data gained from New Shepard project and it has been under development for several years. The technology is also used as a base for the lunar lander under development for the Artemis Program. Blue Origin is also developing an orbital launch vehicle New Glenn in Cape Canaveral's rocket factory. Its engines are being built in Huntsville Alabama, where they also are restoring the historic Test Stand 4670 at NASA Marshall Space Flight Center. (Blue Origin 2020a; Blue Origin 2020b; Space.com 2020.)

Figure 5. New Shepard (Blue Origin 2021)

Blue Origin's rockets New Glenn and New Shepard (figure 5) are designed with reusability in mind. The first stage launch vehicles of both rockets can be reused, which is enabled by vertical take-off and landing with minimal reconstruction. The liquid fuelled engines used by the company make possible a precise landing on the platform, which allows a high asset utilization and a decreased cost when using the vehicles. To maintain safety and reliability, New Shepard is being put through strict testing programs. Blue Origin has succeeded in various crew capsule escape tests that make sure the astronauts are safe during all stages of the flight. To achieve a safe preparation for human spaceflight, the company is also running a payloads program while repeatedly testing the operations and technology. The acquired information from the testing of New Shepard will be used in the future development of New Glenn. (Blue Origin 2020c.)

SpaceX is an American privately held aerospace and aviation company that focuses on designing, manufacturing, and launching rockets and spacecraft. The company was founded by Elon Musk in 2002, and its headquarters are in Hawthorne, California, but the company is working in six different facilities across the US. SpaceX is also currently building a new launch site to the Cameron County area in Texas. This is stated to be the world's first commercial launch location specifically designed for orbital missions, and it also serves as a build and launch site for the Starship test articles and spacecraft of the

company. The ultimate goal of SpaceX is to revolutionize the concept of space transportation along with making life multiplanetary. The specialties of the company currently revolve around Falcon 9 and Falcon Heavy rockets, Merlin Rocket Engines, Dragon Cargo and Dragon Crew spacecrafts, Draco and SuperDraco Thrusters, PICA-X high performance heat shield material, and Satellite Development. (SpaceX 2020b; SpaceX 2020c.)

SpaceX has reached many milestones throughout the years. In 2008, their Falcon 1 became the world's first privatively developed liquid fuel rocket that succeeded to reach the orbit of Earth. In 2010, SpaceX returned a spacecraft from the low Earth orbit (LEO) for the first time and became the only private company ever succeeding to do so. The company achieved another milestone in 2012 with their Dragon spacecraft – it became the world's first private spacecraft to attach to the ISS. Since then, Dragon has made multiple cargo resupply missions to ISS and back for NASA. In 2015, SpaceX made history again with the first ever orbital class rocket landing, when their Falcon 9 succeeded in delivering 11 communication satellites to orbit, and the first stage of the rocket returned and landed successfully to the landing zone. Next year, in 2016, SpaceX achieved their first landing on a droneship after Falcon 9 launched the Dragon spacecraft to ISS – the first stage of the rocket returned and landed successfully on the company's "Of Course I Still Love You" droneship. In 2017, the world's first reflight of an orbital class rocket was achieved by the company, along with returning the first stage of Falcon 9 back to Earth for the second time. The Falcon Heavy -rocket made its first launch to orbit in 2018, launched its payload to space, and landed successfully 2 of the total 3 boosters. In 2019, SpaceX's Crew Dragon -spacecraft successfully reached the ISS and docked autonomously with the orbiting laboratory as the first American spacecraft. In 2020, SpaceX launched two astronauts of NASA to the ISS in their Crew Dragon and made history by becoming the first private company that sent a crewed spacecraft to space. The astronauts Bob Behnken and Doug Hurley returned successfully back to Earth in August 2020. (Howell 2020; SpaceX 2020b; SpaceX 2020c.)

Figure 6. Falcon 9 (SpaceX 2020)

SpaceX has designed and manufactured their Falcon 9 rocket (figure 6) to be a reliable and safe transport vehicle for both people and payloads. This two-stage rocket can reach beyond the Earth orbit, and the company claims it to be the world 's first reusable orbital class rocket. The most expensive parts of Falcon 9 can be reflown, which decreases the cost of accessing space. SpaceX is also currently developing a fully reusable transportation system called Starship. The system consists of the Starship spacecraft and the Super Heavy rocket, which will be used to carry crew and cargo to the orbit of Earth, the Moon and Mars. According to the company, this launch vehicle will be able to carry over 100 metric tons to the orbit, which would make it the most powerful rocket in the world. (SpaceX 2020a; SpaceX 2020b; SpaceX 2020e.)

Virgin Galactic is the world’s first vertically integrated aerospace company that focuses on commercial spaceline operations. It is a British company founded in 2004 by Sir Richard Branson. Its headquarters and flight operations are located in Spaceport America that is the world’s first commercial spaceport based in New Mexico in the US. Spaceport America also works as a launch location and training location for astronauts. Virgin Galactic’s sister company called The Spaceship Company, which operates and develops space vehicles. Originally Branson predicted that the company would be flying customers into space by 2007, but the plans have been pushed forward with the 2007 fatal explosion during a ground test, and with the 2014 tragic test-flight crash and development issues. In

2018 their VSS Unity test vehicle made a significant accomplishment by reaching space with an altitude of 82.7 kilometres. (Encyclopædia Britannica 2020b; Howell 2019; Virgin Galactic 2020b; Virgin Galactic 2020c; Virgin Galactic 2020f.)

In 2020, Virgin Galactic has signed two Space Act Agreements with NASA. The first agreement focuses on developing hypersonic transportation technologies that focus on environmental responsibility and customer experience. With this agreement, the collaboration is expected to strengthen between Virgin Galactic, The Spaceship Company, and NASA. The second agreement with NASA is focusing on orbital human missions to the ISS. Virgin Galactic's role is identifying potential passengers, training, and conducting the flights to ISS and back. The company is planning to have its first powered spaceflight with two test pilots from Spaceport America. If the test flight is successful, another powered spaceflight is expected to happen with two test pilots and four mission specialists. If both flights succeed, the company is predicting Sir Richard Branson to board a flight in 2021. (Foust 2020b; Rose 2020; Virgin Galactic Holdings, Inc. 2020.)

Virgin Galactic works on innovating reusable space vehicles that cost less to launch, are safer, and environmentally sustainable. The company wants to offer experiences to non-professional astronauts in micro-gravity and high acceleration environments. The company will also offer researchers a chance to examine and study space. Virgin Galactic's future vision is to operate in various locations with multiple vehicles. The aim is to ensure that the growing demand is met by providing transcontinental services to passengers travelling to Earth orbiting science laboratories or hotels and between different planets. The company has agreed to develop a spaceport in Abu Dhabi in addition to the plans of operating from Spaceport America. The company has already reserved flights for hundreds of customers from more than 60 countries. (Howell 2019; Telford 2019; Virgin Galactic 2020a; Virgin Galactic 2020c; Virgin Galactic 2020f.)

Figure 7. WhiteKnightTwo and SpaceShipTwo (Virgin Galactic 2020)

Virgin Galactic is working on the reusable SpaceShipTwo spaceflight system. It consists of WhiteKnightTwo, which is a custom-built, carrier aircraft and SpaceShipTwo, which will be the world's first privately built spaceship aiming to be used for commercial customer flights (figure 7). The current SpaceShipTwo was named as VSS Unity by Professor Stephen Hawking in 2016 unveiling ceremony. WhiteKnightTwo has a design that offers extensive and effortlessly accessible payload area during the separation of the spaceship. SpaceShipTwo is a winged spacecraft that is invented to carry two pilots and six customers. The spacecraft is fully reusable excluding the rockets oxidizer and fuel. The design has unique capability to transform its shape in space during flight. A repeatable safe reentry is ensured by rotating the tail booms and wings upwards. (Virgin Galactic 2020a.)

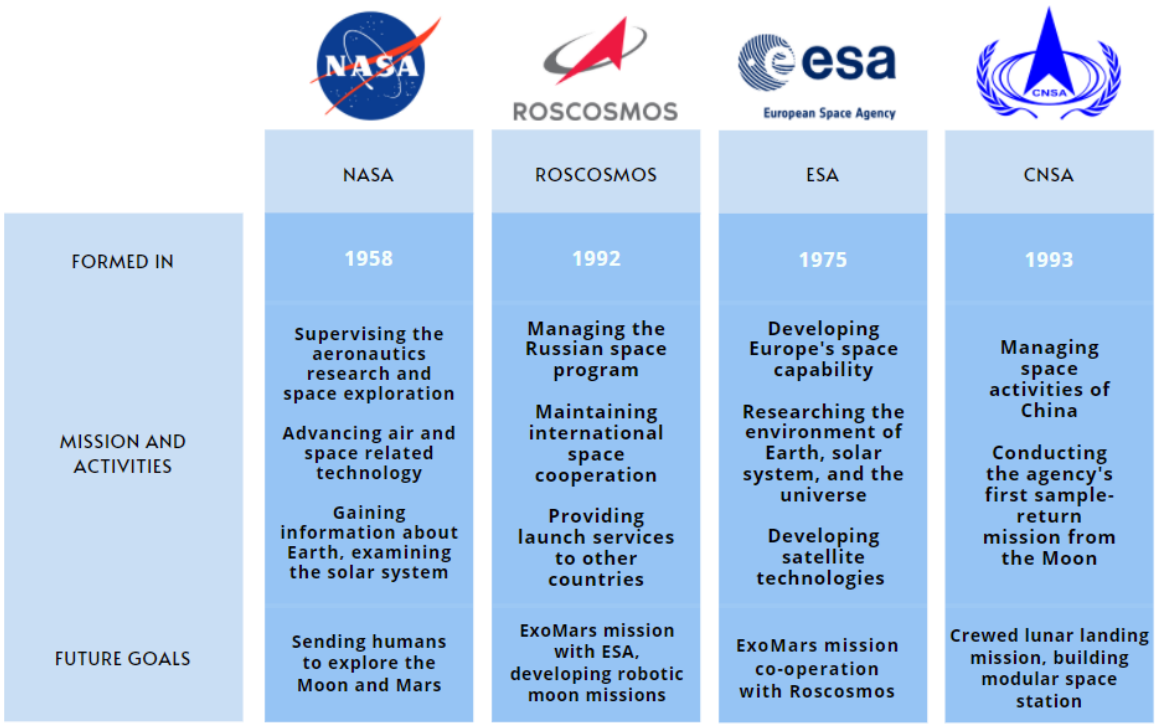

Figure 8. Governmental space agencies

Since the industry is going through evolution, the roles of space agencies are also changing. When the first agencies were founded in the 1950's, they were the main actors and investors in the industry. Space agencies need to redefine their role in the national space industry and foster future collaborations with the private sector. To include private sector actors to their operations, these agencies need to focus on attracting international investment and encourage private sector involvement in the national space sector. Almost every country in the world has a space agency of their own, but NASA, Roscosmos, ESA and CNSA (figure 8) are among the largest space agencies in the world. Some of them are already working with private space companies or with other international collaborations. (Merhaba & al. 2019.)

NASA was founded in 1958 to supervise the aeronautics research and space exploration conducted by U.S. It is responsible for the air and space related technology and science. The first human spaceflight programs founded by NASA were The Mercury, Gemini, and Apollo, which aided the agency to learn about space travel. By these programs, NASA was able to land the first human on the Moon in 1969. Today, the agency has visited every planet in the solar system and numerous other celestial bodies. NASA focuses on conducting scientific research by launching astronauts to orbit, gaining information about Earth by using satellites, sending space probes to examine the solar system and beyond, and developing the air travel along with other flight aspects. Valuable information, for example a better understanding of weather patterns, has been gained by using satellites.

NASA has astronauts currently working and living on the ISS and the next step for the agency is to send humans to explore the Moon and Mars. Also, the agency collaborates with the American aerospace industry through NASA's Commercial Crew Program. The program supports space industry companies developing and operating new generation of space technology that enables access to LEO and the ISS. (National Aeronautics and Space Administration 2017; May 2020.)

Roscosmos was formerly known as the Russian Federal Space Agency (RSA). The agency was formed in 1992 after the collapse of the USSR. In 2015, RSA and United Rocket and Space Corporation (URSC) were merged into Roscosmos. During the 1950s and 1960s Space Race, the former USSR had several world firsts, including the first human in space. Roscosmos was founded to oversee and execute a reform of the Russian space industry. The agency ensures the effectuation of the space program of the Russian government along with its legal procedures. It also assigns orders for the manufacturing, developing, and supplying space equipment and infrastructure objects. The responsibilities also include maintaining the international space cooperation and providing launch services to other countries. The agency has been a major contributor on resourcing the ISS from the beginning still to this day. On the commercial side, Roscosmos has been cooperating with Space Adventures since 2001 and has flown a total of seven customers to the space station. In the future, Roscosmos will co-operate with the European Space Agency on a major Mars mission, called ExoMars. The agency's other plans for the future include developing a series of robotic moon missions, called Luna-Glob. (Howell 2018b; Shelley 2019; State Space Corporation ROSCOSMOS 2020; U.S. Embassy & Consulates in Russia 2020.)

The European Space Agency (ESA) was established in 1975 from the merger of European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO). The mission of the agency is to develop the space capability of Europe and ensuring that investment in space is beneficial to the citizens of Europe and the rest of the world. The organization coordinates the financial and intellectual recourses of its 22 member nations and co-operates closely with other space organisations outside Europe. This enables the agency to implement actions and programs that no European country can achieve alone. The programmes carried by ESA are created for researching Earth and its space environment, the solar system, and the universe, along with developing satellite technologies and promoting European industries. Along with these ESA manages the information needed to understand and respond to threats from space and the Earth. The agency has set goals for 2030 in various fields to ensure the safety of Earth, space, and the environment. ESA has also launched Boost! – ESA's Commercial Space

Transportation Services and Support programme, which promotes plans for commercial space transportation services. The agency is fostering entrepreneurship, encourages competitiveness and growth in Europe's private space sector. The programme also includes supporting national space transportation objectives of the ESA Member States regarding spaceports, testing facilities, and services related to them. (Encyclopædia Britannica 2020a; The European Space Agency 2021a; The European Space Agency 2020b; The European Space Agency 2020a.)

The history of China National Space Administration (CNSA) begins with The Ministry of National Defence's Fifth Research Academy that was founded in 1956. It was responsible for developing ballistic missiles and later in charge for the first phases of China's space program. In 1992 China started its own human spaceflight program and year after in 1993, Chinese Aerospace Corporation was founded to supervise the manufacturing of space-equipment. At the same time CNSA was founded to manage national space activities. China became the third country to achieve human spaceflight by launching its first taikonaut Yang Liwei into orbit in 2003. Today, China is considered as largest force in space after Russia and the US. The agency has its own small space station, and its future plan is to build an even larger modular space station starting in 2022. CNSA is also conducting its first sample-return mission from the Moon and will begin the next research phase between 2023-2027. The agency's other plans include preparing for a crewed lunar landing mission taking place in the 2030s and building an outpost near the lunar south pole with international partners. On the commercial side, the operators of China's space industry have established China Commercial Space Alliance, which operates under CNSA. The alliance is assisting in regulating and promoting the country's rapidly growing private space sector. (Howell 2016; Jones 2019; Logsdon 2016; Williams 2020.)

2.3 Future space tourists

The terms astronaut, cosmonaut, taikonaut, and spationaut are commonly used when talking about professional space travellers. They have been trained by governmental space agencies such as the NASA, ESA, or Roscosmos to serve as a member of a spacecraft crew. The training of professional space travellers was exclusively conducted by the governmental space agencies until 2001. The flight of the first non-professional astronaut, Dennis Tito, started a new category of space traveller, a spaceflight participant who is defined as a person who pays to travel to space. This term is approved by NASA and Roscosmos to differentiate a professional astronaut and a civilian space traveller from each other. (Seedhouse 2008, 1.)

There are different categories for the future space tourists. The first category includes the wealthy elite who is able to afford the expensive ticket, and the commercial scientist astronauts who are hired to fly a payload or conduct research in space. The second category consists of people who are waiting for the decreased ticket prices. The third category is people who value the feeling of being involved in space tourism and want to witness the experience of spaceflights indirectly. These people will travel to spaceports and expect to feel welcomed to spend time in a similar environment as a commercial airport or a cruise ship terminal. Money will be spent on souvenirs, food, and beverages, along with accommodation. (Seedhouse 2017, 3.)

The personalities of the pioneering space tourists can be divided into three types. There are people who want to remake their self by leaving the Earths familiar structure and society. By joining a spaceflight, they seek to achieve a life-transforming experience. Others want to experience something extraordinary out of the everyday life. To these people, a spaceflight represents a once-in-a-lifetime adventure. Some people seek for admiration from the public and wish to gain respect for their bravery. Also, there are those who want to board a spaceflight just to show the world that they are able to participate in such luxurious activity. (Toivonen 2021, 105-106.)

2.4 Terrestrial space tourism

Terrestrial space tourism can be defined as entertainment experiences in which the participant is not required to physically leave Earth. These activities are for example visiting space related exhibitions, museums and observatories, visiting spaceports, stargazing, UFO hunting, meteorite rock collecting, space movie-related travelling, eclipse tours, and watching the Northern Lights. Another form of terrestrial space tourism is cyber space tourism, which includes virtual gaming environments and virtual reality travel. One example is the start-up company SpaceVR, which offers 360-degree space tour experiences. The company's future plan is to send cameras to the ISS and film interactive 360-degree 3D videos. The footage will be used on virtual reality headsets such as Oculus Rift and Samsung Gear VR. Another example is public virtual reality tours that are already available in many locations. One of them is in NASA's Kennedy Space Visitor Center located in U.S., which presents realistic 3D simulations of the soil of Mars. This form of space tourism gives an opportunity to experience space for many people who are unable to experience the commercial space tourism due to health or financial reasons. Other advantages of virtual tourism compared to real space travel are safety, environmental sustainability, easy access and budget friendliness. (Toivonen 2021, 8-9.)

Another example is the company Space Adventures who offers experience to learn and survey the preparations of Russian manned spaceflight program. Customers can also experience what kind of training private and professional astronauts go through, for example to complete a spacewalk or to fly the Soyuz spacecraft. All of these programs are organized at the Yuri Gagarin Cosmonaut Training Center located near Moscow, Russia. In Baikonur Cosmodrome located in Kazakhstan the company offers customers possibility of witnessing a real rocket launch. The customers are able to follow the final preparations and launch of the Soyuz rocket less than 2 kilometres away. (Space Adventures 2021f; Space Adventures 2021h.)

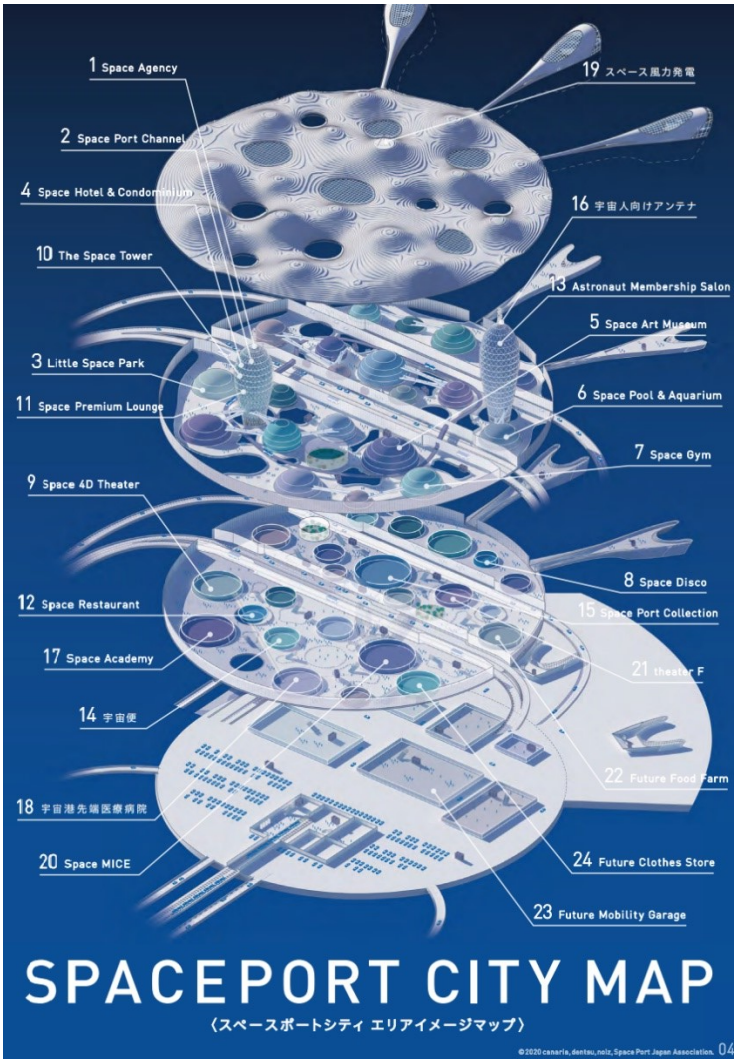

Figure 9. Concept of Spaceport city Japan (Space Port Japan Association 2020)

When commercial spaceflights become part of everyday life, the concept of future spaceports will serve as a new type of transportation hub. Spaceports could include a combination of space travel with entertainment, futuristic architecture, and research facilities. One example is the Japanese Spaceport City, which is planned to be the first spaceport in Asia (figure 9). The overall plan of Space Port Japan Association is to become the hub for the

space travel business in Asia. Traditional spaceports have been around for some time in the form of federally owned facilities for rocket launches. In the recent year's, programs like NASA's Commercial Crew and Cargo have enabled an access for private space companies to join the business which has created a need for commercial spaceports. The types of the rockets used as well as the people boarding them defines what kind of spaceport is required, varying from a large-scale structure to small pads of concrete. In addition to the launch area, other facilities are required to serve the needs of space travellers. These include for example astronaut training facilities, medical facilities, and emergency facilities. Added amenities, such as hotels, entertainment facilities, restaurants, theme parks, and space camps provide activities and relaxation for the customers of spacelines along with their family and friends. Even if no launches are taking place, services like these can operate as destinations in themselves. (Dean 2020; Seedhouse 2017, 3-6; Space Port Japan 2020.)

Spaceport America located in New Mexico, U.S., is the world's first spaceport purposely built for commercial operations. The site is licensed by the Federal Aviation Administration (FAA) and has its own restricted airspace, vertical launch complexes, runway and low population density surrounding the area. In 2019 Virgin Galactic moved all their operations to the Spaceport America. There have already been 300 launches done at the spaceport, which hosts aerospace missions, vertical rocket launches, high altitude balloon missions, and also, the world's largest rocket competition, the Spaceport America Cup. Their vision is to become a leading multi-modal spaceport for aerospace operations, development, testing and research and also serve as a hub for point-to-point space transportation. (Spaceport America 2021a; Spaceport America 2021b.)

Figure 10. Map of active spaceports that perform orbital human launches

The main location for spaceport development worldwide is the U.S., with 12 government-licensed commercial launch sites supporting a combination of horizontal, vertical, and non-traditional launch systems. These sites combine multi-user establishments and exclusive use locations. The development of spaceports has also started in several other countries around the world including Australia, New Zealand, Guam, Singapore, Japan, Sweden, Norway, UK, Italy, Spain, Brazil, Costa Rica, and Mexico. But right now, there are only three active spaceports in the world that perform orbital human launches. These ports are, the Kennedy Space Center in U.S., Baikonur in Kazakhstan and The Jiuquan Space Launch Center in China (figure 10). (Roberts 2020; Web Team 2020.)

The NASA's Kennedy Space Center (KSC), located in Florida, U.S., has been operating since the late 1960's. The spaceport has been hosting all of the crewed spaceflights of the federal government, and is known for the launch of Apollo 11, which led Neil Armstrong and his two crewmates to enter surface of the Moon. The facility was also the launch site subsequent flights of the Apollo program as well as all 135 space shuttle missions. Ending the operations of the shuttle program led to decreased workforce, but the officials are still aiming to keep KSC in the frontline of the crewed spaceflight operations of America. (Wall 2018.)

The Baikonur Cosmodrome, located in Kazakhstan, is the world's first and largest space launch facility in operation. It was built in 1950's to be the base for the Soviet space pro-

gramme. The facility is leased to Russia until 2050, and it hosts numerous scientific, commercial and military launches. It is known for several historical launches; the first manufactured satellite Sputnik 1, the first astronaut Yuri Gagarin, and the first space tourist Dennis Tito. Since 2011, after the end of NASA's Space Shuttle program, Baikonur became the main launch site for sending crewed missions to the ISS. (Toivonen 2021, 96.)

The Jiuquan Space Launch Center (JSLC), the longest-serving rocket facility in China, was established in 1958 with Soviet assistance. Hundreds of military tests and numerous remote sensing satellites have been launched from this spaceport, as well as the first Chinese crewed spaceflight in 2003. The main military operations of the facility have been moved elsewhere, and nowadays Jiuquan serves as a launch site for the civilian manned space program and satellite operations. The China Great Wall Industry Corporation is advertising the commercial launch activities of JSLC to international customers. (James Martin Center for Nonproliferation Studies 2011.)

2.5 Suborbital and orbital space tourism

Spaceflights can be divided into suborbital and orbital flights, in which the biggest difference is the speed of the vehicle. An orbital spacecraft is flying generally at a speed of 17,500 mph or greater, and it must reach so-called orbital velocity, which defines a speed that is enough to get an object to stay in orbit, while a suborbital rocket flies at a lower speed. Even greater speeds enable multiplanetary travelling. According to the Fédération Aéronautique Internationale, an international organisation focusing on aeronautical and astronautical activities and definitions, defines, that the space begins 100 kilometres up. This definition is known as the Kármán line – the border between atmosphere of the Earth and space. This is somewhat higher than what the U.S. Air Force considers as the definition. (Encyclopædia Britannica 2011; Fédération Aéronautique Internationale 2020; Federal Aviation Administration 2020b; Mann 2020; Seedhouse 2008, 1.)

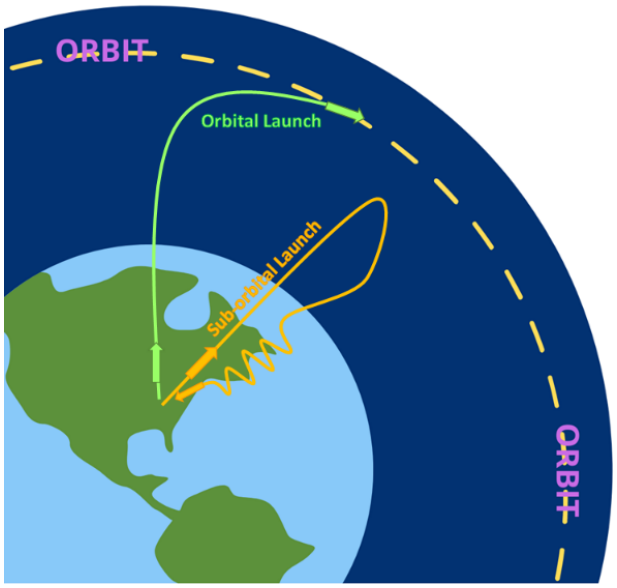

Figure 11. Human spaceflight (adapted from Federal Aviation Administration 2020b s.a.)

In suborbital flights, the spacecraft reaches space, but is not able to reach the orbit, as figure 11 shows. It will fly to a certain height depending on the speed of the vehicle and when the engines are shut off, the vehicle will come back down. Even during these kinds of flights, the passengers have a chance to experience a few minutes of weightlessness during a freefall. This occurs at the top of the flight arc while falling towards the Earth. As suborbital space tourism does not require astronaut training from the passengers, it will be the first form of so-called common space tourism to operate. Though, training for the in-flight basics, such as weightlessness, equipment usage, safety, and acceleration is needed before attending a suborbital spaceflight. (Federal Aviation Administration 2020b; Mann 2020; Toivonen 2021, 11.)

As in 2021, the most advanced competitors in the field of future suborbital spaceflights are Blue Origin and Virgin Galactic. Both companies will use rocket-powered systems that can carry up to six passengers. Virgin Galactic's spacecraft SpaceShipTwo reaches around 90 kilometres and also allows the passengers to float in microgravity before heading back to Earth. The company has sold tickets to approximately 600 passengers, ticket prices varying from 200 000 dollars to 250 000 dollars. Passengers will have three-day training before the flight. Blue Origin's rocket New Shepard is able to reach an altitude of more than 100 kilometres and then it floats in microgravity for a few minutes before returning back. The company has not yet determined how much tickets will cost, but it will price them comparable to competitors. Compared to Virgin Galactic's plans for passenger training of three days, Blue Origin is expecting passengers to train for one day before the flight. (Sheetz 2020.)

Space Adventures has also announced a cooperation with SpaceX to fly up to four private astronauts to low-Earth orbit with SpaceX Crew Dragon spacecraft. The goal of the mission, which lasts up to five days, is to break the altitude record for the private citizen spaceflight. The spacecraft has been designed to fly autonomously, but the passengers will get proper training in case of emergencies. The mission is said to happen around late 2021 or early 2022. Space Adventures also cooperates with ZERO-G Experience company that offers weightlessness flights. (Chang 2020; Space Adventures 2021e; Space Adventures 2021i.)

Another option for a microgravity experience is parabolic “zero-gravity” flights. During them, a microgravity environment is created by flying an aircraft in alternating upward and downward turns. The passengers vary from scientists conducting microgravity experiments to those who just want to experience the feeling of weightlessness. Zero Gravity Corporation, a private space tourism and entertainment company, is offering a commercial opportunity to join zero-gravity flights in the US. Since 2006, the company has provided thousands of individuals weightlessness experiences without going to space. ZERO-G uses a modified Boeing 727-200 for hosting their zero-gravity flights. Another example of a company offering zero-gravity experiences for the public is Vegitel, a Russian aerospace tourism operator. The company operates the weightlessness flights from Chkalovsky airport in Moscow, and also offers tours of the Yuri Gagarin Cosmonaut Training Centre. Vegitel is using IL-76 MDK aircraft flying laboratory for their flights. (Gohd 2020; Vegitel 2021; Zero Gravity Corporation 2021.)

Figure 12. Concept of Bloon (Zero2Inifinity 2021)

One form of suborbital tourism is reaching near space with a high-altitude space balloon (figure 12). Several companies, such as Zero2Infinity, Space Perspective and EOS-X Space, are currently developing their concepts for lifting passengers to space by using helium- or hydrogen fuelled balloons. The space balloon systems are stated to be environmentally friendly, as the fuels used produce zero emissions. Zero2Infinity is working on their concept of Bloon, a four-hour long space balloon experience during which the passengers can enjoy a view of Earth at an altitude of 36 kilometres. The cabin can fit up to four passengers and two crew members. The company is making test flights in various airports and air force bases in Spain, and states that several launching spots for commercial bases are being considered. (Space Perspective 2020; Space Perspective 2021; WAYA Staff 2020; Zero2Infinity 2020.)

Space Perspective is promoting its concept of Neptune capsule, which will offer suborbital space balloon flights up to the altitude of around 30 kilometres. Up to eight passengers at a time can be onboard of Neptune capsule, which is equipped with amenities such as bar and lavatory. The six-hour flight will end with the capsule splashing down to the ocean. A recovery ship will then collect the balloon, capsule, and the passengers, and transport them back ashore. Space Perspective is aiming to conduct the first test flight of Neptune 1 around the first quarter of 2021 and has set a target for operational flights to begin in 2024. (Space Perspective 2020; Space Perspective 2021.)

A Spanish start-up EOS-X Space is planning to launch their high-altitude balloon flights from the Middle East. Their space balloons will lift a pressurised cabin to the altitude of 40

kilometres, providing the passengers an experience of seeing the curvature of Earth. The cabin can fit up to five passengers and one crew member at a time. EOS-X Space is aiming to reach a goal of sending 10,000 customers to space by 2030. The earliest plans for starting the flights are set to summer 2021. (WAYA Staff 2020.)

To this date, orbital space tourism has only been flights to the ISS with the Russian Soyuz spacecraft, but as private companies entering the field, more options are developed and offered for the future space tourist. In February 2021, SpaceX announced the world's first all-commercial astronaut mission to be conducted towards the end of the year at the earliest. Billionaire Jared Isaacman bought all four seats of the Crew Dragon spacecraft and is donating three of them to the general public. The other passengers flying alongside commander Isaacman will be an employee of St. Jude's Children's Research Hospital, a member of the public chosen through a fundraiser campaign for the hospital, and an entrepreneur chosen through an eCommerce competition. The mission, called Inspiration4, will take the crew to orbit and back, and no professional astronauts will be on board. The inspiration4 crew will go through commercial astronaut training, emergency training, and mission simulations before the multi-day journey, which orbits Earth every 90 minutes on a customized flight route. In the end of the mission, the Dragon spacecraft will do a water landing off the coast of Florida. (Sheetz 2020; SpaceX 2021c; Wall 2021.)

Axiom flights on SpaceX capsule are supposed to start in 2022 and be one of the first flights not involving any governmental space agencies. Before the 10-day mission in microgravity, the three participants are required to take fifteen weeks of training at space agency facilities. During the mission, the company is going to send an Axiom astronaut with the participants to serve as the flight commander and to oversee them while in the ISS. NASA has set up a price list for charging companies, such as Axiom, to use the ISS for commercial business activities. For each tourist, the company is charged 35 000 dollars per night, which includes the usage of amenities of the station. In addition, the price of the rocket ride, which Axiom pays to SpaceX, is around 55 million dollars. To the customer using this kind of service, the total price reaches millions of dollars. On the beginning of 2021, Axiom Space announced its four clients for the Axiom Mission (Ax-1). The mission is planned to happen during 2022 and it will be the first in a series of flights to the ISS. (Axiom Space 2020b; Chang 2020; Pearlman 2021.)

Roscosmos is sending two commercial passengers to the ISS in 2023, after a decade long break from the space tourism industry. During the break, the state space corporation has cooperated with Space Adventures in sending their customers to the ISS and on Soyuz trips. This time Roscosmos is the one sending the customers to the ISS but is working

together with Space Adventures. For the first time ever one of the passengers will perform a spacewalk with a cosmonaut, which is a first for a commercial passenger. (Grush 2020.)

An example of Space Adventure's in space experience is flying with the Russian Soyuz spacecraft to the ISS, where customers will be staying and working for 10 days or more with professional astronauts. Another experience is the Circumlunar mission, which is yet to be confirmed for launch. The mission takes two private astronauts and one cosmonaut around the far side of the Moon. But before they get to fly around the Moon, they will stay in the ISS approximately 10 days, and from there a second rocket will launch a Lunar Module. The Moon journey will last approximately six days. (Space Adventures 2021c; Space Adventures 2021d; Space Adventures 2021i.)

Figure 13. CST-100 Starliner (NASA 2021)

Boeing is developing its own commercial spaceflight services with spacecraft Starliner (figure 13). The company is in collaboration with NASA's Commercial Crew Program and the agency has ordered six missions to the ISS with the Starliner. These will be Boeing's first commercial human spaceflight missions. The spacecraft could take up to seven passengers to LEO, and to the ISS it could take four NASA-sponsored crew members with a possible space tourist as the fifth member. The Starliner is designed with reusability in mind, and it can be used up to 10 times. (Boeing 2021; Sheetz 2020.)

Virgin Galactic does not have plans of developing an orbital spacecraft of its own right now, but the company has signed an agreement with NASA's Johnson Space Center to be a part in the process of providing orbital spaceflight services. Virgin Galactic has received 12 deposit agreements from customers since starting the co-operation with NASA, but the final prices are still to be confirmed. The new orbital astronaut readiness program under development is aimed to provide private customers a chance to purchase missions to the ISS, and it is based on Virgin Galactic's experience of commercial spaceflight training. The company states to offer the participants and unique approach to orbital spaceflight from the procurement of transportation to the training and preparing for the flight. (Sheetz 2020; Virgin Galactic 2021.)

In the future, there could be hotels rotating the Earth's orbit, positioned approximately 500 kilometres above the planet's surface. These kinds of facilities could include for example restaurants, gyms, well-being areas, auditoriums for business meetings and plant rooms. The hotel would be built with large windows and telescopes to help gazing the Earth or stars. Contact shuttles from Earth could take around 20 minutes flight time to reach these space hotels. (Toivonen 2021, 18.)

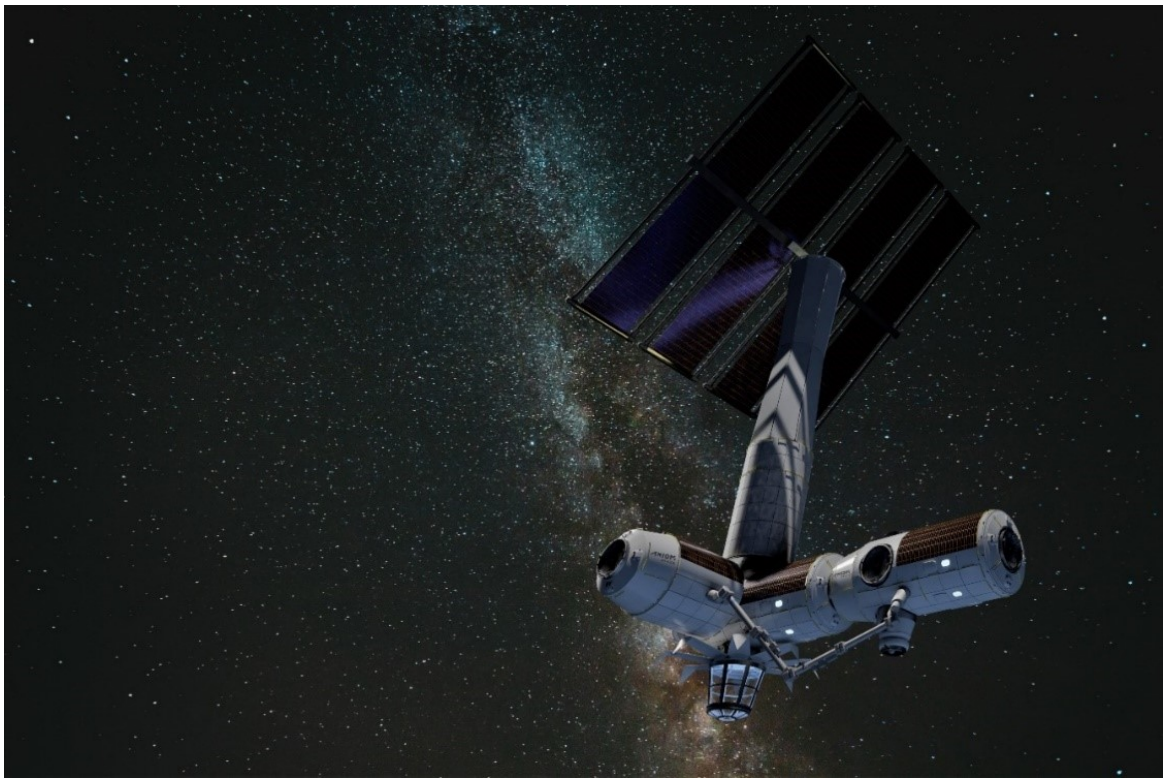

Figure 14. Axiom Station (Axiom 2021)

Right now, the ISS is the only habitable human-made orbital infrastructure in space. NASA is planning to retire the station in the future, which has led the agency to become more open towards companies developing businesses on the ISS. After the retirement of the station, the agency is planning to buy space habitat capability from commercial suppliers such as Axiom and Orion Span. Axiom was chosen by NASA in January 2020 to develop a module that will be attached to the ISS in 2024 and used for commercial business purposes. After the complete retirement of the current space station, Axiom module will be separated and used as a part of the company's own private station (figure 14). Axiom Station will provide more accommodation for astronauts and add more manufacturing and research possibilities. The station is aimed to be less costly, and easier to upgrade and preserve than the ISS. (Axiom Space 2020a; Chang 2020; Toivonen 2021, 18.)

Figure 15. Aurora Station Multi Module-Exterior (Orion Span 2021)

Orion Span is also developing a platform to be attached to the ISS. The concept of Aurora Station (figure 15) is designed to be smaller, more adaptable, more cost-efficient, and faster to position compared to the ISS. Orion Span is planning to start offering tours to Aurora Station after its successful placement into LEO. The deposit for a 12-day trip is 80 000 dollars per customer, and the total pricing starts at 9.5 million dollars. According to the company, the price is all inclusive and it covers the launch cost to Aurora Station. During the stay, the customers are expected to work together while participating in the daily tasks of the station. The activities include for example cargo transfers, daily exercise, selected operational tasks, and taking part in voluntary science projects. (Chang 2020; Orion Span 2020a; Orion Span 2020b; Orion Span 2020c.)

For the humankind to explore Mars, there are many scientific, strategic and practical reasons. For example, NASA states that exploring the planet will help to improve the quality of life on Earth. Mars is seen as a possible destination for humankind to survive, as it is the solar systems most Earth-like planet. The first possible human colonies outside the Earth would most likely be located in the orbit and are estimated to be finished as early as 20 years from now. Private companies such as Blue Origin, Virgin Galactic and SpaceX could be the potential key players in the future development of space colonies. The private companies could provide reliable and cheap access to space with reusable spacecrafts. (Toivonen 2021, 14-59.)

SpaceX is working on interplanetary transport mission which includes constructing bases on the Moon and building cities on Mars. The company is aiming to send their first cargo

to Mars in 2022 to identify hazards, to research possible water resources, and install initial power, life support and mining infrastructures. The subsequent mission, carrying both crew and cargo, is planned to happen in 2024, with an aim to be prepare for the future crew flights and to build a propellant depot. SpaceX's ultimate goal on Mars is to build a self-sustaining colony which could also be used as a base for space tourism operations. (Toivonen 2021, 14.)

The company's goal of building cities on Mars requires an affordable solution which is why the Starship system will be fully reusable, and it uses in-space propellant transfer during flights. These factors will make it a less expensive option for carrying humans on long interplanetary flights. The lunar optimized Starship was chosen by NASA to be a part of the Artemis program aiming to land humans on the Moon together with Blue Origin and Dynetics. The system will be used for transporting crew members from Earth to the surface of the Moon and lunar orbit. The first private passenger of Starship was announced by SpaceX in 2018. The Japanese art curator and fashion innovator Yusaku Maezawa will be flying on the first private lunar flight around the Moon in 2023. (SpaceX 2020c; SpaceX 2020d; SpaceX 2020e.)

2.6 Regulating space tourism

Space law can be defined as a collection of laws guiding space-related operations. The term is often connected to the rules, principles, and standards of international law regarding outer space, which have been developed with the support of the United Nations (UN). In addition, the concept of space law consists of international regulations and agreements, national directives and laws, execute and administrative orders, and legal agreements. The Committee on the Peaceful Uses of Outer Space (COPUOS), which operates under the UN, has concluded five international treaties regarding space-related operations. These treaties, which are often referred as the "five United Nations treaties on outer space", are the Outer Space Treaty, the Rescue Agreement, the Liability Convention, the Registration Convention and the Moon Agreement. These treaties focus on various space related issues, such as the freedom of exploration, scientific research, prevention of harmful interference with space activities and the environment, the utilization of natural resources in outer space, safety and rescue of spacecraft and astronauts, liability for damage caused by space objects, non-appropriation of outer space by any one country, arms control, and settlement of disputes. (Krause 2017; United Nations Office for Outer Space Affairs 2021a.)

The Outer Space Treaty, an agreement signed in 1967 between the USSR, the United Kingdom and U.S., became the foundation of international space law. Since then, 104 nations have signed the treaty. This agreement has provided a lasting framework for all the nations to ensure a peaceful exploration of space. Many bilateral and multilateral agreements outside of the UN have been added to the outer space law, which has led to the need for a guidance for managing all the outer space regulations. These laws should not only be limited to the outer space law, especially due to the growth of privatisation in space. Instead, other regulations and laws should be applied as well. (The European Space Agency 2020a; Grush 2017; United Nations Office for Outer Space Affairs 2021a.)

Space law aims to support the interests and benefit of all humankind by responsible and rational approach regarding the use and exploration of outer space. The law addresses various aspects, for example conservation of the space and Earth environment, usage of space-related technologies, military operations in outer space, protection of national interests, distributing information about the potential dangers of outer space, fostering international cooperation, and the settlement of disagreements. With the new subjects and actors appearing to the field, COPUOS discusses new topics such as the promotion of space law and problems regarding space debris. International academic seminars, like European Centre for Space Law (ECSL) and International Institute of Space Law (IISL), are crucial for improving knowledge and the organization. (The European Space Agency 2020a; United Nations Office for Outer Space Affairs 2021a.)

The existing space law recognizes the space environment more as an economic resource than as something to be protected for its own sake. The current megatrend of environmental protection on Earth outweighs the concern of non-sustainable operations happening in the space environment. Mutual sustainably oriented global legislation should be carefully planned and executed to ensure sustainable commercial utilisation of outer space to bind all the space economy operators. The current international law should also be updated to regulate the commercial space activities and the space tourism industry and, in the future continue to ensure the achievements made in space technology and science for peaceful purposes and for the benefit of all humankind. In addition to the regulations, the ethical responsibility of sustainable decision-making should be included in the business models of private companies. (Toivonen 2021, 115-118.)

The commercial launch operators face many challenges because of the complex regulatory environment, which for example discourages the possible private sector investments and complicates obtaining the required spacecraft launch and recovery approvals regard-

ing the launch site, range safety, and environment. For example, the Federal Aviation Administration (FAA) regulates the commercial space transportation activities in U.S. The FAA is also responsible for permitting licences for commercial spaceports. The agency has issued regulations regarding the safety of private human spaceflight passengers and crew. The regulations cover topics such as the operator's responsibilities in conducting a launch with human on board, providing information of safety and the risks of space travel, as well as the general security and training requirements for passengers. (The Federal Aviation Administration 2020a; The Federal Aviation Administration 2020c; Seedhouse 2008, 6.)

One of the future concerns of the growing space tourism industry is that it will remain commercialised only for the rich and powerful. To avoid the exclusion of others, both international and private organisations need to address the topic when regulating the industry. The future regulations should especially consider the legal challenges, that are seen as violations, related to governments controlling the space access and the businesses operating in space. Space preservation, space conservation and space stewardship have been proposed as possible guidelines for the commercialisation of space. Space preservation values space for its own sake, no matter the benefits that could be gained from it. Space conservation cares and protects the resources gained from the universe and ensures that benefit equally shared. Space stewardship guides how to manage space resources sustainably. (Toivonen 2021, 116.)

3 Sustainability and Sustainable Development

Sustainability can be defined as the research of how natural systems work, maintain their diversity, and create everything needed for the ecology to stay in balance. It is based on a theory that the environment, economy, and society are interconnected elements of a larger system. All of the elements must function in balance for the system to stay life-sustaining. Since humans keep moving forward economically and technologically, there is a need for sustainable guidelines. Sustainability helps humans on protecting the environment from devastation and harm, while living in harmony with the natural world. It also takes into consideration the long-term impacts of humans using natural resources to sustain the modern way of life and examines how these actions can be improved. (Dillard, Dujon & King 2009, 15; Mason 2021.)

The concept of sustainable development was defined by the World Commission on Environment and Development in Brundtland Report, also called Our Common Future (1987, 41) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The report was conducted to address the issues concerning environmental problems, economic growth, and social justice along with finding ways for long-term solutions and better cooperation between countries. Sustainable development aims to combine the protection of social and environmental balance with economic development. The linkage between economic health, biodiversity health, and the health of developing nations has become the justification for sustainable development and a structure for many definitions of sustainability. (EUR-Lex 2020; Farley & Smith 2013, 44; Jarvie 2016; World Commission on Environment and Development 1987, 41.)

3.1 Three pillars of sustainability

The World Summit on Social Development has defined three areas that contribute to the social science and philosophy of sustainable development – environmental sustainability, economic sustainability, and social sustainability. These three pillars serve as a foundation for the concept of sustainability, addressing the problems occurring in the world. Sustainability is often linked to climate change, which is largely caused by industrial practices, threatening the life on the planet. The three pillars are also informally known as planet, profit and people. (Mason 2021; Youmatter 2020.)

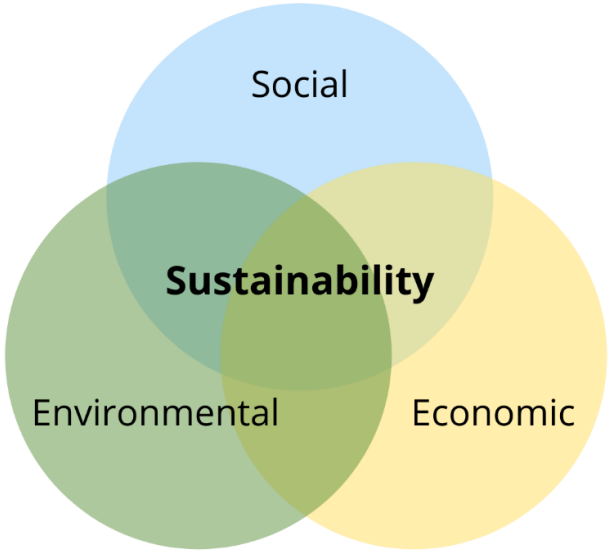

Figure 16. The three pillars of sustainability (adapted from Circular Ecology 2021 s.a.)

Environmental sustainability, which is one of the three pillars as the figure 16 shows, examines the factors that are causing strain on the environment and it defines how integrity and sustainability of natural resources, ecosystems, and air quality should be protected. A central concern of sustainable development is to find the best ways to distribute and maintain the natural resources. Incentives how an individual person can protect the environment are for example, reducing the power consumption, recycling and by using the public transportation or walking. Businesses have directives to keep their carbon emissions low and prevent pollution, but both parties can install renewable power sources to their businesses and houses. Developing biotechnology and technology can help with sustainable development and ensuring the protection from potential future damages that technological progress may cause to the environment. Increasing consumption and dependency of natural resources that cannot recover as fast as used, for example minerals and oil, contributes to climate change and environmental contamination. This behaviour creates ecologically desolated landscapes along with so called “environmental cliff” which will be the result of continuous unsustainable consumption among the developed nations. These unsustainable consumption patterns lead to decreased environmental, economic, and social securities, such as drastic weather changes, loss of assets and lives. (Farley & Smith 2013, 47-58; Mason 2021.)

Prosperity, which can be defined as a state of social and financial success together with an improved life quality, is an important part of environmental sustainability. In addition to material security, humans need intangible securities to thrive. This includes happiness, health, family, certain freedoms, and property. Prosperity has vital psychological and social dimensions, and it highlights the importance of every member of society to participate

freely in the actions and life of the community. It addresses the ability of human beings to thrive while considering the ecological boundaries of the planet. The most urgent mission of the human history is to build conditions for making it possible, as many factors are linked together and changing human behaviour is in itself a challenge. One way to do this is sustainable living. The elements of sustainable living are considered to include a stable economic system with adequate employment, a low rate of inflation, and sufficient necessities for enabling comfortable living with moderate expenses. Crucial government services such as health care, education, communications, and public transportation systems require a healthy ecosystem and taxable wealth to function properly. In terms of the human ecological sustainability, our needs for water, food, and energy arise as the key factors. (Northrop & Connor 2013, 5-6.)

Economic sustainability presents organisations and businesses goals and inducements on how to be sustainable beyond the normal legal requirements. It also encourages an individual person to do their part on sustainability where and whenever possible. One of the issues regarding economic sustainability is to get consumerism under control to protect the environment. As the market of supply and demand is increasingly focused on consumption, maintaining the modern lifestyle demands lots of resources continuously. Economic sustainability holds a lot of disagreement with political ideologies regarding what is economically sensible, along with their effects on business and employability. The idea of economic development is to boost the economic wellbeing while reducing the financial burden by hosting focused programs and actions in communities, especially in the developing countries. This process aims to build the local wealth and tax base, create and preserve jobs, and diversify the economy without making compromises on life quality. (Mason 2021; Romer 2016.)

It is important to maintain the value of natural capital for the future generations when using the planets resources. This can be done with an investment that allows access to the service provided by the resource, even when the original resource can no longer be used. An example of this kind of investment is supporting future renewable energy projects with the profit gained from oil production. It has been proposed that changing the sustainability mindset towards the concept of social bequest would ease the process of finding new substitutions. (Farley & Smith 2013, 51-52.)

Sustainable development is also a social issue. The value of social sustainability comes from the need to uphold the society, and it is a critical subject from the perspective of sustainability. The most important aspect of social sustainability is to raise awareness of the

matter and legislate the harmful activities, such as pollution, of businesses and other organisations to protect the well-being of people. Social sustainability also emphasizes that access to basic resources should be maintained without making compromises to the overall life quality. From an educational viewpoint, the concept also includes increasing the knowledge regarding environmental protection, being aware of the consequences of failing to meet our environmental goals and encouraging the society to make more sustainable choices. As taking care of the sustainability of environmental systems also benefits the sustainability of human social systems, not paying enough attention on it poses a threat for the human security as well. Social well-being can be described as the fulfilment of basic needs along with fostering the social, political, and economic freedom. The wide research and practice of the social well-being add definition to social sustainability on the areas of community well-being, human-centred development, and sustainability. From these three practices, four global principles and key elements of social sustainability have emerged, which include human equity, well-being of humans, democratic civil society, and democratic government. (Dillard, Dujon & King 2009, 15; Farley & Smith 2013, 56-58; Mason 2021.)

3.2 The UN Sustainable Development Goals

In 2015, all United Nations Member States agreed on the 2030 Agenda for Sustainable Development plan, which introduced 17 Sustainable Development Goals as an urgent call for action. These SDGs serve as a guideline for all countries to develop prosperity and peace today and in the future. The Agenda acknowledges that all strategies must be connected to each other to achieve results on ending poverty, reducing inequality, improving health and education, encouraging economic growth, preserving oceans and forests, and fighting against climate change. (United Nations 2021; United Nations 2015, 5-6.)

Figure 17. Sustainable Development Goals (United Nations 2021)

The SDGs (figure 17) focus on five areas that are critical for the survival of the planet and humanity. These areas are People, Planet, Prosperity, Peace, and Partnership. People goals emphasis ending hunger and poverty of all forms and supporting equality and dignity for everyone in a healthy environment. The goals for Planet concentrate on acting for protecting the Earth with sustainable natural resource management, sustainable producing and consuming, and taking action to combat the climate change. For Prosperity, the goals are set to achieve fulfilling lives for all human beings along with maintaining harmony between the nature and social, technological, and economic development. As peace and sustainable development cannot exist without each other, the goals for Peace are set for working towards violence-free societies that support justice, peacefulness, and inclusion. The goal of Partnership focuses on the needs of the poorest and most vulnerable, through Global Partnership for Sustainable Development. With participation between all countries, stakeholders, and people, the world will be changed for the better and the lives of all will be thoroughly improved. (United Nations 2021; United Nations 2015, 5-6.)

3.3 SDGs in space technologies

Space technologies have many ways to support the 2030 Agenda for Sustainable Development in all of the goals. The first goal is to end poverty, which aims to protect the less fortunate, improve access to basic services, and support people in case of disasters. Space technologies can help to improve the sustainable use of natural resources, forecast natural disasters and organize aid, map populated areas and access to basic services, and provide effective support to vulnerable groups. The second goal is to end hunger and malnourishment. With space technologies, crop production can be optimized through knowledge-based management and more efficient use of existing resources. It can also

help to develop livestock management by improving identification and monitoring of efficient grazing. The third goal seeks to ensure health and wellbeing in all of the stages of life. Space technologies can help to improve issues related to cognition, vision and disability assistance, monitor factors like traffic and air quality that affect human wellbeing and health, enable possibilities for a remote healthcare, and aid the health promotion and disease prevention through the use of portable monitoring devices. It can help to identify and monitor disease patterns and spreading factors and help to define areas that require disease-control planning. (United Nations Office for Outer Space Affairs 2021b; United Nations Office for Outer Space Affairs 2021c; United Nations Office for Outer Space Affairs 2021d.)

The fourth goal promotes opportunities for lifelong learning and seeks to ensure overall and equal quality of education for everyone. Space technologies can provide remote learning and e-learning for isolated and remote communities, deliver lifelong learning opportunities, help to reduce dropout rates by electronic attendance monitoring and providing incentives for parents, and provide online education content and high-speed internet through satellites. The fifth goal strives to achieve gender equality and empower all girls and women. Space technologies can help to support this through providing access for education in the isolated and remote communities, offering career development opportunities, supporting female entrepreneurship with soft infrastructure, and providing access to training, safety and information in the work environment. The sixth goal aims to ensure that all people have access to water and sanitation, which is managed sustainably. Space technologies can offer meteorological forecasting, access to technical knowledge, infrastructural support and water quality monitoring to achieve this goal. (United Nations Office for Outer Space Affairs 2021e; United Nations Office for Outer Space Affairs 2021f; United Nations Office for Outer Space Affairs 2021g.)

The seventh goal aims to ensure that reliable, inexpensive, modern and sustainable energy is available to all. Space technology can help to reach this goal with forecasting wind and solar energy production from other sources to estimate the amount of energy required, identifying optimal locations for renewable energy production, power grid synchronisation, seismic surveying and by monitoring critical infrastructure such as energy networks. The eight goal encourages sustainable economic growth, decent work quality along with productive and full employment for everyone. Space technologies can support this through monitoring lone employees, establishing secure and safe working environments, supporting the growth of GDP and global economies, and by participating in a number of areas such as finance, banking, service delivery, communications, and agriculture. The ninth goal is about promoting sustainable and inclusive industrialisation, building

resilient infrastructure, and fostering innovations. Space technologies can support this goal by contributing to mapping and monitoring infrastructure, assisting smart mobility, and construction surveying. (United Nations Office for Outer Space Affairs 2021h; United Nations Office for Outer Space Affairs 2021i.; United Nations Office for Outer Space Affairs 2021j.)

The aim of the tenth goal is to reduce inequality within and between countries, especially in the most vulnerable areas. The usage of space technologies can help to improve connectivity in remote areas, support reliable access to information, and allow remote participation in democratic operations. The goal 11 focuses on the challenges of maintaining cities, creating jobs, and fostering prosperity without draining the land and resources. Space technologies can be beneficial for urban planning and infrastructure monitoring, city service improvement, development of Smart Cities, air quality monitoring, search and rescue operations, and disaster management. The goal 12 aims to ensure responsible and sustainable patterns for production and consumption. Space technologies can assist with the management of natural resources, monitoring trafficking of endangered species along with the products of human slavery, tracing dangerous goods and food, supporting Smart Agriculture combined by Earth observation and satellite systems. (United Nations Office for Outer Space Affairs 2021k; United Nations Office for Outer Space Affairs 2021l; United Nations Office for Outer Space Affairs 2021m.)

The goal 13 is a call for action to fight against climate change and its impacts. For this goal, space technologies can be utilized for forecasting weather, monitoring climate change, search and rescue operations, and disaster management. The objective of the goal 14 is fostering sustainable development by protecting the oceans, seas, and other marine resources while using them in a sustainable manner. Space technologies can contribute in various ways, such as monitoring and mapping marine areas, monitoring unregulated and illegal fisheries, assessing and monitoring coastal and marine resources, tracking and navigating fishing boats, tracing fishery products, monitoring climate change especially on the subject of water temperature, and identifying algal bloom. The goal 15 encourages to promote, restore and protect the sustainable usage of terrestrial ecosystems, manage forest in a sustainable manner, halt the degradation of land, stop biodiversity loss, and counter desertification. Space technologies can support this goal by monitoring terrestrial biodiversity, monitoring bio-geophysical surface of land, and tracking poaching along with identifying smuggling routes. (United Nations Office for Outer Space Affairs 2021n; United Nations Office for Outer Space Affairs 2021o; United Nations Office for Outer Space Affairs 2021p.)

The aim of goal 16 is to advance inclusive and peaceful societies in order to promote sustainable development, to provide an access to justice for everyone, and to build accountable and effective institutions. Space technologies can assist on reaching this goal with legislation enforcement, conflict monitoring, supporting access to reliable information, and enabling the participation in democratic operations for remote communities. The goal 17 aims to revive the Global Partnership for Sustainable Development and reinforce the means of implementation. Space technologies enable this through exchange of information, data, and technical knowledge, international cooperation initiatives, sharing of infrastructure, and using open-source databases. (United Nations Office for Outer Space Affairs 2021q; United Nations Office for Outer Space Affairs 2021r.)

3.4 Sustainability and sustainable development in space tourism

As commercial space tourism industry is still in its development stage, there is a possibility of planting sustainable actions and values into all operational levels. Not including sustainability in the business model can cause social pressure risk, regulatory risk, and market perception risk. To maintain future credibility among the next generations, serious sustainable actions need to be included in all strategies between private companies and governments. The companies of commercial space tourism industry need to address the issue since they are starting to operate in an era of global environmental crisis. (Toivonen 2017, 32; Toivonen 2021, 61-78.)

Major expertise needed for controlling sustainability in the operations include project management skills, future thinking and skills to deal with uncertainty and complexity. To achieve controlled tourism development, special organisational regulations and structures are needed. The decision-making process is influenced by culture, governance and resources in both local and global levels. Since space tourism is still in its early stage, it offers a great opportunity to experiment domestic and international policy implementations to determine whether the valuation of an environment can coexist between the public and private sectors. It could help to examine if this coexistence could create profits while protecting the fragile environment at the same time. The industry should enhance sustainable development and planning by implementing long-term perspectives to short-term actions, while incorporating critical thinking and practicality and considering various policy domains at different levels. (Toivonen 2017, 32.)

There are already future sustainable development approaches in the tourism field. One of them is the sustainable indicator-based framework that includes practical actions and measurements for protecting the environment that already is affected by tourism. But since the commercial space tourism industry has not yet fully started its operations, there

is still a need for more futuristic tourism-oriented research methods for assisting in the process of improving the future forecasting and planning process. The industry needs a sustainability oriented future plan that highlights using the knowledge of previous tourism destination planning to avoid possible environmental mistakes. (Toivonen 2021, 48-65.)

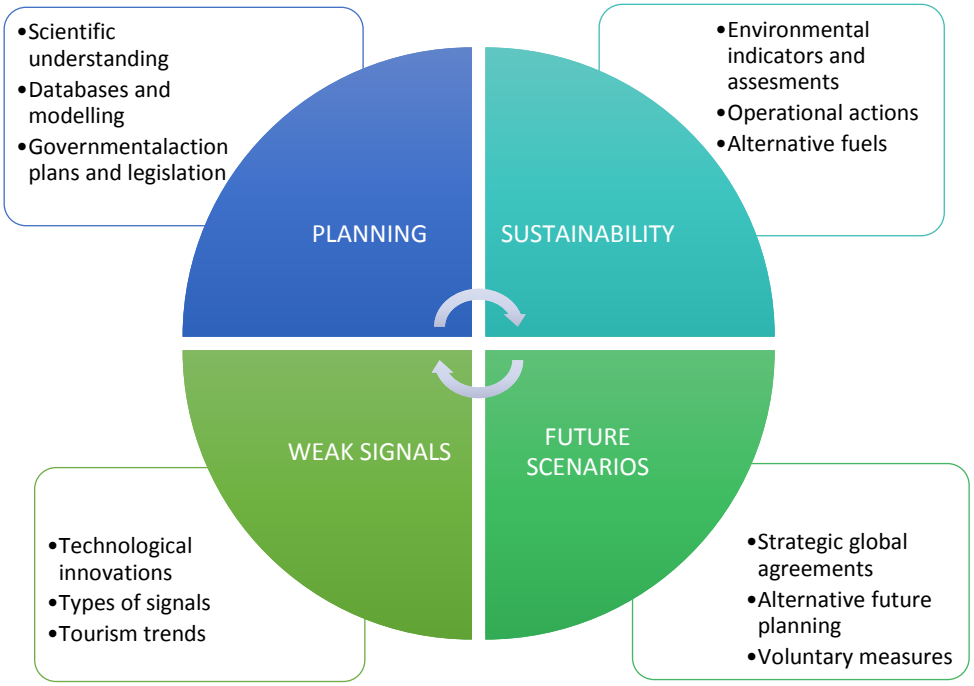

Figure 18. Sustainable Future Planning Framework. (adapted from Toivonen 2017, 27 s.a.)

One of these kinds of tourism oriented future research methods is the Sustainable Future Planning Framework (figure 18), which helps to foresee the potential human actions and behaviours, and how they could affect future sustainability. The framework can also be used to assist in the development process of future destinations similar to Butler's Tourism Area Life Cycle model. It works in line with the principle of procedural tourism development, with a focus on sustainability, planning, weak signals, and future scenarios, to work in synergy to reach sustainable future planning. The planning in the framework involves scientific understanding, databases and modelling, and governmental action plans and legislation. Sustainability involves environmental indicators and assessments, operational actions and alternative fuels. Weak signals include technological innovations, types of signals and tourism trends. The future scenarios involve strategic global agreements, alternative future planning and voluntary measures. (Toivonen 2017, 27-31.)

Including sustainable development in the business is still a new concept in the space tourism industry, but to avoid creating an unsustainable image of the future space tourism field, sustainability should be included in the operations of the industry along with noticing

the important role of the space environment itself. Even though it is still a new idea, these two can be linked together in five different levels which are operational level, resource level, survival level, cultural level, and economic level. (Toivonen 2021, 61-78.)

3.4.1 Operational level

The discussion concerning environmental and climate issues, such as emissions, depleting natural resources and global warming, usually brings up the impacts of transportation industry rather than the impacts of space industry. Reason for this is that the impacts of the industry are still small as the launches are quite rare. It is evident that the technical and safety issues of sub-orbital or orbital flights are higher on the priority list of the vehicle designers than sustainability issues, as the current motivation is to lower the cost of accessing space. The environmental impacts will be a greater issue when the commercial space tourism becomes a part of everyday life and the number of spaceflights increase. The rising public sustainability concern will require the commercial space tourism industry to include sustainability into the development and designing processes on the areas of future infrastructure, from space systems and other technologies to spaceports. (Fawkes 2007; Jindal, Bharti & Chalia 2018; Toivonen 2021, 69.)

The concept that all space tourism operators should implement to their operations is green design, which has a long history being a part of sustainable development. Before the current trend of consumerism, sustainability was the norm as utility items were produced locally, but everything changed due to the increased consumer demand. This has challenged companies to design and produce products that consider the environment and give consumers the maximal benefit with minimal use of energy and materials. This has led to companies experimenting with new sustainable-based technologies and to develop alternative systems, so already recycled materials can be reused again. The concept of redesigning can help with achieving a more responsible future. In space tourism, green design could be included for example to spaceport ground facilities, space suits or other operational systems such as the reusable rockets. (Toivonen 2021, 69.)

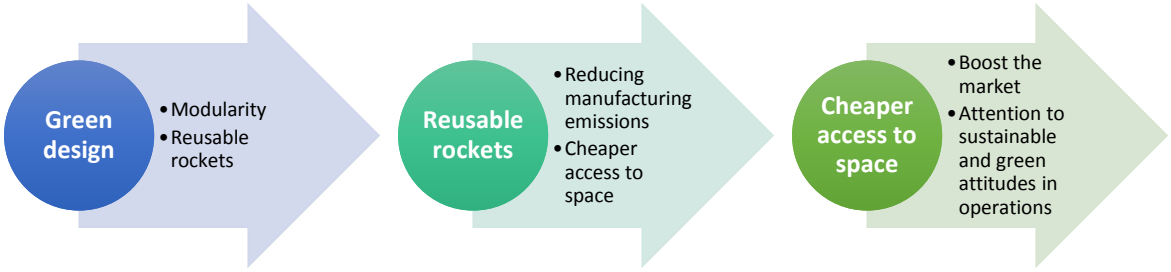

Figure 19. A possible future framework for more sustainable operations

Industry operators have already addressed this issue with modularity, a new concept of rocket systems, that will enable the evolution of traditional rocket systems to more adaptable and maintainable spacecrafts that will help to get closer to a sustainable space infrastructure. As the process of rocket manufacturing generates a lot of pollution and carbon dioxide (CO_2), building reusable rocket systems helps by reducing the environmental impact. These kinds of reusable and module rocket systems can be used for different mission purposes, and reusability enables the manufacturing emissions to be spread over their lifetime. This would greatly reduce rocket manufacturing emissions. Besides rocket reusability, reusing engines and changing fuels into more sustainable options, as already done in the aerospace industry, should be considered. In the future, reusable systems are also able to provide cheaper access to space and boost the space tourism market and the sustainable crewed space transportation market. This could create an ideal symbiosis (figure 19) between the new generation of low-cost launchers and sustainable space travel. The current pioneers of the commercial space tourism industry are SpaceX, Virgin Galactic, and Blue Origin, who are already working on the development of reusable rocket systems, even though the operations have been mostly focused on reducing the cost of the launches instead of doing innovations for environmental reasons. In the future, there is a possibility that the companies will pay more attention to sustainable and green attitudes in their operations. (European Commission 2020, 8-9; Kordina 2020; Toivonen 2017, 24; Toivonen 2021, 91-101.)

The Falcon launch vehicle family, developed by SpaceX, are the first and only reusable orbital class rockets. Falcon 9 is designed to refly multiple times in its lifetime and withstand re-entry, which is different compared to most rockets that are designed to burn up during the process of re-entering the atmosphere. Falcon rockets can descend on landing zones near launch pads or on autonomous droneships out on the ocean. The cost of space access is reduced with reusability and reflying the most expensive parts of the rockets. (SpaceX 2021a; SpaceX 2021b.)

Virgin Galactic is aiming to transform the current environmental impact, safety, and cost of space launch. The company's WhiteKnightTwo, a twin-fuselage carrier vehicle, is designed to carry SpaceShipTwo, which is a reusable spaceship. WhiteKnightTwo is developed for launching SpaceShipTwo thousands of times, and it has a rapid turnaround time for providing frequent launches for various spaceships. SpaceShipTwo is designed to be fully reusable, only the fuel and oxidizer of the rocket motor needs to be refilled after each flight. The lightweight carbon-fibre frame of the vehicle was designed to dramatically decrease the fuel burn. (France-Presse 2013; Virgin Galactic Holdings, Inc. 2019, 11; Virgin Galactic 2020e.)

Blue Origin's New Shepard and New Glenn systems have both been developed to be reusable for lowering the cost of space access. The vertical take-off and vertical landing techniques allow the first stages of the rockets to be reused with minimal restoration. The rockets are landed precisely on the landing zones with throttleable liquid fuelled engines. The New Glenn, an orbital launch vehicle currently in development, is designed to fly at least 25 times. Its engines are designed to be reusable, and they are the world's most powerful engines that use liquefied natural gas and liquid oxygen. Another mission under the NASA's Artemis programme is using New Shepard to test landing technologies to be used on the Moon. The New Shepard system's use of liquid oxygen (LOX) and liquid hydrogen (LH2) as propellants is marking progress towards sustainable space economy. These propellants enable the heavy lift needed to reach orbit and secure a safe landing. LH2 and LOX are crucial for the future lunar missions, as they can be harvested from water stored in the surfaces of the Moon and other surfaces in the solar system. (Blue Origin 2020c; Blue Origin 2021a; Blue Origin 2021b; Cornell University 2020.)

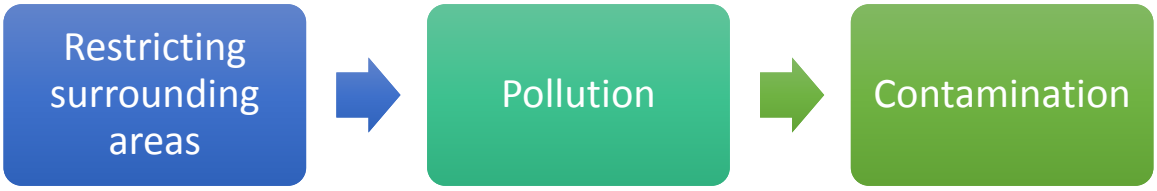

Figure 20. Main environmental impacts of spaceports

The industry should not forget spaceports either from the sustainable development plans. These facilities can have various impacts on the surrounding areas (figure 20). Rocket launches may require restricting the air space during the launch, or cause possible evacuation of residential areas, and if waterways are close by, they need to be closed temporarily. Launches can cause noise and light pollution that affects people and animals, while

failures in rocket launches and accidental discharge of rocket fuel and debris can contaminate the environment and water quality. They can also have impact on local water supplies as each launch requires vast amount of water. The emissions discharging from the rockets can affect the air quality and the rocket operations can cause damage to cultural and historic resources. These are just few impacts that spaceports can have on the surrounding environments. (National Parks Conservation Association 2021; Toivonen 2021, 69.)

The Baikonur Cosmodrome has also been connected with various environmental concerns. For example, a research done in the 1990s revealed that the rockets launched from the spaceport had caused mass deaths of birds and wildlife along the flight paths in Sakha Republic. Scientific studies also concluded that the rocket launches affected the health of the population and the environment, which showed as increased cancer rates and acid rains in the area. Even though some of the rocket flight paths were altered after these findings, the polluted scrap metal is still being processed in the local recycling operations. The Baikonur launch site has later on agreed to develop the environmental sustainability improvements of the existing launch vehicles, which has allowed Russia to continue renting the spaceport and its launch site for ESA and NASA. These examples indicate that spaceports need to be designed with sustainability in mind from the start. One of the best examples of sustainable practices included to the operations from the start is the Spaceport America. Their facility, the Gateway to Space, has been built with sustainability and efficiency in mind, while the same time it respects the areas ancient surroundings. It is located mostly underground, is powered by renewable energy, and produces carbon-negative energy. (Toivonen 2021, 69-96.)

Another obstacle the growing industry needs to solve is the issue of failed launches and the pollution they leave behind in the surrounding areas of the spaceports. An example of this happened in Alaska's Kodiak Island in 2018 when two rockets crash-landed during test launches. More than 230 tons of ground was contaminated with unspent fuel that leaked on the launch site. These kinds of spills can kill animals, plants and even the nematodes and bacteria in the ground. Similarly, successful launches can contaminate the surrounding area with heavy metals and pollutants that can leach into groundwater and build up in the bodies of animals. In the Kodiak Island case, the ground had to be treated with high temperatures to burn off the fuel, which led to the ground being altered in a way that all living organisms died. This kind of treatment causes ground to be infertile. (Calma 2019.)

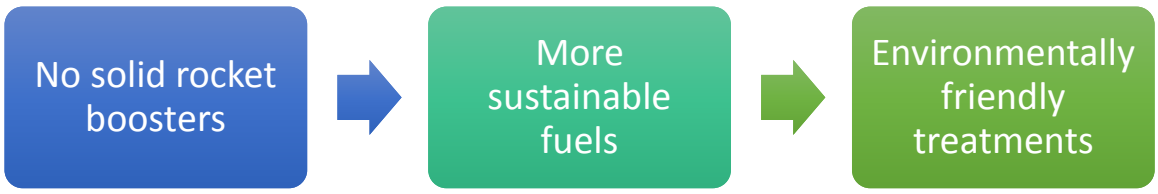

Figure 21. How space operations could be more sustainable

So, one of the most important actions when moving towards sustainable space operations (figure 21) would be to discontinue the usage of solid rocket boosters, as they release ozone depleting toxic compounds. Another action to be considered is changing the usage of hypergolic and fossil fuel-based rocket fuels such as RP-1, which is a highly refined form of kerosene, to more sustainable choices. These kinds of fuels could for example be hydrogen or methane. Hydrogen can be produced from electrolysis and by continuing the same process while extracting CO_2 from the atmosphere, the final result is methane. Since there is a chance of rocket launch accidents, which can cause fuel leakages to the ground, more sustainable treatments are required. For example, in the case of Alaska's Kodiak Island fuel leakage, the spaceport could have used another option, phytoremediation, to treat the ground instead of burning off the fuel. The treatment breaks down a large chain of hydrocarbon molecules in kerosene by utilizing microbes and plants in the soil. Even though this treatment requires a lot of time, experts suggest this to be good method for curing the environment, especially in the areas where the level of pollution is low. These kinds of alternative biology-based methods are already being used in some spaceports. (Calma 2019; Mandow 2020; Kordina 2020.)

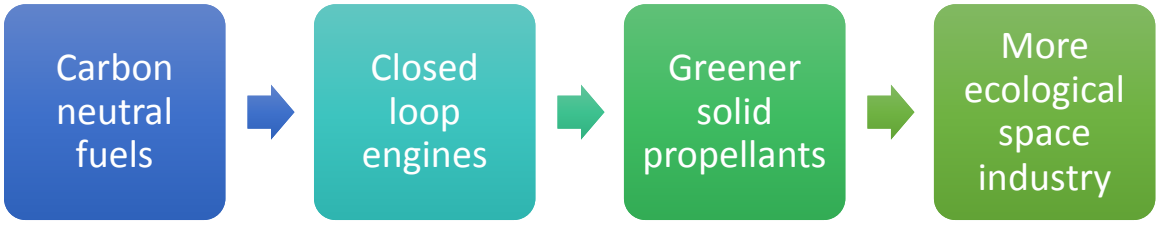

Figure 22. Other options how space industry could achieve more ecological future

There are various methods to achieve more ecological future in space industry (figure 22). The leader of the Australian National University Solar Thermal Group, Professor Wojciech Lipiński, suggested new ways for producing carbon neutral fuels for the aviation and aerospace industry. According to Lipiński, the carbon neutral fuels are produced from renewable carbon sources, such as air captured CO_2 and biomass, solar energy, and water. These kinds of synthetic fuels could improve the sustainability of aerospace transportation. Using carbon-neutral options in the production of rocket fuels could decrease the net

climate impact of rockets indirectly, but even more importantly, their whole production pipeline should be focusing on carbon neutrality. Another solution for the industry is to utilize the closed loop engines, as they have more complete combustion and lower pollution rates compared to open cycle engines with gas generators. Closed loop engines can also do more work with the equal amount of fuel than open cycle engines. Also, the industry needs to improve the manufacturing of rockets, which is far worse for the environment compared to the launches, as the process releases a lot of CO_2 to the atmosphere. (Kordina 2020; Mandow 2020.)

Another way to achieve more ecological space industry is to increase the budgets of development and research in private space companies and agencies, especially regarding the development of greener solid propellants. Current research suggests that a greener solid propellant can be retrofitted to already existing launch system, providing the best environmental gain and optimal return on investment. Other benefit is the potential increase of interest in the space industry, which could boost the number of research openings for other stakeholders, as well as lead to the development of environmental performance metrics. These performance metrics could be used as a marketing tools to promote the sustainability of the launch industry for space tourism. (Jindal & al. 2018, 499.)

3.4.2 Resource level

Increasing consumerism and usage of Earth's resources has been one of the major environmental concerns of the modern times as humanity is limited to only one planet at the moment. Travelling to space has been viewed as a waste of assets as the development of space industry and accessing the outer space uses enormous amounts of non-renewable natural resources. On the other hand, space exploration can help humans to find alternative solutions for depleting materials on Earth and other energy resources from the solar system. Using rockets has also enabled the development of satellite systems that bring further knowledge of the universe and help to understand how humans affect the Earth. (Kordina 2020; Mäkinen 2020; Toivonen 2021, 56-75.)

Figure 23. How the issue of depleting resources could be solved

The issue of depleting natural resources of Earth could be solved with expanding resource mining to space. Many metals on Earth will soon be extinct because of the increasing consumption to sustain the modern way of living. The increased search for substation materials and recycling is not enough and soon there is a need for the basic raw materials. In theory, rockets could bring back replacement resources from the solar system. The future extra-terrestrial settlements, such as colonies in Mars and Moon, and resources gained from the solar system could help to protect the Earth's environment. This could lead to an ideal environmental sustainability (figure 23), but it does not come without consequences. Even though space could offer vast amounts of resources needed on Earth, there is a possibility of this also causing a disaster with the increased consumption boom affecting the environment. Also, colonising and mining other planets comes with a high risk of contaminating these other celestial beings and planet Earth, since it is impossible to completely sterilise personnel and materials from organisms. (Toivonen 2021, 56-86.)

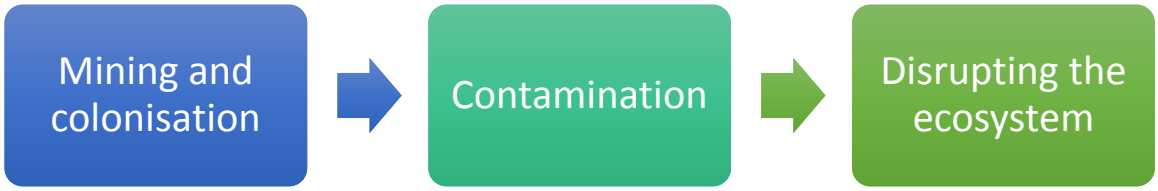

Figure 24. The possible impacts of space mining and colonisation

A major environmental concern since humans set foot in space is the risk of contamination (figure 24). As number of models and physical evidence shows, invading species are able to affect the original wildlife drastically. One example is the Galapagos Island which had its own untouched ecosystem. Visiting boats brought ants from the mainland, which led to a domino effect of reduction or disappearance of the original species. Similar kind of effect can also happen if humans land on Mars, as there is a risk of carrying trillions of earthly microbes with them. In case life exists on Mars, which is still under research, this could cause a major interruption on the Martian ecosystem as there is no data on how the earthly microbes would react with it. This could also occur the other way around by bringing possible organism from other planets to Earth. On the other hand, colonisation of other planets could help with the issue of overpopulation and reduce the environmental impact

on Earth by moving a proportion of human activity to outer space. (Bharmal 2018; Mäkinen 2020; Toivonen 2021, 86.)

Regulatory bodies, such as the International Council of Science Committee on Space Research and NASA's Office of Planetary Protection, address the ethical concerns of Earth-born organisms entering alien worlds, and support the research of long-term technological sterilisation solutions. NASA's Office of Planetary Protection also develops and implements actions to protect the explored environments, the Earth and science. The Committee on Space Research (COSPAR) has also formed a planetary protection policy to comply with the UN's Outer Space Treaty. The planetary protection determines that the possible microbiological contamination stays within the acceptable limit during missions and takes into consideration the possibility of a spacecraft crashing on the planet surface. (The European Space Agency 2021b; Toivonen 2021, 56-86.)

ESA considered the contamination issue in their ExoMars 2016 project, which is searching for signs of past life on the surface of Mars. The spacecraft used in the project was built in completely new cleanroom to ensure that the microbiological contamination could be little as possible. All of the hardware used in the construction of the spacecraft and rover had to be disinfected with sterile 80% isopropyl alcohol numerous times. The cleanroom itself was cleaned with more aggressive chemicals, such as hydrogen peroxide. Dry heat treatments were also used for the hardware, in which the surfaces were treated with temperatures between 110°C to 125°C for several hours. To ensure that the procedures were working as planned, almost 3000 microbiological tests were conducted throughout the whole operation. (The European Space Agency 2021b.)

NASA has also made a sustainability policy that guides the agency's missions without compromising Earth's resources with the future generations in mind. To make sure that this goal is met, NASA calculates risks of the missions, risks to the environment and communities while keeping in mind that everything is adjusted within existing resources. Some of the agency's sustainability objectives are increasing the use of renewable energy, reporting, measuring, and reducing greenhouse emissions, preventing pollution, eliminating waste, and increasing recycling, protecting and conserving water resources, managing and evaluating their operations and missions' effects in short-and long-term, and operating under all regulations and laws regarding healthy environment, environmentally-sound operations, and energy security. (Serafini 2019.)

ESA is supporting the United Nations Sustainable Development Goals through various activities addressing environmental protection, economic growth, and social development.

Space technologies, along with satellite data and space applications, have a big impact in addressing the environmental sustainability issues. The focus of the agency is on developing long-term technology and the growth of the space industry in Europe by responsible production operations and constant innovation. An example of ESA's projects is the Micro-Ecological Life Support System Alternative, MELiSSA, which could help the humanity to live self-sustaining life in space, while providing clean water and food for the people on Earth. The project aims to achieve this by converting CO_2 and organic waste into oxygen, food, and water by using biological photosynthesis. (The European Space Agency 2018.)

The space-based applications and satellite telecommunications form the base of ESA's activities. The data and services from Earth observation enable the monitoring of land, air, and seas, and provide the core for weather reports along with informing refiled agencies in case of natural disasters. The agency runs projects focusing on coastal monitoring, agriculture and rural development, forestry information, food security, along with providing information of geohazards, urban development, and hydrology through Thematic Exploitation Platforms. (The European Space Agency 2018.)

Some of the projects, such as the Clean Space initiative, aim to lessen the environmental impacts of space activities. The Clean Space activities include endorsing sustainable technologies, industrial materials, and processes, and conserving the Earth's orbit as a debris-free safe zone. The agency's CleanSat initiative focuses on reducing the production of space debris through decreasing the mass being put into high density debris areas, such as LEO and geostationary orbit, and developing technologies that take into consideration the lifespan of the hardware. The initiative also promotes "end-of-life passivation", which includes discharging the batteries and emptying the tanks of satellites to prevent debris explosions. An In Orbit Servicing Vehicle (IOSV) will be used for various activities in orbit, including safely de-orbiting the satellites reaching the end of their lives. The IOSV is also designed to refuel and manoeuvre the satellites, along with demonstrating which technologies are required to extend the lifespan of the missions. (The European Space Agency 2018; The European Space Agency 2020c.)

3.4.3 Survival level

There are several ways for humankind to go extinct, including different natural disasters such as super volcanoes, human inflicted disasters such as nuclear war, outer-space disasters such as asteroid impacts or gamma-ray burst and finally global disease pandemics such as the ongoing COVID-19. Several of these have the ability to change natural resources needed for suitable living conditions. Climate change has also created uncertainty

regarding the survival of human race in the changed environment. Several industries, including tourism have been contributors towards climate change with the carbon emissions created by tourism activities such as transportation. (Toivonen 2021, 77.)

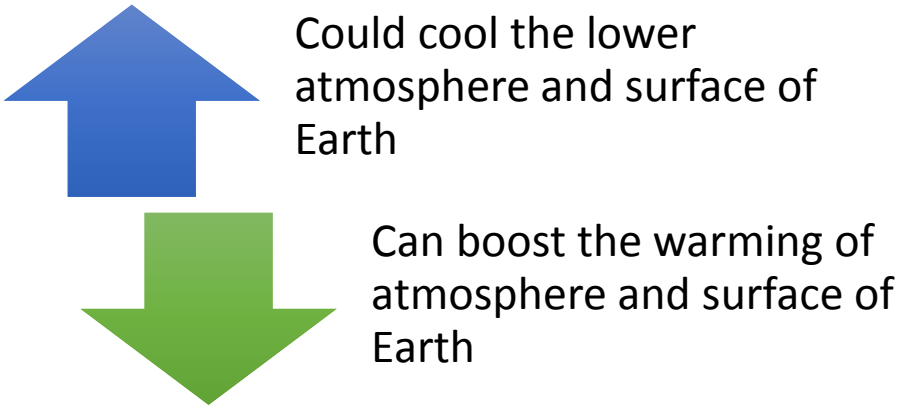

Figure 25. Two different findings of rocket emissions affecting the climate

The environmental impacts of space tourism raise two opinions. Entrepreneurs investing in space travel industry argue that the future space travel would leave a smaller carbon footprint than the current aviation industry, while the scientists worry about the impacts of increasing rocket launches. One of the worries is the black carbon and soot caused by rocket emissions, which will stay in the stratosphere for years, as they cannot be washed away by winds or rain. The emission impacts can boost the effects of climate change, such as ozone layer depletion, rising temperature and glacier retreat. Another concern in addition to the narrow knowledge of the effects and causes is the need of further research and regulation of the carbon footprint in space. A study funded by NASA and the Aerospace Corporation claimed that 1000 suborbital hybrid engine launches will cause distribution of ozone, and considerable changes in the global atmospheric circulation and temperature (figure 25). The calculations showed that 1000 launches from a single location would result in 600 tonnes of black carbon being released into the stratosphere. The findings revealed how the possible impacts of mass commercial space tourism could affect the vulnerable atmosphere of Earth. Another research conducted by Ross and Sheaffer in 2014, showed that the rocket launch emissions could actually have an impact on cooling the lower atmosphere and surface of Earth instead of causing temperature increase. To gain a full understanding of the long-term consequences on climate, more research is required. (Toivonen 2017, 24; Toivonen 2021, 32–33; University of Central Florida 2016.)

The sole purpose of rockets is to extract as much kinetic energy out of chemical bonds as possible. The launches can produce various emissions – the most common being carbon soot, carbon monoxide, CO_2, chlorine, water vapor, alumina, mono-nitrogen oxides and

sulfuric compounds. These can cause various effects, such as the depletion of the ozone layer, acid rains that harm the environment, and some of the substances cause the atmosphere to trap more heat from the sun. Hydrogen is often considered to be the sustainable and low polluting energy source, which is not the case, as it is only an energy vector and needs to be generated by using fossil fuels. This sort of fuel has the equal carbon footprint to burning gasoline if it is produced without carbon capture and storage that would make it mostly carbon neutral. (Kordina 2020; Toivonen 2021, 70.)

Figure 26. How ceasing of space tourism growth could affect the survival of human race

Critical claims of commercial space tourism becoming new environmental strain might be right in short-term but not in long-term. Ceasing the growth of space tourism could lead to a loss of various future benefits (figure 26), such as low-cost solar power and new carbon-neural power from space. Another benefit the end of space tourism development affects is the possible outer space colonisation that is seen as a human insurance policy for the future. There have been speculations that humans have a limited time to develop other living solutions for the human race, since the needed resources on Earth could possibly run out before a solution is found. Furthermore, humans need to consider if there are other ways to achieve these benefits instead of being reliant only on the development of space tourism. Other solutions could be public-private partnerships and governmental investments, which could bring professionals and scientists together. (Toivonen 2021, 70-77.)

3.4.4 Cultural level

On a cultural level, space travel has influenced global environmental movements such as the Earth Day and has helped to raise awareness of how humans affect their home planet with their actions. The photograph of Earth, taken by the Apollo astronauts, became the symbolic icon of environmentalism, and for the first time ever got the attention of wider public. It presented the Earth as a fragile object that is influenced greatly by the human actions. As some of the global weather event impacts can also be seen from space, they can work as a reminder to the viewer how unique the Earth's atmosphere is and how it protects humankind from radiation and cold temperatures of outer space. (Fawkes 2007; Toivonen 2021, 72-73.)

Some astronauts have experienced a change of worldview and waken up to the current environmental crisis while gazing down to Earth from space. To benefit practical climate change actions on Earth, the next space tourists, who most likely are wealthy elite, could get the same feeling of our planets fragility as the astronauts had. Their environmental awakening could help to benefit the climate change projects if the wealthy customers get inspired of investing in environmental protection. The fact is, if the atmosphere of the Earth is destroyed, the human race does not currently have other planets to live in. (Toivonen 2021, 72-73.)

3.4.5 Economic level

On the economic level commercial space tourism industry could foster the global development, as well as ultimately advancing human development to reach beyond Earth and the solar system. Economic development of space tourism could also reduce the cost of accessing space, which could help with several environmental issues, such as enhancing environmental policymaking and developing climate research by lowering the cost of environment-monitoring satellites. Other benefit the economic development of space tourism could provide is to supply low-cost, clean solar energy from space on a large scale, which is a necessity to develop poorer countries' economies without excess pollution. This could be achieved with the low launch cost that only the development of commercial space industry could achieve. (Toivonen 2021, 74-75.)

4 Research Design

In this chapter, the chosen research method and the data collection method are introduced. Choosing these methods is an important part of the research, and therefore it should be done with consideration. During the selection process, it was considered which method was the most suitable to provide material for answering the research problem. When conducting research, it is also important to pay attention to the reliability and validity of the it. These concepts and their implementation in this research are also addressed in the chapter.

4.1 Qualitative research

Research methods are divided into quantitative and qualitative research. Quantitative research is guided by a specific research problem, and it is used for solving something. This type of research is conducted in a scientific environment and it focuses on past events. Qualitative research often emphasises the future, and the method focuses on studying human world phenomena in a social environment. This research was conducted to study space tourism as a phenomenon and to gain an overall picture of the current situation of the commercial sector to see how much the industry has evolved since the earlier studies. (Pitkäranta 2014, 8–59; Puusa & Juuti 2020, 80.)

The key feature of qualitative research is that it is based on the examination of people's subjective views and experiences. It is used to improve, renew and develop the subject under investigation. Qualitative research often aims to provide a holistic understanding of a specific topic, which leads to an interpretation of the subject. The research aimed to gather a deeper understanding of what the current situation is in the space tourism industry in terms of environmental sustainability. As the environmental aspect is often strongly connected with ethical considerations, the research also took this into account in both theory and the interview questions. Since the industry is still in its development stage and has not yet fully started, the research concentrated on the future prospects of the field. The research problem was approached by gathering theory from literature and articles, combined with gaining knowledge in the form of interviews. Therefore, qualitative research method was the best option to achieve the desired results. (Pitkäranta 2014, 8–59; Puusa & Juuti 2020, 80.)

4.2 Semi-structured interview

The research material was collected through semi-structured interviews, which were conducted separately between three people who are connected to the space tourism field

through different perspectives. Additionally, some commercial operators of the space tourism industry were contacted, but they declined the interview inquiries. The semi-structured interview was selected on the basis of giving the interviewer a balance between structured and unstructured interviews.

Semi-structured interviews, sometimes known as focused interviews, are close to unstructured interviews due to their openness. The process of semi-structured interview follows pre-selected themes with specific questions related to them. The semi-structured interview assumes that the interviewees have experienced or gone through a particular process or matter. Before the interview is conducted, the researcher has to review previous research and literature on the subject to be able to identify the relevant factors of the research topic. This way the researcher deepens the knowledge of the whole phenomenon. The advantage of semi-structured interview is that the researcher is able to clarify and broaden the questions when needed. For this research, the themes and questions were chosen in advance to give the interviewee an idea of the topic in question, but still leaving enough room to answer the questions more widely. The themes in the interview structure varied from the sustainable practices of space tourism industry to regulating the growing field, as well as more ethical questions of the colonisation of other planets and the usage of the resources of the Earth and outer space. (Puusa & Juuti 2020, 112; Tuomi & Sarajärvi 2018, 64–65.)

The implementation of semi-structured interviews varies from almost unstructured interview to structured interviews. (Tuomi & Sarajärvi 2018, 65). As the semi-structured interview has a wide variety of implementations, structured interview is its opposite with its incapability to modify to the changes during the interview. It does not allow deep investigation of the topic due to its strict interview structure and the unstructured interview can lead too far away from the topic. The semi-structured interview method was seen as the best option to this research due to these reasons.

The most important goal of the interview is to get as much information about the research topic as possible. An interview framework that has been thought in advance gives the interview a structure and helps to ensure that the researcher gets relevant information for the purpose of the research and its problem. This also helps to keep the focus of the interview on the research topic. The pre-selected themes are based on the research framework of what is already know about the phenomenon. The framework and themes of the interview was designed in advance, based on the topics already covered in the theoretical part of the research. It was designed to give a wider and deeper understanding of the topic which could be used to support the already gathered theory. Thus, contemplation of

the themes in advance does not mean asking pre-selected questions in a formal framework. Instead, the subject is encouraged to talk about the topic quite freely. The interview process aims to find relevant and worthy information regarding the purpose of the research, which is why a certain structure should be followed. The aim of the framework was to have a clear but open structure, which could be modified to match the flow of the interview if needed. The questions were designed to examine the current and future state of the research subject. (Puusa & Juuti 2020, 112; Tuomi & Sarajärvi 2018, 64–65.)

4.3 Data collection

The contact information of the interviewees was found either through own networks or from the internet. The interviews were conducted between February 16th to February 18th of 2021. All of the interviews were conducted remotely due to the current COVID-19 situation using two different software. One of the interviews was conducted using Zoom – a video conferencing software and two using Microsoft Teams – a team collaboration software. The lengths of the interviews varied from 20 minutes to one and a half hour. The interviewees were asked for their permission to use their names on the final paper and all of them gave their consent.

The advantage of interview is its flexibility, as the researcher is able to repeat questions, clarify answers and expressions, correct misunderstandings and have a discussion with the interviewee. The question structure can also be arranged by the interviewer to an order they see as the most appropriate. The benefit of the interview is that it can be conducted with persons who have knowledge and experience of the research topic. The interviewees were chosen to widen the knowledge of space tourism field to fulfil the theory collected for the theorical part of the research. Other motivations were to find if the interviews could give more information about the topic and to gain insight from a humane point of view in addition to theory. (Tuomi & Sarajärvi 2018, 64.)

The qualitative interview situation should be rather informal than formal kind, more similar to a discussion or conversation, than a question-and-answer sort of situation. The approach of qualitative research requires certain skills, careful planning and consideration to be successful. These include contemplation and preparation in advance, developing an interview schedule, as well as conducting and analysing the data carefully after the interview. If the interviewee does not have enough knowledge nor experience about the topic, it can lead to the gained information to remain limited. The disadvantage of the interview compared to other research methods is its time-consuming nature. This was considered when interviews were scheduled by arranging enough time for every interview. Reason for

this was to ensure that the interviewer nor interviewee would not feel pressure during the interview. (University of Leicester 2021b.)

The first interviewee was Pekka Janhunen, a space plasma physicist, who has done computer simulations in the domain of space plasma physics and invented electric solar wind sail principle. He is working at Finnish Meteorological Institute as a research manager and is leading a team, which is part of The Centre of Excellence in Research of Sustainable Space by the academy of Finland. He is also working as a scientific and technical advisor for a start-up company Aurora Propulsion Technologies, whose domain is to commercialize inventions of electric solar wind sail and the plasma break. The second interviewee was Vesa Heilala, who is the vice president of Finnish Astronautical Society. He is also going to be the first Finnish space tourist flying with Virgin Galactic. He has witnessed a variety of space activities in many places. The third interviewee was Annette Toivonen, who is a PhD thesis researcher, with expertise in sustainable space tourism. She has also published a nonfiction book about sustainable space tourism and works as a space tourism lecturer at Haaga-Helia University of Applied Sciences.

Permission for recording the interviews was asked beforehand from the interviewees and the software's own systems were used to record the interviews. At the same time the key points of the collected data were written by hand to ensure that in case of error occurred, the key points would be saved. All of the interviews were conducted in English to eliminate the extra step of translating the collected data and to avoid translation mistakes when writing out the research findings. The interview questions (appendix 1) were sent at the same time with the interview requests, to make sure that the receiver got the best idea of what the topic of the interview was about.

4.4 Data analysis

When the data collection is considered, it is also necessary to think how the data will be analysed. When doing qualitative research, the analysis is not only in the end, but also a part of the whole writing process. The goal of analysis in qualitative research is to understand and unravel the overall picture of the phenomenon with the data. All data conducted from the interviews was first transcribed to a separate document after each interview. Transcribing, the first step of the analysis process, is used to decompose speech into written form. The method offers the researcher an opportunity to get acquainted with the material closely and to make observations and interpretations of it. Transcribing is a key part of the process of capturing and analysing qualitative data, which requires time and accuracy. (Kallio 2021; Pitkäranta 2014, 9.)

After the transcribing process, the data was analysed next with the content analysis method. In content analysis, the material is examined in detail by searching for and summarising similarities and differences. Content analysis, like discourse analysis, is a text analysis method that examines materials that are already in text form or changed to such form. The texts to be analysed can be almost anything: books, diaries, interviews, speeches and discussions. The aim of the content analysis is to form a summarised description of the topics under study, which links the results to the wider context of the phenomenon. (Saaranen-Kauppinen & Puusniekka 2006a.)

In addition to the content analysis the thematic analysis method was used to analyse the data. The thematic analysis emphasises what has been said about each theme. Overall, it is a method of breaking down qualitative material and grouping it according to different topics. This makes it possible to compare the occurrence of certain themes in the material. Thematic analysis is used as a tool to start looking for actual topics, themes, from the data. When organizing the material, the sections of each interview that talk about a certain topic are gathered under each theme. The research report usually presents samples and quotations in connection with the discussion of the themes. The sections quoted from the material are intended to offer illustrative examples and to provide the reader with evidence that the researcher has actually had some material on which to base the analysis, and that the material has provided indications to these particular themes. (Saaranen-Kauppinen & Puusniekka 2006b; Tuomi & Sarajärvi 2018, 79.)

5 Research Findings

In this chapter, the interview results are discussed one theme at a time. The findings are presented by looking for similarities and differences, as well as summarising the views of the interviewees. In addition to analysing the answers, the discussion is supported by quotations from the interviewees concerning the specific themes.

5.1 Space tourism practices

As there is no concrete suborbital or orbital tourism yet, it limits the knowledge of environmental impacts of the future industry. Even though the common view is that sustainability needs to be considered in the regulations and operations of space tourism, no specific sustainable practices exist yet. As there is very little information about the practices of the companies, it sets a challenge to form a regulatory framework for the operations. As Janhunen also pointed out, the current space tourism industry is only in the early stages of development, and there are no regular space tourism operations yet. He pointed out that many companies have been developing their operations for over 10 years, but the actual flights are still yet to be started. The environmental issues of the industry are recognized in general, but the concrete sustainable actions are still almost completely missing.

> "I think there is a general consensus that people are trying to take the environmental aspects into account." – Janhunen

The interviewees were asked about the current environmental sustainability practices in space tourism, as well as possible suggestions for the future, to gain more information about the topic. A concept that came up in all of the interviews was reusable rockets, which many companies are currently developing or already using. It is a sign that observational environmental sustainability has taken a part in the field of space tourism, Toivonen stated. Though, Heilala pointed out that currently the main motivation for developing reusable systems is actually reducing the costs of the operations. Janhunen highlighted that attention needs to be paid on the materials being used when building the rocket frames of reusable systems.

> "The observational environmental sustainability has taken place in the industry; best example of this could be the reusability of the rockets." – Toivonen

> “When the Falcon 9 rocket actually was able to return back to the planet in 2018, that was the first sign that this new space industry could act in more sustainable format in the future than these previous agencies, like NASA and other countries, when they traditionally used a rocket once.” – Toivonen

Janhunen pointed out that even though reusability is currently the most promising approach to the sustainability issue, it is not an absolute requirement for developing environmentally friendly systems. He explained that there are always trade-offs, one example being the comparison between reusable rocket and its corresponding expendable, single-use system. Reusable systems always need extra hardware, such as retrorocket, thermal shield, or landing legs. On the other hand, single-use systems do not require any of these, so the rocket cores can be simpler and more lightweight, and therefore require less propellant. Another important step towards more sustainable actions in the industry would be to stop using solid rockets, especially those that contain chlorine, as the element can destroy the ozone after being released in the stratosphere.

> “Second important thing is not to use solid rocket that contains chlorine, because its ammonium perchlorate is the chemical which is used as an oxidiser in the traditional types of solid fuels.” – Janhunen

> “Chlorine is a bad element to release to the stratosphere because it can destroy the ozone. Chlorine containing compounds are basically bad in the stratosphere.” – Janhunen

When asked about a possibility of using other kinds of power sources instead of fuels in the rocket systems, Janhunen elaborated that for example using solar power is not suitable for orbital launches, as a certain amount of energy is needed to reach the orbit quickly enough. If the required speed is not reached, the vehicle basically falls back to the atmosphere. Currently, the chemical rocket engines are one of the only solutions that are powerful enough to reach the orbit. However, Janhunen explains that after reaching the orbit, there is a possibility to continue the travel by using other types of energy sources. One option could be using electric propulsion, which utilises solar energy from large solar panels or solar panel wings, as well as using electric thrusters.

> “The challenging thing of launching to orbit is that the energy must be produced quite fast, so you have less than 10 minutes to reach the final speed, which is sufficient for you to remain in orbit. There are not many processes known that can produce such launch power density, except the chemical rocket engines.” – Janhunen

> “Once you are in the orbit or in any kind of stable orbit in space, you have all the other options if you want to continue to somewhere else, for example to the Moon.” – Janhunen

Another topic connected to sustainability issues of the industry are the fuels used in rocket launches. Janhunen brought up that the usage of hydrazine should be eliminated from the industry, as it is a highly poisonous, carcinogenic, and also unsafe option due to its ability of exploding all by itself. According to his knowledge, hydrazine is not used as a main propellant by the new space companies, but it is still being used for altitude control. Other fuel options exist that are safer to use than hydrazine. Janhunen also points out that carbon dioxide and water vapor are creating environmental exhaust, as they are greenhouse gases in the stratosphere. When rockets are launched through stratosphere, water vapor is released in the process, which warms up the climate. Though, he highlights that the climate warming effect of rocket launches should not be overemphasised, as their effects are still extremely small at the moment, for example compared to the emissions coming from cars.

> “One should eliminate using hydrazine as a fuel because it’s very dangerous. If it is used as a main propellant, you may get pollution problem in the vicinity of long spat in the surrounding area.” – Janhunen

> “These other fuels, kerosine and or even this rubber propellant that Virgin Galactic is using is much more environmentally safe. Because it is not at least poisonous or carcinogenic.” – Janhunen

Toivonen highlighted the world of virtuality, including Virtual Reality and Augmented Reality, as one of the most environment friendly options for experiencing space tourism since it does not require the participants to actually leave the planet. She also adds that the space tourism experiences could be combined with other types of virtual destination experiences, such as watching the Northern Lights in Lapland. Toivonen points out that in general, sustainability should be included in the operations of space tourism companies.

> “Companies should continue including sustainability in all levels of operations in the future.” – Toivonen

When the field grows, new commercial spaceports will be needed. As the spaceport operations can affect the surrounding environment and the health of the population, interviewees were asked about possible actions that could be taken to make the operations more environmentally sustainable. Toivonen stated that in the building process of a spaceport,

all operational sustainability issues should be taken care of, similarly as when building traditional tourism sites and destinations. She mentioned that when Spaceport America was built, many sustainability issues were considered and taken care of, for example by including solar energy in the operations.

> "When building spaceports, you have the operational sustainability. It is the same thing as building any tourism destination or site – you have to take care of all things included in that operation." – Toivonen

Also, the location of the future spaceports was highlighted in the answers of Toivonen and Heilala. Toivonen mentioned the Spaceport Cornwall in the UK as an example, which is located in a countryside with small villages in the surrounding area. The spaceport operations can cause community related issues, such as affecting the life of the local villages with mandatory road closures. Heilala pointed out the safety concerns regarding spaceports – a wide safety area is needed to avoid possible damages to the surrounding buildings, for example in a case of an accident occurring during launch.

> "All kinds of community related environmental issues need to be solved so that space tourism operations will be successful in certain regions. That is maybe the key thing I would point out, the community." – Toivonen

> "You need to carefully think the location of spaceports. It is better to be somewhere with no population nearby." – Heilala

Both Janhunen and Toivonen mentioned the noise pollution, which is another issue connected to spaceports. According to Toivonen, solutions to reduce the noise pollution from rocket launches are being considered, for example by designing the fleet aircraft in a way that the loudest part is launched from high enough. Janhunen states that in principle, this would be possible to solve by launching rockets from an airplane, from an ocean base, or from a balloon, instead of the ground. For example, a balloon could be lift up to 20 kilometres of height above the ocean, and then conduct the rocket launch from there. This would eliminate the noise pollution from the land area. Using the lifting balloons would also mean that roughly two times less propellant is needed for the launch, and a two times smaller rocket would be sufficient to reach the orbit for the same payload. If a rocket is launched from about 20 kilometres altitude, it would not need to fight its way through the lower atmosphere and against the gravity of Earth, according to Janhunen.

> “I would say that the noise pollution is one of the things to be concerned about in the vicinity of the launch pads. Rockets are not silent, there is basically not much that you can do about it.” – Janhunen

Even though the balloons could be more environmentally friendly option in general, it should be taken into consideration what is used for lifting them. Janhunen explained that according to a paper he has written, using steam instead of helium or hydrogen to fill up the balloon would be a more sustainable method for lifting it up to stratosphere. If using water vapor as the lifting gas is possible, there is a chance for the space activity to become more sustainable and environmentally friendly by eliminating the noise pollution from the ground, along with reducing the amount of required propellant. He stated that if possible, helium should be eliminated from the space industry and not used for the balloons, especially in a large scale. Helium is currently being used in some rocket launches as the pressurizer gas for filling the tank after the propellant has been used. This helps to avoid the tank collapsing after running out of liquid, but it is a non-sustainable method, as the used helium is lost after every launch. Using Helium is not sustainable in the long run, as it is a so-called noble gas – a by-product of the natural gas industry. It is not possible to get on Earth from any other reasonable sources except that it exists in the mixture of the some of the natural gas wells, Janhunen stated. Hydrogen is renewable and not a limited resource, but it requires a lot of energy to make, and therefore is not a good solution from the environmental point of view, he explained.

> “Helium as a lifting gas for balloons is not a good idea in the large scale, because when the balloon bursts at the high altitude, the bubble of helium rises to space because it is a lightweight gas.” – Janhunen

> “Using hydrogen as a lifting gas for balloons should also be limited. Hydrogen needs a lot of energy to make and its of course an explosive gas, it is basically dangerous.” – Janhunen

> “One thing that might have benefit for the sustainability is the steam balloon.” – Janhunen

The interviewees were asked about who is responsible of the sustainability of space tourism, whether it is only with the operators, or should the customers be responsible for their actions as well, for example in the form of a voluntary carbon offset. Heilala stated that the operators should hold the main responsibility and have their own sustainable practices ready for the operations. The knowledge of big companies is much wider compared to the customers that possibly know very little about the operations. Toivonen agreed that compensation schemes could be a future option for space tourism. She suggested that the

customers could pay something for the emissions they cause, and therefore be more environmentally conscious. The compensations could be used for environmental projects on Earth, Toivonen explained.

> "I think the operator has the main responsibility. A customer with a limited knowledge about these things can do very little." – Heilala

> "Compensation schemes similar to the aviation industry, or some other kind of emission cost, could be a possibility for the future space tourists." – Toivonen

5.2 Regulating space tourism

There is already international space law regulating the space activities on Earth and space but regulating the new space activities and the space tourism industry is still unclear. The interviewees were asked about the possible options to address the issue – who should be responsible for monitoring the commercial activities, and what kind of regulations should be added in the future. All of the interviewees stated that a change is needed to the current regulations and laws. Janhunen pointed out that the all the current international agreements are very old and created at a time when not even an idea of the new commercial space companies existed. At the moment, the space tourism sector is mostly regulated by the aviation authorities and law. The suborbital space tourism vehicles are considered to be basically airplanes, as they still stay in the ordinary airspace during the flight, he explained. Janhunen and Toivonen both stated that the future legislation should be updated to include the space tourism field and combine laws from both the aviation industry and the space industry. Toivonen pointed out that as there is currently no law for the new commercial space activities, the operators are basically free to do anything they want.

> "The five international agreements concerning space are all very old – they are from the Cold War era basically. When those agreements were signed, there was absolutely no idea of the present company based so-called "new space movement", or new space start-up companies." – Janhunen

> "There is not really a law yet for the new space activities, as we can see. Now we have the world's richest men launching satellites and other kinds of space activities – they can literally do anything they want. Because no law is preventing that from happening, there is a strong need for a law that covers all kinds of new space activities, including space tourism." – Toivonen

> “There is clearly big need to make updated regulations regarding the modern space industry and including space tourism field.” – Janhunen

Toivonen stated that a global law binding all nations together, such as the United Nations Outer Space Treaty, would need to be expanded to cover the new space activities and the field of space tourism. Especially if suddenly many countries start to progress rapidly on their space technology innovations, there needs to be a binding mutual law that includes the new space activities, she explained. Toivonen added that the key thing is to get this new regulation process started, for example by utilising something that already exists, such as the earlier mentioned aviation law. The future law should include aspects that can advance sustainability in the new space activities. On the other hand, Heilala stated that the current knowledge of the space tourism activities is still too little, which would make the process of forming any concrete regulations difficult.

> “The key thing is to get it even started and copy something that already exists – so maybe some of the aviation laws could be a good start. Taking some parts that are related to sustainability especially at the moment, and then advancing it.” – Toivonen

> “Let’s say when the first ten thousand customers have gone to space, then we have more knowledge and data, which helps us to make better laws and regulations. We have too little knowledge at the moment.” – Heilala

Janhunen pointed out that the space tourism field itself is still not in the most desperate need of new regulations. Legislation is needed in many other parts of the space activities as well. The field in the most urgent need for new regulations is the orbital debris, he stated. Space tourism does not have much impact to the issue, as the vehicles only travel to the orbit and back without leaving anything permanent in orbit. Therefore, the suborbital and orbital tourism is not causing any problems from the viewpoint of debris, he explained. Also, Janhunen brought up that regulations are needed for space mining as well, since currently no laws concern the mining of Moon, asteroids, or other heavenly bodies.

> “The field that needs new regulations now is the orbital debris, it is an urgent problem.” – Janhunen

> “There is also a need for legislation of space mining, but it is not yet a concern of space tourism. In some stage, the space tourism might extend to Moon and asteroids and so on, but we are not there yet. We are still only waiting for the lower Earth orbit tourism to start.” – Janhunen

The topic of colonizing other planets, for example Mars, has come up in the plans of private companies. This has raised many ethical questions regarding who can or should be allowed to use them, or should it even be allowed at all. The interviewees were asked about their possible viewpoints on the topic, and how the issue could be addressed in the future. The possibility of a mutual ownership agreement for legislating and colonizing other planets was another question regarding the topic. According to Janhunen, the current international space agreements restrict the ownership of a heavenly body. So, it is specifically stated that owning Mars for example is not possible. Though, in case something would be built on the surface of the planet, the structure could be owned by the builder, but not the land or area itself, he explained. Toivonen and Heilala highlighted that there are lots of ethical questions regarding the humanity's rights to start conquering the neighbouring planets and how it should be done. They both agreed that the concept of a mutual ownership could be a possibility in case new regulations to the issue are addressed in the future. Heilala also stated that as the costs would be huge, a shared funding between nations would be needed for the mutual ownership process. Toivonen pointed out that one concern regarding the mutual ownership is how the cooperation would actually succeed, as humans naturally tend to disagree, but still trying it out would be a good start.

> "Something like a mutual ownership is most likely to happen in the first place. And then we will see how the cooperation will go." – Toivonen

> "It should be like that each country or continent have their own parts; they should not be owned by companies." – Heilala

5.3 Future of space tourism

As planets can have their own ecological balance and ecosystems, there is discussion whether or not it is right for humans to interrupt them for example with the future Mars colonization. Janhunen pointed out the question if life actually exists on Mars or not. It is not certainly known yet, but as for example ESA's trace-gas orbiter has not found any new organic gases in the atmosphere or Mars, that is a strong sign that life does not exist on the planet. He added that in case life would exist on Mars, it would be below the surface, as over it the conditions simply are not suitable for life. Life always needs three things; an energy source, liquid water, and nutrients – all these are probably under a certain depth below the surface of the planet. Janhunen explained that on Earth we have a similar so-called deep biosphere, so as there are lots of bacteria even kilometers deep in the fractures of rocks. In Mars, a similar thing should exist if there is life at all. But even if there would have not been any life at all, the planet is still a potential scientific treasure due to

the possibility that old rocks found of its surface could contain very high-quality fossils. According to Janhunen, there are no other bodies in our solar system or the rest of the universe, which could have preserved this kind of old specimen possibly containing signs of the ancient life of Earth. The very dry and cold conditions of the Martian surface enable the preservation of organic molecules very well.

> “If there would be organic gases in the atmosphere of Mars, we should have already noticed them with the trace-gas orbiter. I take that as a rather strong indication, that probably there is no life on Mars, and probably has never been.” – Janhunen

> “Mars is valuable for science, even if there has not been found any life. It is the only body in the solar system, which might have preserved very old Earth meteorites that might contain fossils of ancient life of Earth.” – Janhunen

If humans land on Mars, the old specimen will not be destroyed just by landing there, Janhunen explained. The thing he mentioned that should not be done is terraforming the planet. If the temperature of the planet is raised, that would almost certainly ruin the ancient specimen on the surface. If the temperature of Mars rises above the freezing point and there is moisture, that is a sure way of destroying the old biomolecules. Janhunen stated that the question of harming life would need to be considered more carefully if life actually is found outside of Earth. Heilala pointed out that in the case of coming back from Mars or Moon for example, one should be careful of not bringing back anything that could possibly harm the life and ecosystems of Earth.

> “I would say that let’s worry about this if life is actually found somewhere else.” – Janhunen

> “Of course, you need to be very careful if you come back, that you do not bring anything with you that might harm the environment of Earth.” – Heilala

The interviewees were asked their viewpoints on humans using the already depleting resources of Earth for exploring the solar system and colonising other planets. Toivonen highlighted that this is another completely ethical question addressing what kind of right we have as humans to go after ruining our own planet, just to simply take off and ruin the next one if we are using the same exact techniques. Developing a technical solution for avoiding the devastation of any environment would be needed, she stated. Janhunen agreed that this kind of question regarding extra-terrestrial settlements or extra-terrestrial activities of space exploration cannot be categorically answered yes or no. These kinds of

outer space activities should be considered from a case-by-case and the-cost benefit ratio; what is and what is not beneficial. He pointed out that also on Earth, things that are certainly a waste of resources, are done. Heilala stated that exploring the outer space could be seen as an investment for the future – if we ruin Earth, the human race could still have a possibility to live on some other planet.

> "I think the key thing here is to kind of try to develop such technical solution that nothing needs to be ruined anywhere – we should really aim for that." – Toivonen

> "One should consider these kinds of things from a "case by case" basis, instead of the perspective if some proposal is outside Earth or inside Earth." – Janhunen

The interviewees were also asked for their viewpoints on humans using the outer space resources, for example to save the resources of Earth, and if this kind of activity should be somehow regulated. Janhunen and Toivonen agreed that this is another ethical question, which does not have one right answer. Using outer space resources could be justified with that it is done to save the Earth, but it also raises the questions of the humanity's rights to use those resources, Toivonen pointed out. She explained that normally if humans have colonised something, for example in the Arctic areas, someone has already been living there. That already raises big questions as you have to respect the original inhabitants. On the other hand, as there is currently not any known living species in space, making a conscious decision of harming other life could be left out, Toivonen added. Janhunen pointed out the comparison between the extremely common space resources, such as asteroids, and the unique and rare form of life on Earth. He explained that one could justify using some of the outer space resources there are lots of is alright, as there is no lack of them, and even after using some there would still be plenty left. Heilala suggested that using the outside Earth resources should be somehow regulated in the future, for example in the form of taxes.

> "We can of course justify it enough in a way that we are saving the Earth by doing it elsewhere, but at the same time, do we have a right to do so as humans." – Toivonen

> "Life is very valuable and precious, as it probably is very rare in this universe. Even if there is life elsewhere in the galaxy and the visible universe, it is not the same kind as ours. On the other hand, for example asteroids, they are extremely common in the universe and there is no lack of them." – Janhunen

The interviewees were asked about the possible positive environmental impacts that space tourism could have. Janhunen stated that it is quite early to say any concrete examples yet, but overall, it is sufficient to allow the field to operate, as it holds potential for having positive impacts. He highlights that this topic also has many viewpoints; one could argue that space tourism is not really good thing at all as it uses natural resources for fun or for nothing. On the other hand, it could be seen as a positive thing as it allows to develop the space technology, such as Earth observation satellites, which can be quite beneficial for mankind as a whole. The satellites help to gain information of what is happening on Earth, beneficially in a way that helps to reduce unnecessary consumption of natural resources, he explained.

> "The question is only that to what extent, space tourism specifically benefits the other types of space activities. So, I would say that probably there are environmental benefits, and possibly there are, therefore it is a good thing to let it happen. It is quite early to say though." – Janhunen

Toivonen and Heilala both brought up the possibility of space tourism affecting the customers viewpoints on the importance of Earth and its environment. Seeing the Earth from space could make people realize how beautiful the planet is, as well as understanding how lonely the humanity actually is. In the answers was pointed out that these kinds of experiences could also inspire the customers to act more environmentally friendly, such as the wealthy making environmental donations for the benefit of the Earth.

> "Literally seeing the planet and understanding that if we ruin the Earth, we do not really have an escape planet at the moment, so it is better to really take care of the environment." – Toivonen

> "So, it is more or less like a mental thing, that somebody goes to space and looks down to our planet and thinks "maybe we should do something that it will be safe". – Heilala

Lastly, the interviewees were asked about their visions of the space tourism industry within the next ten years. Janhunen highlighted that orbital space tourism could be operating in the next decade, especially if Elon Musk (SpaceX) succeeds with his ongoing Starship project. There is also a possibility for an opposite scenario occurring, which would mean that something has really gone wrong on the development of orbital tourism, he added. Both Janhunen and Heilala mentioned that the costs of commercial space travel could be much lower in the future, and that the space travel experiences would be affordable for a large proportion of the world population. Heilala pointed out that the space tourism industry will likely have more companies and nations operating in the field in the next

ten years. Toivonen brought up that the ongoing COVID-19 pandemic has had its effect in the increased interest towards space tourism, as the urge to travel has bottled up. She also added that regarding future, cultural sustainability is connected to space tourism through educating the youth how the new era of space could operate more sustainably.

> “After 10 years we already probably have large-scale space orbital tourism, or we have seen some kind of spectacular failure of the whole enterprise of Musk.” – Janhunen

> “Space tourism will be bigger, there are more companies coming. There will be Virgin Galactic and SpaceX, but there will also be for example Japanese, Chinese, and more American companies. If we now have two or three big companies, after a decade there will be ten or more companies in the field.” – Heilala

> “Before Corona, it was seen as bad thing to develop space tourism, especially in the middle of this kind of environmental crisis. But now because of the situation, all travelling stopped and individuals have bottled the urge to travel, and lot of them actually have been able to save quite a lot of money.” – Toivonen

> “Another angle to space tourism sustainability is cultural sustainability, which is what I have been doing myself as launching a university course on sustainable and responsible space tourism. That is literally educating the youth how this new era of space could be done in sustainable format in the future.” – Toivonen

6 Discussion

This chapter observes the connection between the theorical framework, and the results achieved by using the qualitative research method. The chapter also discusses possible further research proposals and the reliability of the research. In addition, the success of the research process, as well as and one's own learning and development during the thesis process are evaluated.

6.1 Consideration of results

The aim of the research was to gain an understanding of the state of the space tourism industry, as well as understanding how environmental sustainability is currently included to the field. Furthermore, the research problem addressed how environmental issues should be considered in the operations of the field in the future. Since the industry is still in its development stage and regular flights have not yet started, the research concentrated mostly on the future prospects of the field. The research problem was approached by gathering theory from literature and articles, combined with gaining knowledge in the form of interviews.

Throughout the research could be seen that the space tourism phenomenon is rising interest. The field has progressed a lot in the last few years and it has never been so close to success than now. There is still a need for more development, but the operators are very actively expanding their operations. The control of the space industry is no longer only within the large industrial groups, corporations or superpowers. New players from both private and public sectors as well as new spacefaring countries have started their operations in the industry, which is experiencing a transformation from government collaborations and large government investments to an era of participation, innovation, and commercialisation. The space industry is moving towards a field of better accessibility and openness for new operators and diverse activities. (Merhaba & al. 2019.)

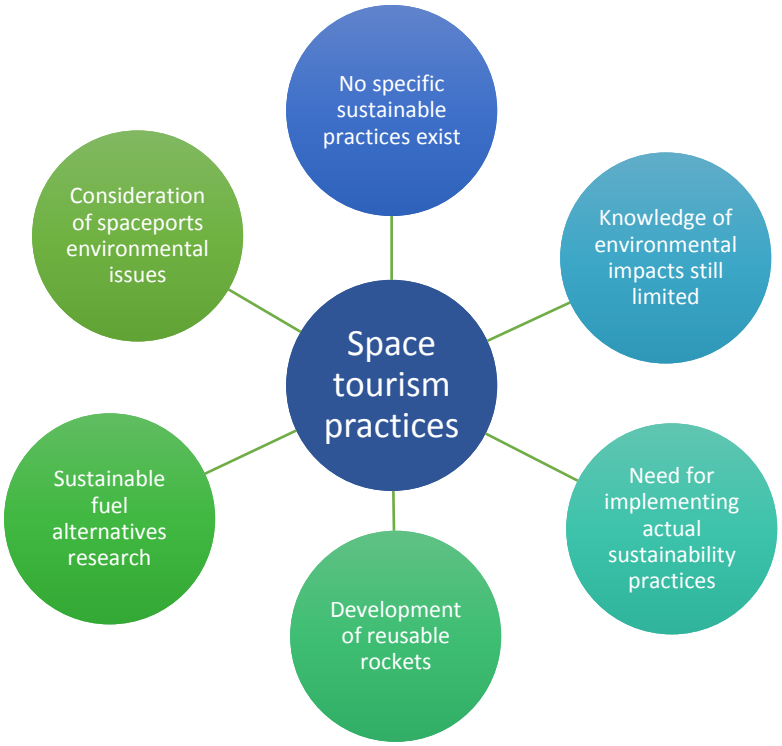

Figure 25. Main findings of the environmental practices in space tourism

The environmental concerns regarding space tourism are recognised in general, but the industry is still in a need for actual practices and actions (figure 25). The most advantaged operators in the field of commercial human space flights and in the development of reusable rockets are SpaceX, Virgin Galactic and Blue Origin. (Grady 2017). Due to the industry being still in its development state and as there is no concrete suborbital or orbital tourism yet, the knowledge of the environmental impacts of this future industry remains limited. The environmental sustainability has only a little part in the operations of the private space industry operators, and it is hard to find concrete sustainability practices of these companies since they do not share them publicly. Right now, the only visible sustainable action of the companies is the development of reusable launch systems, which could also help with the process of rocket manufacturing. As this process generates a lot of pollution and CO_2, building reusable rocket systems could help reducing the environmental impact. (Kordina 2020).

Even though there is a common view that sustainability needs to be considered in the regulations and operations of space tourism, no specific sustainable practices exist yet. The current motivation is after all reducing the costs of the launches through reusability, instead of focusing straight on being sustainable. (Grady 2017). The companies should implement sustainability practices to their operations through other ways, for example by supporting environmental charity. The interview findings pointed out that the industry will

most likely be depending on the wealthy individuals at the start. This could benefit the environmental organisations since there is a possibility of inspiration to act more sustainable among the customers after seeing the planet Earth's vulnerability from space.

Most sources vaguely brought up the emissions of rocket launches as the worst environmental impact. Therefore, to understand how the industry is really affecting the environment, the only option was to search detailed technical information and learn about the scientific side. Additionally, the interview findings brought information regarding the more technical parts of the current operations. For example, the rocket launches need a lot of energy to reach the orbit. As the only way to achieve this is by using fuels, the industry probably would not ever be completely emission free. After reaching the orbit, the rockets could use solar power or other sources of power to continue the actual travel in the outer space. This was a new sustainable point of view found during the research.

The findings also brought up that there is currently no fuel that is completely safe and environmentally friendly, which is why the companies and governmental agencies should invest more time to the research of sustainable fuel alternatives. The operators should stop using certain fuels and change them to more sustainable choices. (Kordina 2020). The interview finding mentioned that the future spaceports should consider environmental issues, such as noise pollution, emissions and safety of the surrounding areas. Solutions for the noise pollution could be transferring rocket launches to the sea bases or use airplanes or balloons to lift the rockets up in the sky and continue the launch from there.

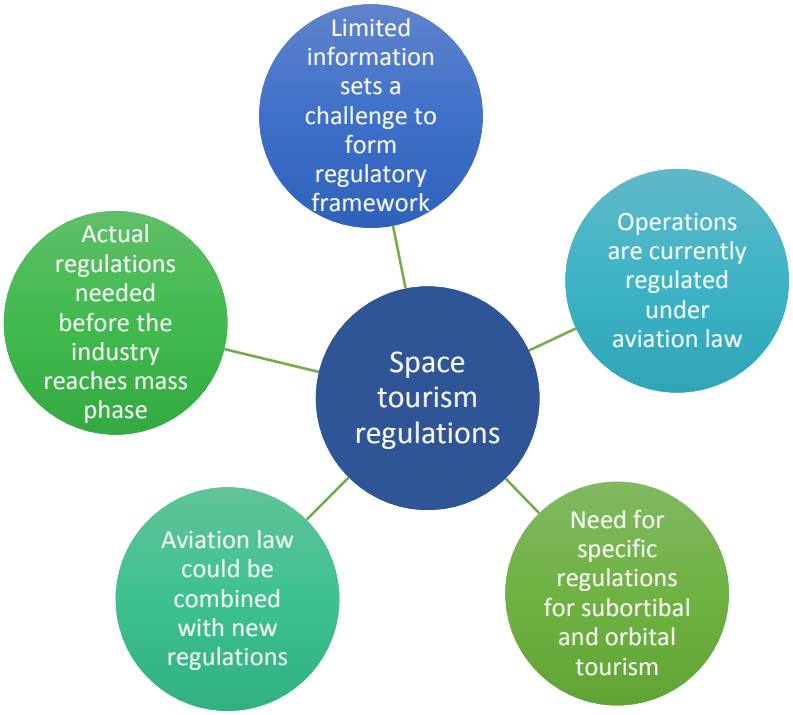

Figure 26. Main findings of space tourism regulations

The research findings (figure 26) pointed out that the current limited information about the practices of the operators sets a challenge to form any regulatory framework for the space tourism industry. The space tourism operations are currently regulated under the laws and authorities of the aviation industry. Both the theory and interview findings pointed out that the future space tourism field and its operations should be regulated in the future. According to the interview findings, the regulatory framework could be a combination of the current aviation law and new regulations. In the future, questions related to responsibility of the operations should be also considered in the field. These changes of regulations should be taken into consideration as soon as possible before the industry reaches the mass phase. Also, governments need to note that space tourism is an existing phenomenon that might become reality in the near future.

In the far future, if the colonisation of Mars succeeds, the regulations should be updated to involve possible space tourism activities. One interviewee pointed out that no one can own a planet, as the current international space agreements restrict the ownership of a heavenly body, but a person can own an infrastructure built on the planet. If the possible colonisation happens, the question is, which regulations and laws does it follow; should it be bound to Earth or have its own legislative framework. For now, the suborbital and orbital tourism are in greater need for new regulations.

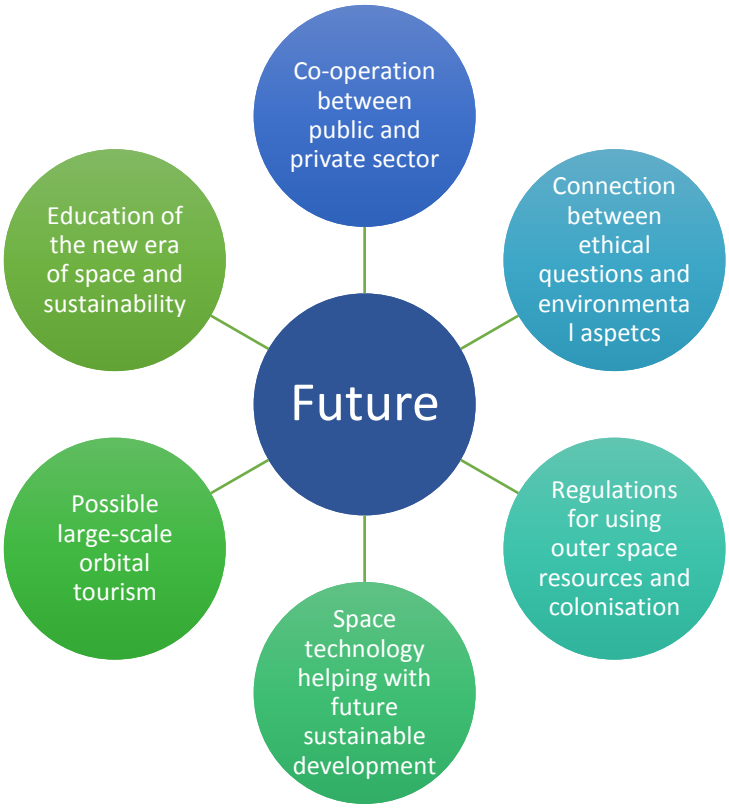

Figure 27. Main findings of possible future scenarios of space tourism

There are many possible future scenarios on how the field might develop in the future (figure 27). Ethical questions should also be addressed, for example regarding the future colonisation of other planets, as well as using resources of Earth and outer space. As the ethical side is strongly connected to the environmental aspect, these kinds of questions of what is wrong and what is right will most likely remain a part of the discussion regarding space exploration. One might argue what rights do humans have to colonise or use other planets resources after ruining our own, others might justify the usage of outer space resources to save Earth and its environment.

A surprising finding was how much space technologies in general can be utilised in sustainable development. For example, in the SDG's, the current and future space technologies can help in areas such as improving the sustainable use of natural resources, forecasting natural disasters, providing remote learning and e-learning for isolated and remote communities, delivering lifelong learning opportunities, improving connectivity in remote areas and enabling remote participation in democratic operations. Another unexpected finding was how much governmental agencies, private commercial space operators and nations have started to cooperate and support each other. The future era of collaboration is growing in the fields of space technologies, space exploration and in the space tourism

activities. For example, NASA and Blue Origin are cooperating under the Artemis Program. The mission is using New Shepard to test landing technologies to be used on the Moon. The New Shepard system's use LH2 and LOX as propellants and are crucial for the future lunar mission. This is marking progress towards sustainable space economy. (Cornell University 2020; United Nations Office for Outer Space Affairs 2021b; United Nations Office for Outer Space Affairs 2021e; United Nations Office for Outer Space Affairs 2021k.)

One interviewee pointed out that in the next ten years, the space tourism field either has finally reached the phase of large-scale operations in the orbital tourism, or the industry has seen some kind of spectacular failure during the development stage. There is a possibility that the cost of commercial human space flight is more affordable, and the regular space tourism is finally operating. Other interviewee brought up that the future education will include educating the youth about the new era of space and how sustainable actions should be considered. For now, the commercial space industry is continuously aiming to lower the cost of accessing space and develop safer systems. The space industry in general is trying to develop solutions for the environmental issues on Earth, while at the same time the exploration of the universe continues.

6.2 Suggestions for development of further work

During the thesis process we realised that the space tourism phenomenon is a relatively large concept that can be addressed from many viewpoints. This research aimed to address space tourism and environmental sustainability, which included connecting the topics on various levels. In case the concepts of space tourism and sustainability are addressed again in future research, it would be interesting to examine the phenomena through the social and economic aspects as well. Using the qualitative research method and semi-structured interviews for this kind of research problem was noticed to be an effective way to examine the phenomenon. For the future research, we would recommend using similar kind of approach. The future researcher could interview representatives of companies involved in space tourism, as well as experts who are connected to the field. Depending on the research problem and topic, the spectrum of the interviewees can vary a lot. Researching the environmental sustainability during the time of this thesis had its own challenges, as the knowledge and data of the operations was still very limited. In the future, if the actual commercial space operations have started and this new field of tourism. Again, as the challenge of researching the space tourism phenomena is the width of the topic, it is important to focus on outlining the approach style and research problem carefully.

6.3 Reliability of the research

The usage of validity and reliability in the qualitative research has naturally sparked a debate since they have been originally made to measure the trustworthiness of the quantitative research. The key feature of qualitative research is that it is based on the examination of the subjective experiences and views of humans. The trustworthiness of qualitative research must be understood more broadly than just through the concepts of reliability and validity. The credibility of qualitative research shows differently in its various stages. The researcher's own learning is transparently included in the process, which impacts the reasoning chains and helps to highlight the novelty value of the research. The researcher needs to be able to give explanation of the data collection and analysis of the data. The clearer, more illustrative and detailed the researcher can express the different stages of the research, the better the credibility can be evaluated. (Puusa & Juuti 2020, 181; Tuomi & Sarajärvi 2018, 119–123.)

During the evaluating process, the researcher strives to make their own path of reasoning as transparent as possible when analysing and interpreting the results. This has been shown in the whole research process through evaluation and justification of results. To make it clearer and more detailed, the concepts of reliability and validity are applied to show the trustworthiness of this research. Reliability can be assessed in many ways. One aspect of the reliability of qualitative research is transferability. Transferability is established by considering whether the research results could occur in another research, and whether the topic could be re-examined. As the space tourism field is still in its development stage, it offers many possibilities for further research especially from the viewpoint of sustainable development. The material gained during this research process can be used as a foundation for re-examining the phenomenon later on, as the space tourism industry is rapidly changing and evolving continuously. (Jyväskylän yliopisto 2010; Puusa & Juuti 2020, 181.)

The selection of the phenomenon to be studied, as well as the research problems, are based at least partially on the researcher's personal motivation and views. Both of the authors had gained a basic interest and background to the topic from "Responsible Space Tourism" course at Haaga-Helia University of Applied Sciences. In addition, the authors had taken other university level courses of sustainability and corporate social responsibility. The quality of research is influenced by the researcher's ability to build a functional research design and selecting a target group that matches the research question. Reliability was enhanced by creating a clear research report structure, which was made to be easy

to follow. The theorical framework contains clear main themes, space tourism and sustainability, which are connected to each other through various levels. The interviewees were chosen to match these themes. (Puusa & Juuti 2020, 181.)

Validity can be shown with the results of the study. The results need to be relevant to the research problem and the chosen method of the research must be suitable for examining the research topic and materials. The chosen method was the qualitative research to achieve the desired results as the method is used for examining phenomena and often has a focus on the future. The research problem was to gather a deeper understanding of what the current situation is in the space tourism industry in terms of environmental sustainability. The research also aimed to define possible future vision of the space tourism industry. (Jyväskylän yliopisto 2010.)

Also, the used terminology and sources must be relevant to the content. (Jyväskylän yliopisto 2010). The research problem was approached by gathering theory from literature and articles, combined with gaining knowledge in the form of interviews. In the used sources, attention was paid to make sure they were reliable, versatile, current and relevant to the topics researched. All theories and facts were carefully examined to ensure that there were no misunderstandings. Both international and national articles and publications were used in the theoretical framework and in the empirical part of the research. Also, ethical aspects were considered in both theory and the interview questions. The sources were used according to the official reporting guidelines through the whole process of thesis.

To enhance validity, the interviews were recorded to make sure that the answers and findings were understood correctly when they were transcribed. This was also used to ensure that nothing was left out by accident. All interviews were transcribed straight away to another document. In addition, objectivity was used during the analysis of the research results and no own opinions were added to the findings. Relevant terminology to the topic was used through the research and the used terms were defined for easing the readers understanding.

6.4 An evaluation of the thesis process and one's own learning

The whole thesis process gave us a wide understanding of the different aspects of the space tourism field. The acquired knowledge included history of space tourism, the current state of the field, the most advanced operators of the industry, the different forms of the commercial space tourism, as well as detailed information about the technical side of space operations. In addition to examining space tourism phenomenon itself, we also

deepened our knowledge of sustainability and sustainable development and learned how these concepts can be connected to space tourism on various levels.

Gathering material for the theorical part turned out to be a huge and the most time-consuming part of the research process. As the space tourism phenomenon is a remarkably large topic, it was a challenge to form a clear outline for the theory and limit the amount of information to be included. Due to the development stage of the industry, we realised that we need more technical information to identify the environmental impacts. Even though we had background in space tourism through the university course of Responsible Space Tourism, our limited technical knowledge regarding the topic became clear when examining the space technology, spacecrafts and rocket fuels. Even though finding reliable and accurate information of the various topics was a challenge, we succeeded to gather accurate information and data from various sources in the form of articles, literature, and interview findings. The thesis turned out as a versatile collection of the different themes and aspects of the phenomenon under research.

The curiosity grew as the work progressed, as we both wanted to learn more and more about the topics. This sometimes made it difficult to proceed on the process of defining and assembling the big picture. Analysing the reliability of the information, and for example making sure the technical information is correct to avoid misunderstandings and the possibility of transmitting false information, took lot of time. As the industry keeps changing continuously, staying updated with the operations of the field during the research process required us to keep an eye on the news from the space tourism field actively. It was interesting to follow what kind of advancements happened in the industry through the research process, which gave a feeling that the operators are really pushing forward with making the commercial spaceflight a reality.

The decision to examine space tourism through the concepts of sustainability and sustainable development brought its own challenges to the process, as the available information regarding the topic is still very limited. As the suborbital and orbital space tourism operations have not started yet, it was tricky to find concrete information to form the environmental viewpoints. The challenge especially in the case of private operators of commercial space tourism was that the companies do not share sensitive details of their operations, which required us to really dig deep while researching the topics. Our ambition and curiosity to gain a deeper understanding than the most articles of the topic revealed helped us to stay motivated to examine the environmental aspects diversely. Also, as the environmental issues of space tourism are connected to various ethical questions, a spe-

cial consideration and attention was needed especially when planning the interview framework and analysing the research findings. Due to these reasons, we noticed that examining the environmental sustainability aspects of the phenomenon was a big challenge – conducting the research from the viewpoint of social- or economic sustainability could have brought broader findings considering the still early stage of space tourism operations.

The data collection process through interviews brought up many interesting viewpoints and additional information to the theorical framework. The themes of the interview questions varied from the sustainable practices of space tourism industry to regulating this growing field, as well as ethical questions regarding the colonisation of other planets and using the resources of Earth and outer space. Considering the width of the research topic, the number of interviewees should have been greater, and the selection could have included a larger variety of experts from different fields connected to the space industry. While conducting the interviews, we noticed that the questions should have been customized to fit background and field of each interviewee better to achieve more detailed answers and to gain more viewpoints. With the questions being the same for each interviewee, the research findings remained limited on some topics. In case future research is conducted of a similar topic, we recommend this aspect to be addressed with more consideration in the future. Even though the process had its own challenges, the theorical framework of the thesis was supplemented with articles and literature of the topics, so in the end the material was not too small. The findings were used to draw conclusions on the topic and to develop proposals for future research.

Especially when considering all these challenges, we feel that the final result is a versatile and comprehensive compilation of the space tourism phenomenon and its environmental aspects. Even if the process felt very challenging occasionally, it provided us opportunities for growth and development as it progressed. Overall, the choice of the thesis topic was extremely interesting, and examining it required us to challenge ourselves on various levels. Throughout the process, we got a chance to develop various competences, such as critical-thinking, creativity, data gathering and analysing skills, time management, perception, and patience.

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Appendices

Appendix 1. Interview framework

1. Are environmental sustainability practices currently included in the space tourism field, and if they are, how?
    - Can environmental sustainability be implemented by any other ways than reusable rockets?

2. Do you have any suggestions what else companies could do sustainability wise in the future?
    - As the rockets already can be reusable, could also their fuel be renewable? If yes, how?
    - Could rocket systems use any other forms of power source instead of fuels, even just partially? For example, a combination of solar power and fuel?

3. When the field grows, there will be need for new commercial spaceports. As the studies show that operating spaceports have effects on the surrounding environment and the health of the population, what kind of actions could be done to make the operations on ground more environmentally sustainable?

4. Is the responsibility of sustainability only with the operators, or should the customers also be responsible for their actions?
    - For example, should customers pay voluntary carbon offset that is already used in the aviation field?

5. There is already international space law regulating space activities, but what about space tourism itself? Should the already existing space law be extended to commercial activities, or should someone else take the responsibility of monitoring and regulating them?
    - What kind of regulations should be added?

6. What about the space colonization? As private space tourism companies have plans to colonize Mars, it raises many ethical questions of who can or should be allowed to use the planet. Should using the planet be regulated somehow?
    - If yes, by whom? If no, how do you think this issue should be addressed?
    - Do you think the concept of a mutual ownership, such as the ISS, could work with legislating and colonizing other planets?

7. Do you think it is justified for humans to spend the Earth's resources to explore our solar system and colonize other planets when these resources are already running low? Why?

8. Do humans have the right to use other planets resources, for example to save Earth's resources (for example, non-renewable resources or mine rare earth metals from space)?
    - If yes, why? If no, why?
        - If we start using other planets resources, should it be regulated? How?

9. As planets have their own ecological balance and ecosystems, is it right for humans to interrupt them for example with colonization?
    - For example, there is danger for biological contamination

10. Do you think space tourism could have any positive environmental impact?

11. What is your vision of the state of space tourism in the next 10 years?

12. Before ending the interview, do you have any other topic or point that you would like to bring up?