UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa

Study of the benefits and applications of LEO (Low Earth Orbit) for Communications and definition of space new business models: OneWeb case

Document:
Report

Author:
Paula Juan Garcia

Supervisor / Co-supervisor:
Silvia Rodriguez Donaire / Daniel Garcia Almiñana

Degree:
Bachelor's degree in industrial technology engineering

Examination session:
Fall, 2021.

BACHELOR FINAL THESIS

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Superior d'Enginyeries Industrial,
Aeroespacial i Audiovisual de Terrassa

Report

Study of the benefits and applications of LEO (Low Earth Orbit) for Communications and definition of space new business models: OneWeb case

Paula Juan Garcia

Director:
Rodriguez Donaire, Silvia
Co-Director:
Garcia Almiñana, Daniel

Bachelor's Degree Thesis in Industrial Technologies Engineering
Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa
Universitat Politècnica de Catalunya
13^{th} January, 2022

Abstract

The existing global digital divide between the different geographic areas, leads to almost half of the world's population lacking access to a reliable Internet connection. OneWeb, a global telecommunications company, aims to deploy an initial constellation of 648 satellites in low Earth orbit (LEO) to provide high-speed and low-latency connectivity to governments, businesses and communities around the world. Therefore, this thesis focuses on the study of the benefits provided by this orbit in the telecommunications field, for the subsequent analysis and development of OneWeb's business model, by means of the CANVAS methodology. This project is integrated within the DISCOVERER framework, a European project dedicated to the research of innovative technologies for its application in the lowest orbits (VLEO), in which UPC is involved focusing on the market analysis to solve the existing market challenge.

Keywords: Low Earth orbit (LEO), DISCOVERER, Business Model CANVAS, OneWeb, satellites, constellation, Internet, telecommunications.

Resumen

La brecha digital global existente entre distintas zonas geográficas, hace que casi la mitad de la población mundial carezca de acceso a una conexión fiable a Internet. OneWeb, una empresa global de telecomunicaciones, pretende desplegar una constelación inicial formada por 648 satélites en la órbita baja de la Tierra (LEO), para proporcionar conectividad de alta velocidad y baja latencia a gobiernos, empresas y comunidades de todo el mundo. Por ello, esta tesis se centra en el estudio de los beneficios que aporta esta órbita en el ámbito de las telecomunicaciones, para el posterior análisis y desarrollo del modelo de negocio de OneWeb, mediante la metodología CANVAS. Este proyecto se integra en el marco de DISCOVERER, un proyecto europeo dedicado a la investigación de tecnologías innovadoras para su aplicación en las órbitas más bajas (VLEO), en el que la UPC participa centrándose en el análisis del mercado para resolver el reto de mercado existente.

Palabras clave: Low Earth orbit (LEO), DISCOVERER, Business Model CANVAS, OneWeb, satellites, constellation, Internet, telecommunications.

Acknowledgments

To the director and co-director of this thesis, Sílvia Rodríguez Donaire and Daniel García Almiñana, for having dedicated their time and dedication to this project, as well as for the support and outstanding treatment always received.

To my parents and family, for the unconditional support I have always received. Especially to Josep, Maribel, David and Marcel, for the encouragement and guidance they have given me to move forward, which have helped me to achieve a major milestone today.

To my lifelong and college friends, for accompanying me on this path and paving it with all the happy moments we spent together. To my two Marias, Clara, Adriana, Arnau, and many others, always grateful for having you here.

To all those people who have made me learn and grow to get this far.

My sincerest gratitude.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1 Aim of the project

The purpose of this thesis is to study the benefits and potential that Low Earth Orbits (LEO) provide on the global telecommunications field, based on the analysis and development of OneWeb's Business Model.

2 Scope of the project

The project will include the following aspects:

- State of the art: Analysis of the market segment of LEO industry as well as the analysis of current competitors.
- Brief explanation of LEO internet satellite constellations.
- Study of the benefits and applications of Low Earth Orbits (LEO).
- Analysis of OneWeb Company and its features.
- Study of the feasibility and design of a Business Model using CANVAS representative methodology.
- PESTEL analysis to evaluate the global economic environment of the company.
- Internal and external examination of OneWeb by means of the SWOT matrix.
- Analysis of the risks associated with the company and its project.
- Development of an environmental study regarding OneWeb's business activity impact.

In contrast, the project will not include the following aspects:

- Implementation of the Business Model.
- Exhaustive analysis of the satellite production process as well as the components and materials used to create them.
- Exhaustive analysis of the technology and telecommunications used in the launching into corresponding orbit and during missions.
- Study of the rest of areas where LEO satellites are beneficial.

3 Requirements

The established requirements for the development of this study are the followings:

- This project is integrated within the DISCOVERER research group
- The object of study, OneWeb company, must meet the EU and USA satellite and telecommunications regulation
- This project must fulfil the UPC regulations for final thesis.
- The market study is based on companies that offer telecommunications services

4 Justification

It was only sixty-five years ago that man began to discover space with the first artificial satellite in history, Sputnik 1. Since then, the intense pace of research in technology, telecommunications and space, has allowed humans to begin a new era, the digital era. This new period has involved profound transformations in the actual society, a totally technologically dependent of the satellite's services, specifically on the Internet.

Nevertheless, there are still many places of the world where internet connection is still a challenge, either due to lack of connectivity or slow internet speed. It is estimated that approximately 50% of the world's population, around 3.7 billion people, suffer from a lack of reliable connectivity [23]. This digital divide is especially accentuated in emerging continents, such as Africa, India and many western countries. The percentage of the population living outside the range of a 3G or 4G signal amounts to 25%, approximately 780 million people, as shown on figure 4.1. However, the gap is also evident in rural and remote regions of developed countries.

Due to the interest that the internet generates, many researches have been carried out to improve satellite's characteristics and consequently, their applications on our day-to-day activities. This is one of the reasons why LEO has become attractive, due to the advantages it offers, as a faster data transfer between satellites network and consumer's terminal, among others. Big companies such as SpaceX, Amazon or OneWeb, have recently taken a strong focus of attention on these orbits and its low trajectories, planning that swarms of smaller satellites get positioned on low-Earth orbits to quickly receive and transmit data.

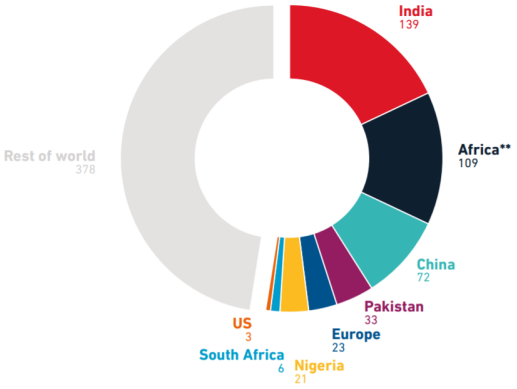

Figure 1.1: Population living out of range of 3G/4G network (million).
Extracted from: [23]

DISCOVERER is a European group research that aims to achieve a path to exploit Very Low Earth Orbits on a commercially way. One of the objectives of this group is to obtain new business models that allow the exploitation of the commercial sector, therefore this thesis will fall within this framework, studying the specific case of OneWeb, a global telecommunications company.

Chapter 2

Background

At the beginning of this chapter, the framework in which this research is integrated, the DISCOVERER project, is presented. This is followed by an overview of the description and evolution of the satellites along with the constellations, ending with a study of the different types of orbits. The analysis is focused on the Low Earth Orbits (LEO), the area where OneWeb operates, analyzing its characteristics, benefits and challenges with respect to other orbits.

1 DISCOVERER project

The project DISCOVERER, officially named as "Disruptive Technologies for Very Low Earth Orbit Platforms", is a European consortium formed by eight institutions, focused on the commercial exploitation of Very Low Earth Orbits (VLEO). The group research is constituted by four universities, two consultancies and two companies of the space sector, respectively:

- The University of Manchester (UNIMAN), Manchester, United Kingdom
- University of Stuttgart (USTUTT), Stuttgart, Germany
- Universitat Politècnica de Catalunya (UPC), Barcelona, Spain
- University College London (UCL), London, United Kingdom
- Euroconsult (ECONSULT), Paris, France
- Concentris Research Management GMBH (CONCENTRIS), Fürstenfeldbruck, Germany
- Elecnor Deimos Satellite Systems (DEIMOS), Puertollano, Spain
- Gomspace APS (GS), Aalborg, Denmark

Through the combined contributions of the mentioned institutions and a 5,726,750€ funding, financed by the European Community (EC), DISCOVERER began on January 2017 and has a duration of 63 months [43]. The initial duration of the project was of 51 months, nevertheless it has been extended because of the health pandemic, COVID-19.

In order to maximize the benefits and overcome the disadvantages adjacent to Very Low Earth orbits (VLEO), the group focuses the research into the following three aspects:

- Research of materials with a lesser impact on the degradation of satellites, as a result of the reduction of drag effect.
- Innovation of propulsion technologies to allow unlimited flight in these orbits.
- Design and development of aerodynamic control methods to fully exploit the VLEO atmosphere.

The involvement of the Universitat Politècnica de Catalunya (UPC) in the project focuses on the application of different business model methodologies to solve the existing market challenge to commercially exploit this space region. So far, a total amount of 52 theses have been carried out, either as final degree or master thesis, and four additional projects are in progress, including this one. Therefore, the mission of this thesis is to add value to the DISCOVERER project by studying and developing a business model for the telecommunications company OneWeb.

2 Satellites overview

Since the first artificial satellite, Sputnik 1, was launched successfully on 1957, humanity has been launching more and more satellites into space every year. On the second half of the 20th century the growth was slow but consistent; from 60 to 100 satellites were launched annually until beginning of the 2010s [64]. Thereafter, such frequency has increased exponentially to the point of reaching 50,000 active satellites in orbit within 10 years if current satellite Internet proposals are implemented [28]. Over the years, the progress and development of satellite technology has grown by leaps and bounds and will clearly keep pace for the next years.

According to the UCS Satellite Database, a total of 4.550 operative satellites were orbiting Earth on September 2021. The largest number of satellites is found in LEO, where the number of positioned satellites has grown to 2.521, compared to 565 in GEO, 139 in MEO and 1.269 in VLEO [8]. Translating this data into percentages: 55.4% of the satellites in space are concentrated in LEO, 12.4% in GEO, 3,1% in MEO and 27,9% in VLEO. The 2551 LEO-based satellites cover a wide range of applications, from civil and commercial to government and military uses. Henceforth, the focus on the next sections will be on the LEO telecommunications segment of satellites, the sector in which OneWeb operates.

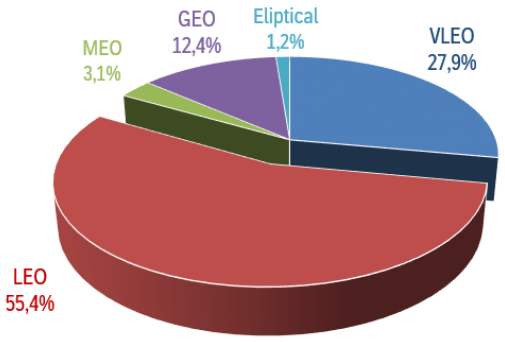

Figure 2.1: Current satellite distribution by orbits.

Small satellites, those considered with a launch mass of less than 500 kilograms, have taken a significant role in the space industry over the last decade because of the reduction in costs associated with them; lower manufacturing costs and may be launched in multiples by smaller launchers. Such satellites are commonly placed in Low Earth Orbits (LEO), rather than Medium Earth Orbits (MEO) and Geostationary Equatorial Orbits (GEO), generally forming constellations of satellites [26]. The following graph shows the growth of small satellites in space over the last decade:

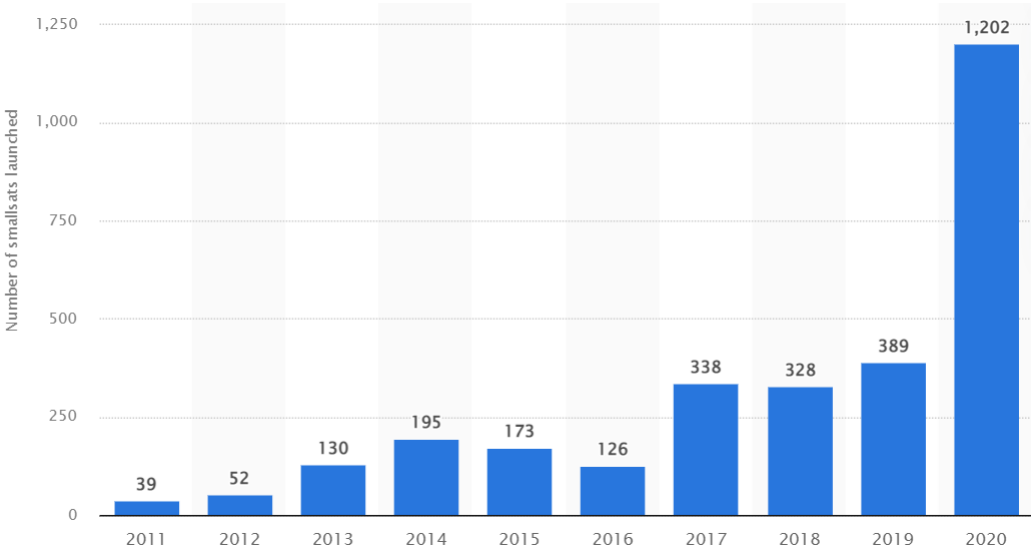

Figure 2.2: Number of small satellites launched worlwide from 2011 to 2020. Extracted from: [58]

3 Satellite internet constellations

Constellations are formed by groupings of satellites functioning as a system towards a common purpose. Although this thesis will focus on those constellations designed to provide worldwide connectivity, there are other applications for which they are being revolutionary, such as Earth Observation and geolocation. Not only has the increase in the number of constellations been remarkable in recent years, but the forecast is expected to continue steadily, as several new projects based on mega-constellations of small satellites are currently planned for commissioning in the next decade, as shown on figure 2.3. The growth in the number of small satellites in orbit, plotted in the graph 2.2, goes hand in hand with the increase in the number of constellations, shown in the graph 2.3.

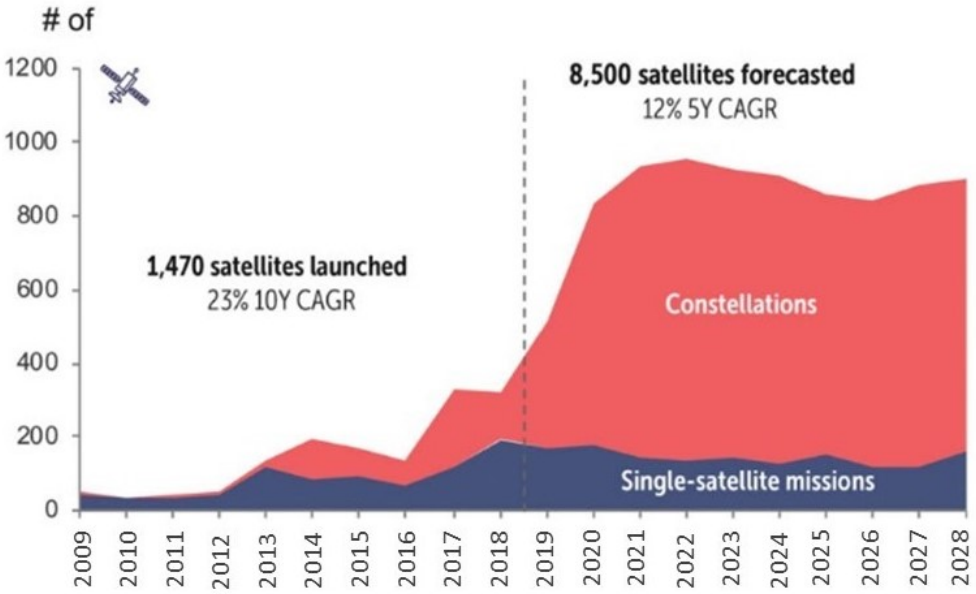

Figure 2.3: Expected number of smallsats forming constellations in space between 2009-2028. Extracted from: [45].

Currently, there are several projects in the telecommunications sector that plan to deploy mega-constellations in Low Earth Orbits. As a LEO-satellite's altitude is just 3% of a GEO-satellite, the roundtrip delays will be much shorter, benefiting real-time applications. Barriers to connectivity on Earth will be mitigated by the high-speed, low-latency broadband services that will be offered by the planned constellations.

The first large constellation projects in Low Earth orbits date back to the early 1990s, when companies such as Iridium, Globalstar, Odyssey, and Teledesic planned to offer worldwide connectivity. However, cost overruns and lack of demand led all of them, except the first mentioned, to cancel their projects. Nevertheless, technology has advanced and demand has increased, encouraging investors and companies to offer a disruptive alternative to provide reliable Internet access through LEO constellations [26].

If one point is clear, is that next generation communication satellites will be powerful and the feasibility of the commercial satellite industry will be guaranteed by a continuous innovation and further development of technology.

4 Earth orbits

Three essential orbit types exists; Geostationary orbit (GEO), Medium Earth orbit (MEO) and Low Earth orbit (LEO). Very Low Earth orbit (VLEO), considered a subcategory of LEO, will be also taken into account as they fall in the framework of DISCOVERER. Each of them provide satellites varying perspectives, involving several factors that determine the best and suitable orbit for a satellite and its purpose. The height of the orbit is a determining factor as it establishes the speed of the satellite relative to the Earth. As satellites altitude is lower and nearer to the Earth, the pull of the gravity becomes stronger, which results in a higher satellite speed. In the figure below, a layout of the orbital altitude and its coverage areas is shown. It can be qualitatively observed that the higher the altitude at which a satellite orbits, the greater its coverage area.

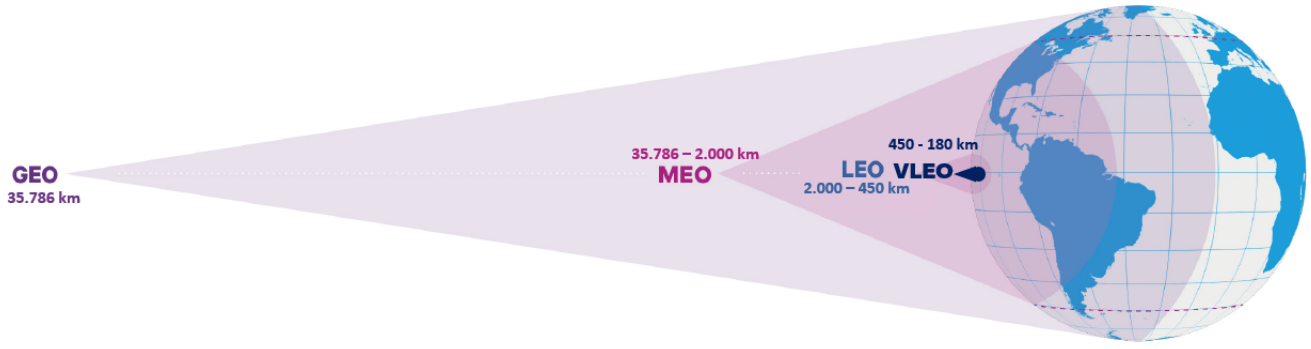

Figure 2.4: Schematic of orbital altitudes and coverage areas
Extracted from: [47]

4.1 Geostationary orbit (GEO)

The geostationary orbit (GEO) is a circular orbit placed at an altitude of 35.786 km above the Earth's equator. A satellite located in this orbit (GEOSAT) lies within the plane of the equator and moves at the same period of the Earth. Therefore, a GEOSAT seams stationary relative to the underlying point. Theoretically, only three GEO satellites are sufficient to provide global coverage [66].

Antennas on Earth can always be oriented in the same position, without the need to rotate them, thanks to the equal period of a GEOSAT and the Earth. Telecommunication satellites have therefore traditionally orbited in GEO. However, since GEO satellites have to operate at such a distance, they are larger and much more difficult to manufacture and launch compared to MEO and LEO satellites.

4.2 Medium Earth orbit (MEO)

Medium Earth orbits (MEO) region comprises the orbits between 2.000 km altitude, where Low Earth orbit ends, and up to heights of 35.786 km. A lower altitude implies a higher velocity, hence the period of a satellite situated on MEO is always less than approximately one day, and up to a minimum of two hours. GPS and navigation satellites are the main application of MEO.

4.3 Low Earth orbit (LEO)

OneWeb's constellation targets Low Earth orbits, so this section will provide a deeper study of this region through the analysis of its characteristics, advantages and disadvantages.

4.3.1 Characteristics

The Low Earth orbit (LEO) area is the closest to the Earth and it is usually at an altitude of less than 1000 km. Even though, it could be up to 2.000 km altitude and as close as 160 km from the Earth [63]. The region comprising the orbits between 160 and 450 km, is referred to as Very Low Earth orbits (VLEO).

Due to its low altitude, the satellite's speed in LEO is very high, over 25.000 km/h. Consequently, the longest time for which a satellite is visible for an on-ground observer on Earth is up to 20 minutes, meaning that the satellite's rotation period over the Earth is between 12

and 16 complete revolutions per day [19]. In order to provide constant coverage, LEO satellites usually operate as part of a constellation. The number of satellites needed to provide global coverage decreases with the increase of altitude.

At relatively low altitudes, the atmospheric drag force is large enough to affect satellites by causing orbital decay, resulting in a lower lifetime of these satellites compared to those in higher orbits. As altitude increases, the atmosphere becomes less dense, implying less effect of atmospheric drag. Hence, in VLEO the drag problem is far greater than the obtained in the higher orbits of LEO.

4.3.2 Advantages and disadvantages

Having defined the characteristics of LEO, the advantages and disadvantages associated to them can be analysed. LEO's strengths are listed below:

- **Signal transmission**: Signal loss is far reduced in LEO, compared to further orbits as GEO or MEO, as the signal travel length is much shorter. Consequently, a reliable connection can be established with less power and reduced antenna dimensions.
- **Low latency**: Latency is the time taken to send data from one point to another. In terms of propagation delay, the maximum round-trip transmission time is merely 13.3 ms, given at an altitude of 2.000 km, the highest LEO orbit [66]. Since the distance to be covered to reach other orbits is greater, the transmission time increases accordingly. Thus, for delay-sensitive services, as voice calls, or real-time critical applications, LEO satellites are the optimal.
- **High bandwidth**: A system of satellites are necessary to deliver global coverage in LEO so the overall network capability of a constellation is considerably greater than in GEO and MEO constellations. Consequently, better signal strength is provided to each user.
- **Reduced costs**: Due to the altitude, placing successfully a satellite in LEO requires less energy and less powerful transmission amplifiers. Benefiting from the low signal loss, most LEO satellites are designed to be smaller than MEO or GEO satellites. Consequently, less powerful launch vehicles are required to launch satellites.
- **Obstacles avoidance**: The fast movement of LEO satellites allow them to not be affected by obstacles, such as trees or cliffs, in the line of sight from terminal to satellite. In contrast, the communication between the spacecraft and ground station in GEO is not

enabled in the presence of large obstacles, due to the relatively static position between them.

- **Roads diversity**: Satellites in LEO have a wider route availability since they do not necessarily have to orbit along Earth's equator as GEO satellites.

While the advantages adjacent to Low Earth Orbits are interesting, there are also some disadvantages to be considered:

- **System of satellites**: Multiple satellites, often mega-constellations, are needed to cover the entire planet.
- **Complex communications**: The communication between the satellite and the ground station is more challenging because of the intermittent contact between them, due to satellite's high mobility. In consequence, the ground control equipment has to be positioned at various strategic points of the planet to guarantee proper monitoring.
- **Reduced lifetime**: The atmospheric presence to which the satellite is exposed at these low altitudes generates a drag force, which implies a gradual deterioration of the satellite until it causes orbital decay.
- **Space debris**: More and more satellites are concurring the LEO region and it is becoming congested with space debris because of an increasing frequency of satellites launches. A satellite is considered space junk one it completes its mission and it is required to activate movement for deorbiting. If in the process a collision is produced, it could puncture the objects, leading to a significant degradation of their functionality. Impacts between them can generate even more fragments of space waste, which are difficult to track, creating a dangerous domino effect, also known as the Kessler syndrome [**8**]. Another consequence of space debris, is the visual pollution it produces from Earth's surface, as it affects the space observation from here.

4.4 Very Low Earth orbit (VLEO)

Very Low Earth orbit (VLEO) are located below 450 km and can reach altitudes as low as 160 km [44]. Although these are the closest orbits to the Earth, they are still located far away from the surface and the operational area of aircrafts. Due to the altitude, satellites placed on a Very Low Earth orbit have the shortest period, consequently, they are able to orbit the Earth several times a day. Nevertheless, being at such low altitude present some key challenges; the

atmospheric density is elevated in VLEO, meaning that the spacecraft is affected by a significant drag force that cause orbital decay and eventually deorbit. [9]

The layer of the atmosphere containing these orbits is known as the thermosphere, considered to be in the range of altitudes between 100 and 500 km [6], above the mesosphere and below the exosphere. The temperature of this region gradually increases with height, and it can occasionally exceed 1500ºC [55]. Apart from the high temperature, this zone is characterized by the existence of aerodynamic forces which can considerably influence the orbital dynamic of the satellites.

VLEO are mainly used for Earth observation (EO) and satellite communications. As the spacecraft located in VLEO are the closest to the Earth, they can gather high-definition pictures and various information about the surface. On the communication side, a fleet of satellites located in VLEO, or LEO, can provide low latency and better broadband services due to its lower position.

4.5 Earth orbits summary

To conclude, a table with the main differences between the orbits studied has been designed:

	VLEO	**LEO**	**MEO**	**GEO**
Altitude	160-450 km	450-2.000 km	2.000-35.786 km	35.786 km
Earth's revolutions per day	12-16	12-16	1-12	1
Satellite life	Shortest	Short	Long	Long
Launch cost	Lowest	Low	High	Highest
Propagation loss	Lowest	Low	High	Highest
Earth coverage	Smallest	Small	Large	Largest
Space debris collision risk	Low	Highest	High	Low

Table 2.1: Earth orbits comparison

Satellite functions and features are basically determined by the satellite's orbiting altitude. Firstly, it can be observed that spacecrafts operating at lower altitudes have a shorter life expectancy. This is due to the density of the atmosphere that can be experienced at these altitudes, which diminishes completely as height increases.

Secondly, the overall cost of launching satellites in LEO and VLEO is reduced owing to the dimensions of these satellites. Smaller sized satellites can be launched as a whole by smaller and less powerful launchers.

Although in orbits further away from the Earth the coverage provided by each satellite is large, the propagation loss is more significant because the signal travel length is much longer.

Finally, the highest likelihood of collision with space debris occurs mostly in LEO due to the high number of satellites expected to operate in this area, turning it into a crowded region. Although constellations are also expected in orbits closer to the Earth, the existing atmosphere causes a faster orbital decay so the region will not be as congested as the previous mentioned.

Chapter 3

State of the art

The project background has provided an insight into the current trends in satellite launches in order to focus the beginning of this chapter towards the market of the satellites under study, the global satellite communication industry. This is followed by an in-depth study of the key players involved in the sector - OneWeb's main competitors. To conclude the chapter, an external strategic evaluation, a PESTEL analysis, has been carried out to identify the macro-environment that the company is currently facing.

1 Telecommunications market overview

Telecommunications have come a long way in a few decades. Traditionally, satellites dedicated to telecommunications have been orbiting at geostationary orbits, but the necessity to be connected across the globe is leading to the emergence of disruptive alternatives to provide satellite-based internet connectivity from lower altitudes as LEO.

Over the past decades, the global communications network has clearly been marked by ongoing technological developments, which have enabled its unstoppable growth; television, telephone, radio, internet are some of the current applications of communication satellites. The global satellite communications markets is forecasted to rise at a compound annual growth rate (CAGR) of 9.1% in the further future, from 2021 until 2028. At 2020, this market had a value of USD 65.58 billion, and will be increased until USD 131.68 billion in 2028, if the predictions are achieved [32], as shown on diagram 3.1.

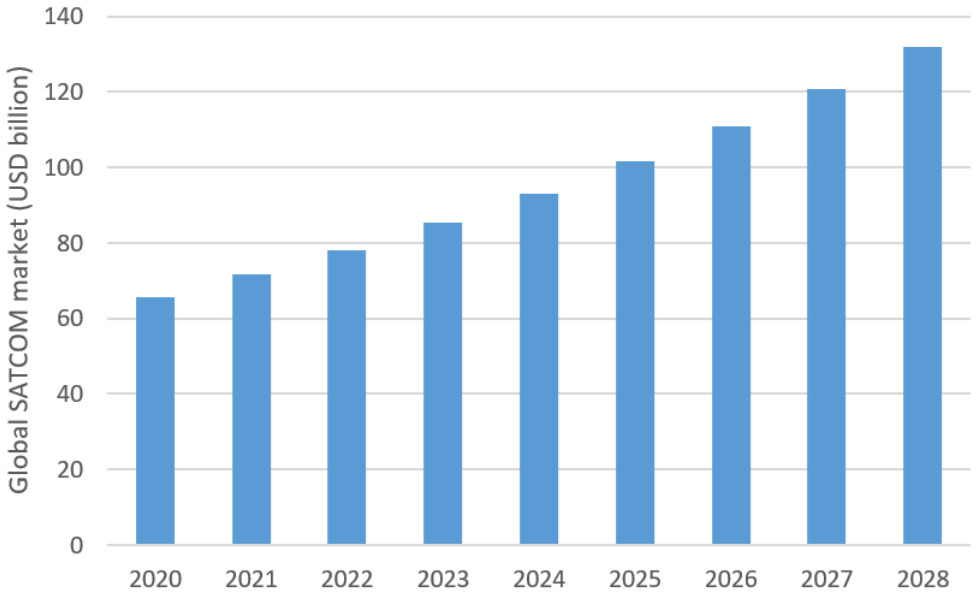

Figure 3.1: Expected growth of the global satellite communication market from 2020 to 2028.

One of the key factors driving the telecoms market is the current user trend towards next-generation technologies. More and more devices and objects are connecting to the Internet to enhance user experiences, known as the Internet of Things (IoT). The IoT has been recognised as a key driver of 5G wireless communications. This fact is driving the deployment of 5G infrastructure to make this technology a reality. As a result, companies in the telecommunications sector have the opportunity to shape a new future for businesses and consumers on the strength of advanced wireless technologies such as 5G [42].

A sector that has benefited from the COVID-19 health pandemic has been the telecommunications sector, due to its industry and business model. At the onset of the pandemic, home confinement in many areas gave way to teleworking, thus increasing the demand for connectivity and network infrastructure. At the same time, the total shutdown of outside leisure activities led to the use of digital entertainment platforms, and its resulting data traffic, such as social networking, online gaming and streaming platforms for series and movies. Although the pandemic is at its end and restrictions are less and less, the consumption of these services has led to a need and demand for higher bandwidths with high-speed connectivity.

If one thing is clear, is that the satellite telecommunications market will be strongly marked by Low and Very Low Earth orbits, since they will be responsible for delivering high bandwidth and low latency internet anywhere in the world, whether on land, sea or air.

2 Analysis of competitors

The analysis of the most important competitors will be carried out in this section, just focusing in companies operating in the lower orbit altitudes, LEO and VLEO, and leaving out of the scope the active organizations operating in other orbits and areas.

2.1 SpaceX - Starlink

The private spaceflight company SpaceX, founded by Elon Musk, aims to develop a constellation of satellites, named Starlink, with the aim to provide high speed broadband internet worldwide even in locations where access is not currently fully available. Starlink is nowadays the most recognised satellite constellation worldwide.

Figure 3.2: Starlink logo.
Extracted from: [30].

Although Starlink's service is also intended to be distributed to businesses and governments (B2B and B2G), as well as OneWeb, it will also offer direct service to its consumers (B2C) for personal use. Currently, it is already offering an initial beta service both domestically and globally with a data speed for the user of between 50 Mb/s and 150 Mb/s, and latency between 20 ms and 40 ms [30]. Nevertheless, Starlink ensures an improvement of this data as the system progress along with the growth of the constellation.

SpaceX is considered the main competitor of OneWeb due to the number of satellites already launched, almost 2000 satellites by early January 2022 [54], and the forecast of having the biggest mega-constellation on a near future, built by a total of 42.000 satellites [27].

2.2 Telesat - Telesat Lightspeed

Telesat is a Canadian satellite operator founded on 1969 and its core business was focused on geostationary orbits until January 2018, when Telesat's first LEO satellite was launched to an altitude of 1.000 km to initiate a constellation of 298 satellites, officially named Telesat Lightspeed [60]. The satellites will be distributed between polar orbits, which will carry 78 satellites, and inclined orbits, where the remaining 220 satellites will orbit [53].

Unlike Starlink and Project Kuiper, Telesat Lightspeed will be focused on B2B and B2G transactions with the aim to provide high-speed and cost-effective internet worldwide for commercial, government and defence markets.

Figure 3.3: Telesat Lightspeed logo.
Extracted from: [60].

2.3 Amazon - Project Kuiper

Amazon, a major global firm well known for e-commerce and cloud computing services, is building Project Kuiper; a constellation of 3.236 LEO satellites capable of supplying broadband service worldwide to its users and enable connectivity solutions for wireless operators extending LTE and 5G service to further territories. As well as Starlink's costumer segment, Project Kuiper also expects to deliver its service to businesses, governments and individual users.

Amazon may be considered a dangerous competitor for OneWeb, both because of the company's high revenue available to invest in the project and because of its worldwide recognition. Even so, while the company plans to invest more than USD 10 billion in this project, no satellites have been launched yet, in data of early January 2022. Although the FCC already approved the satellite's request on July 2020 [56], first 2 satellites of the Kuiper's constellation are expected to be deployed by the end of 2022.

The intention of project Kuiper is to deploy satellites in three different altitudes between 590 and 630 km, region considered as LEO, but fairly close to VLEO [46].

Figure 3.4: Project Kuiper logo.
Extracted from: [61].

3 OneWeb vs Competitors

The following table shows a summary of the competitors' characteristics defined in the previous section together with the features of the object of study, OneWeb's constellation.

	Expected number of satellites	**Current number of satellites**	**Orbit**	**Altitude [km]**	**Expected coverage**
OneWeb	648	394	LEO	1.200	Global
SpaceX - Starlink	42.000	2.000	VLEO	335-570	Global
Amazon - Project Kuiper	3.236	0	VLEO	590-630	Global
Telesat - Telesat Lightspeed	298	1	LEO	1.000	Global

Table 3.1: OneWeb vs Competitors

OneWeb and Starlink are the most advanced ones to reach their target constellation initial size, holding further commercial launches on schedule to achieve full deployment and global coverage by 2022-2023. Telesat with its Lightspeed constellation is likewise firmly on board, although on a lower scale. Finally, there is Amazon as an exception, which information is still almost unknown but may become a significant competitor.

4 PESTEL analysis

PESTEL is an acronym that stands for Political, Economic, Social, Technological, Environmental and Legal factors, i.e. a tool used to analyse macro-environmental factors that have a potential impact on the company development.

Political

- The UK's exit from the European Union, the Brexit, has resulted in the loss of access to Galileo's military and defence functionality by not being able to obtain certain valuable information and not being allowed to interfere on the future evolution of the main European satellite navigation systems.[21]

- In September 2021, the British government releases the National Space Strategy, describing its plans to become a leader worldwide in smallsat launch, emphasizing on the role for collaboration with the European Union through the European Space Agency (ESA).
- Public and private space sectors are partnering to solve mutual challenges and to continue growing.

Economic

- The global economic scenario is embittered in the aftermath of the COVID-19 pandemic. However, private investment in space related companies achieved a 8.9$ billion historical peak in 2020. [24]
- The global satellite communications markets is forecasted to rise at a compound annual growth rate (CAGR) of 9.8% in the further future, from 2021 until 2028 [16]. The satellite communications market will be valued at USD 131.68 billion in 2028, if the predictions are achieved. [32]
- Small satellites launching have exponentially increased last decade because of the reduction in costs associated with them. In 2011, 39 smallsats were launched worlwide in front of 1202 satellites in 2020. [58]

Social

- Society technologically dependent, as internet and technology are present on day-to-day activities such as business, leisure, education and communication.
- The pandemic has exacerbated most of society's feelings of loneliness, leading to a deeper necessity of being connected to their immediate family and community.
- The digital divide between rural and urban areas still exists and is causing inequality between both regions. The existing discrepancies not only affect the access to internet, but also in the quality of the connectivity.

Technological

- Smallsats are causing a revolution in the space sector, as thousands of these objects will be launched over the decade, to provide high-speed broadband connectivity even in places where there is no connection accessible at the moment. Currently, the company headed by Elon Musk, Space X, is the leader of the LEO sector, as its constellation is the most advanced one.
- Supply chain disruptions caused by the pandemic chip production shutdown are affecting the space industry, causing a delay in the development of satellites. A wide range of industries and business are also being affected by this chip shortage.
- A new generation of mobile technology (5G) is emerging, which considerably upgrades the characteristics of connectivity compared to previous generations.

Environmental

- Official space debris mitigation regulations are still pending to be implemented worldwide. A study carried out by ESA shows that if actions to continuously remove space debris start in 2060, this would be 25% less effective compared to an immediate start. [16]
- Atmospheric re-entry of satellites could lead to a new ozone hole due to chemicals released during spacecraft burn-up. [51]

Legal

- Because of the fast-moving space technology, the legislation on space-related activities is complex and difficult to implement in many cases.
- Communications via satellite are regulated by a governmental agency named Federal Communications Commission (FCC), which aims to boost connectivity and guarantee a solid and competitive market. [20]

Chapter 4

Case study: OneWeb

In this chapter an in-depth analysis of the particular case of the company OneWeb and its service is presented, gathering all the necessary information to perform an accurate Business Model CANVAS in the following chapter.

1 History and company overview

OneWeb is a satellite communications company headquartered in London, which aims to offer affordable communication services, providing high-speed and low latency connectivity worldwide throughout an initial mega-constellation of 648 satellites, positioned at Low Earth orbit (LEO).

The company was founded in 2012, but eight years later, in March 2020, OneWeb entered in bankruptcy after having already launched its first satellites in February 2019, due to insufficient capital to continue its activity. Few months later, in October, the organization was acquired by a consortium of UK Government and Bharti Global, resuming the process of the constellation's creation and aiming to reach global coverage throughout 2022.

Figure 4.1: OneWeb logo.
Extracted from: [30].

After twelve rocket launches, OneWeb has already deployed more than half of the constellation, with 394 satellites in orbit, and expects seven more launches before the end of 2022. On the graphic 4.2 below, it is shown a launch timeline.

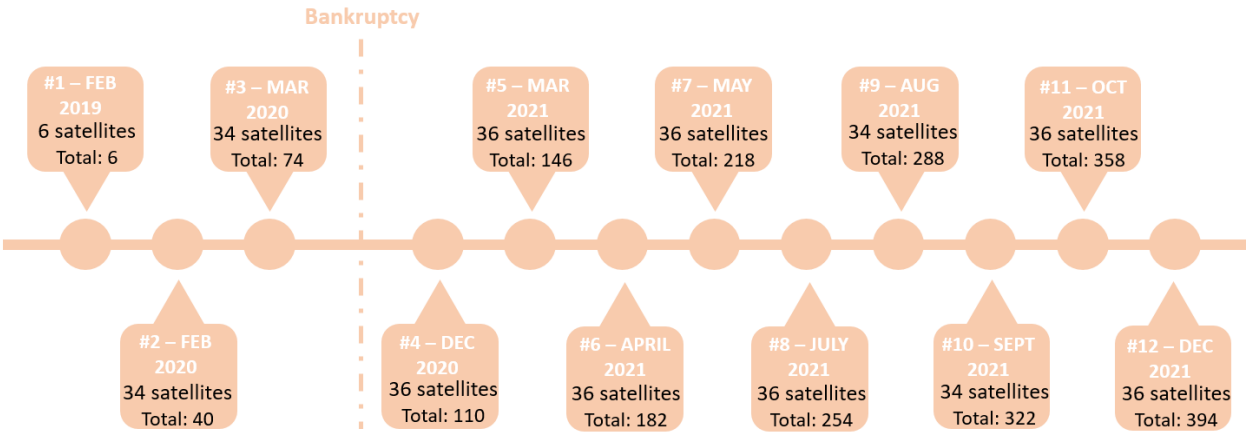

Figure 4.2: Launch timeline.
Extracted from: [36].

In July 2021, with the eighth launch and a total of 254 satellites in orbit, OneWeb celebrated its first milestone; it stood ready to deliver high speed connectivity from the North Pole to the 50th parallel - including the United Kingdom, Canada, Alaska and Arctic Region [52], the area shown on figure 4.3.

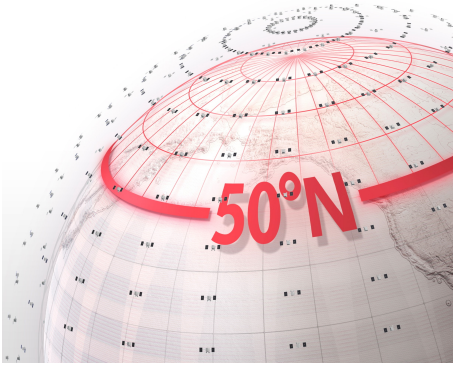

Figure 4.3: 50^{o}N Latitude area coverage.
Extracted from: [49].

Even though the company intended to kick off demonstrations of its service during the summer in order to start offering its commercial service in October 2021, this has been delayed from 5 to 6 months due to global supply-chain issues, especially because of the shortage of semiconductor circuits [40].

By January of 2022, wholesale partners of OneWeb will start testing services, with commercial services likely to be on offer at middle 2022, to the area above 50 Degrees North [40].

2 Company business statement and philosophy

OneWeb seeks to eliminate the digital divide that holds back economies and communities by providing reliable and high-speed access in remote and geographically challenging locations, to businesses and governments, whether on land, sea or air. OneWeb's constellation will be a

game-changer for high-speed communications in the maritime and aviation sectors, which have long had connectivity problems.

OneWeb (OW) expects to spread the corporate office environment everywhere, enabling secure, fast and affording connectivity across their sites, delivered through Distribution Partners. For real-time collaboration applications, OW will be able to connect directly to Cloud providers to deliver the quickest connection. The terminals will not only perform on a standalone basis but can also become a part of a miscellaneous network connectivity solution, acting as a back-up when the primary link crashes or when a capacity boost is needed during time periods of backhaul congestion.

Regarding governmental communications, OneWeb will cover air, land, sea and space communications, as well as military missions requiring high-level security and fast deployability. The system will also be able to integrate into aggregated communications networks in a battlespace, supporting the connectivity delivered by LEO satellites with 5G infrastructure and GEO satellites. In addition, the network will be prepared to allow access to cloud computing and the Internet of Things (IoT).

3 Ownership and employees

OneWeb's staff consists of approximately 500 employees distributed between the headquearters in London, United Kingdom (UK), along with a branch office located in Virgina, United States of America (USA). The team is headed by Neil Masterson, the Chief Executive Officer (CEO) of the telecommunications company.

Neil joined OneWeb in October 2020, post-bankruptcy and under the joint of UK government and Bharti Global, to strategically lead a further stage of the company's journey to achieve its goal. Neil comes from a long-term and successful leadership experience at his former company, where he was responsible for more than $6 billion in revenue. Currently, Neil and ten additional directors constitute the Board of Directors of OneWeb.

Notably, of the 10 additional directors, one is the Executive Chairman Sunil Bharti Mittal; founder and chairman of Bharti Enterprises, one of India's first generation companies, ranked among the world's top three mobile operators. Bharti Global and the UK government acquired OneWeb after the bankruptcy.

4 Investors

OneWeb is now fully funded and debt-free thanks to a $2.7 billion investment [35] of new capital from, in significant amounts, the consortium of the UK government and Bharti Global, but also from other major investors such as Eutelsat, SoftBank and Hughes, three telecommunications companies, and Hanwha, a powerful business conglomerate spanning a wide range of industries.

- **March 2020**: OneWeb files for bankruptcy.
- **July 2020**: UK Government and Bharti Global form consortium and submit winning bid commiting to provide in equality $1 billion.
- **January 2021**: Further funding from Hughes and SoftBank, increasing OneWeb's total investment to $1.4 billion.
- **April 2021**: Eutelsat invests $550 million, bringing the company's funding to $1.9 billion.
- **June 2021**: The company obtains complete funding through Bharti's Global contribution, reaching $2.4 billion.
- **August 2021**: Total funding amounts to $2.7 billion due to Hanwha's contribution.

Thanks to these investors, the company has not only managed to succeeded in raising the full amount of funds required to complete the first generation satellite constellation and ground network, but also has contracted the full amount of major expenditures with respect to its major costs.

5 Partnerships

As OneWeb manufactures its own satellites, it only requires the support of launching partners, enabling it to deploy satellites into orbit and related services, as well as distribution partners, to deliver broadband Internet to consumers.

5.1 Launching partners

OneWeb is supported by few key partners that enable the entire space mission:

- **Arianespace**: Arianespace is a subsidiary of ArianeGroup, which offers launch services for all kind of satellites into any orbit through its three launchers: Ariane, Soyuz and

Vega. The company posseses a launching center in French Guiana, South America, and two cosmodromes in Russia, Vostochny and Baikonur [2]. Airanespace is in charge of all launches of OneWeb satellites by the Soyuz launcher.

- **Starsem**: Starsem is a company committed to supply launch vehicles, managing from vehicle manufacturing, to mission preparations and in-orbit delivery of payloads. Starsem is the supplier of Soyuz, the launch vehicle used by OneWeb. [57]

- **ROSCOSMOS & Russian Partners**: ROSCOSMOS is a state-owned company which regulates legal spatial factors and guarantees the implementation of the Russian government's space program [38]. The company and its partners are also responsible of the following aspects:

  - Launch campaign planning
  - Upper stage launcher manufacturing and operations management
  - Technical management of launch pad and associated facilities dedicated to Soyuz

Figure 4.4: Partners logotypes.
Extracted from: [38]

5.2 Distribution partners

- **AT&T**: AT&T is a major U.S-based telecommunication company, well-recognized for its 2.5 million business customer to whom it provides fiber network. This company has teamed up with OneWeb to bring high-speed connectivity to places where it cannot currently access for business and governments costumers. [33]

- **BT Group**: BT is a multinational telecommunications company headquartered in London that has signed a Distribution Partner agreement with OneWeb to provide connectivity to rural UK.

- **Pacific Dataport Inc. and Alaska Communications**: Both Alaska-owned telecommunication companies have partnered with OneWeb to provide general coverage to Alaska region. [11]
- **Rock Networks**: The partnership between OW and the telecommunications hardware systems integrator aims to serve Canadian Armed Forces. [12]

Although OneWeb has closed deals with many companies, these are some of the most important which have signed a strategic agreement to convert in Distribution Partners.

6 Production system

OneWeb satellites are manufactured in Cape Canaveral (Florida) by Airbus OneWeb Satellites LLC, the joint venture formed by OneWeb and Airbus, a well-known company for its strong presence on the aerospace industry. This powerful partnership between two industry leaders aims to revolutionise the economics of space by producing its own fleet of satellites to deliver cost-effective internet connectivity worldwide.

Although satellite production is based in Florida, the company helds a facility in Toulose, staffed by around 100 engineering and supply chain personnel. The team in Toulouse pioneered the revolutionary manufacturing technology, leading to the first serial satellite mass production. Nowadays, they provide technique guidance to Florida factory.

The production line in Florida is comprised by four parallel-built modules, whereby the final product is obtained by means of an easy assembly, which allows to obtain up to two satellites per day. This is noteworthy because, traditionally, 10 million dollars and more than a year was necessary to build a single satellite [39].

In order to accomplish the high volume of satellites required to complete the constellation, OneWeb Satellites has redesigned the concept of its spacecrafts to obtain them in a massive way with reduced costs.

6.1 Supply Chain

A crucial point to obtain the desired volume is the availability of the required materials, therefore, its industrial supply chain involves approximately 40 suppliers, which are also mass producing the different satellite parts [48]. Some of the known suppliers are the following:

Figure 4.5: Suppliers logotypes

OneWeb Satellites' supplier network is made up of companies from 18 countries and 4 different continents. Due to this diversity, there is an average of 8 flights per week to deliver material to factory, with a time delivering rate of 95% together with a quality delivery rate ascending to a 99% [49]. Due to the high technology available in the company, they continuously perform cybersecurity audits to its all suppliers.

6.2 Satellite characteristics

The satellites manufactured by Airbus OneWeb Satellites are considered smallsats due to its reduced weight and dimensions. These 5-years life spacrafts are equipped with 2 external solar panels, electric propulsion and different antennas for its user links [14].

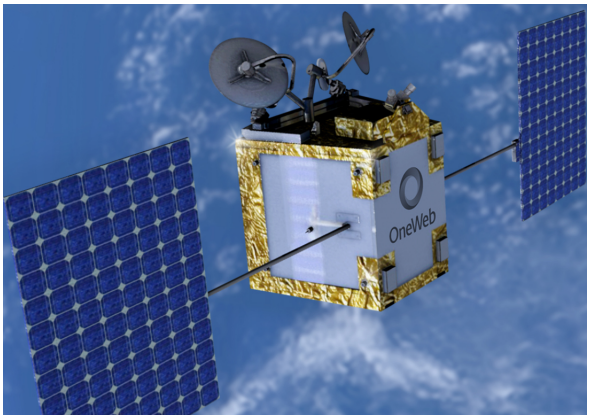

Figure 4.6: OneWeb smallsat.
Extracted from: [65]

On the following table, the main features of OneWeb satellites are designed:

Customer	OneWeb
Manufacturer	OneWeb Satellite (Florida)
Mission	Global connectivity
Orbit	LEO: 1.200 km
Mass	147.5 kg
Dimensions	1 m x 1 m x 1.3 m
Life-time	5 years
Propulsion	Plasmic propulsion system
Battery	Li-ion
Antennas	2 TTC omni antennas 2 Ku-band antennas 2 Ka-band antennas
Stabilization mode	3-axis stabilized

Table 4.1: Satellite main characteristics.
Source: [36] [14]

Plasma thruster systems operate with high-energy radiofrequency waves that transform the propellant into plasma. Currently, a vast number of smallsats integrate plasma propulsion systems because of its highly-effectiveness [17].

Solar panels, shown on figure 4.6, simultaneously allow Lithium-ion batteries recharging and satellite powering. With a luck of sun, these batteries provide power to the spacecraft and payload [5]. Li-ion battery transform sun's energy to electricity, to preserve spacecrafts orbiting the globe.

Regarding the antennas, the system is based on a Ku-band for downlink user communications and a Ka-band for uplink gateways communications [13]. In August 2019, OneWeb managed to bring its priority spectrum rights in the Ku and Ka bands into use, after in-orbit satellites successfully transmitted these frequencies for 3 months [37]. This spectrum complies with the regulations imposed by the International Telecommunication Union (ITU), the organisation in charge of regulating telecommunications worldwide. Within electromagnetic waves, both are considered microwaves, with the difference that Ku-band frequency range is between 12 and 18 GHz, and Ka-band takes from 26 to 40 GHz [18]. The usage of 2 TTC (Telemetry, Tracking and Control subsystems) omni directional antennas is necessary to guide most part of radio wave directions towards the Earth-facing side and to set up communication between the

satellite and the ground [25]. Two TT&C stations are needed to fully control the constellation communication [35].

Finally, three-axis stabilized satellites are equipped with spinning wheels to orient the satellite towards the desired direction.

7 Operations

7.1 Mission characteristics

The launch vehicle responsible to carry OneWeb satellites is named Soyuz, shown on the right. This model provided by Arianspace is a four-stage launcher composed of [1]:

- **Boosters**: First stage consists of four cylinder boosters that are powered by the combination of liquid oxygen and kerosene. After liftoff, these thrusters ignite approximately 2 minutes and then detach.
- **Central core**: Second stage is similar to the previous one but with thrusters around it. Four combustion chambers and nozzles are the responsible of the second stage propulsion, by the central stage ignition of almost 5 minutes.
- **Third stage**: Third stage transports the launcher's avionics between the oxidizer and fuel tanks.
- **Fregat upper stage**: The fourth stage is configured to become independent from the lower stages since it is equipped with its own navigation, altitude and tracking systems and it is able to reboot up to 20 times in flight as it has stored propellants.

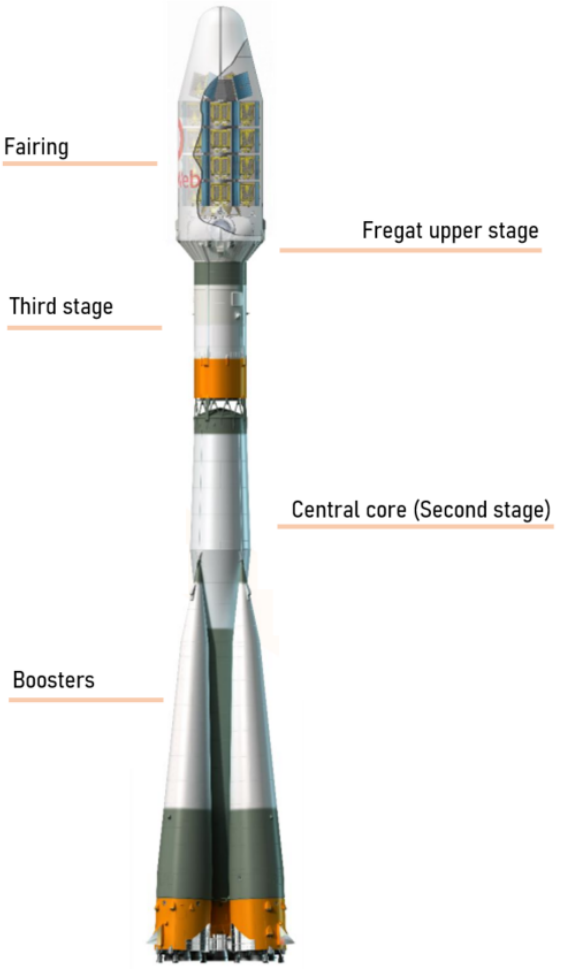

Figure 4.7: Soyuz launch vehicle. Extracted from: [38]

Soyuz also includes a payload adapter/dispenser and fairing, which carries all the payloads to be sent into space, such as satellites in this case.

As shown in the first section timeline graphic 4.2, the average payload in each release is about 34 to 36 satellites. Considering a maximum mass per satellite of 147.5 kg, the total payload of a launcher tends to ascend to 5.800 kg, approximately [36].

The launcher starts the first of its nine separations once it reaches a near-polar orbit at an altitude of 450 km. A group of 2 or 4 satellites is separated from the others each time in order to reach, by themselves, their operational orbit. The following image shows graphically the flight sequence:

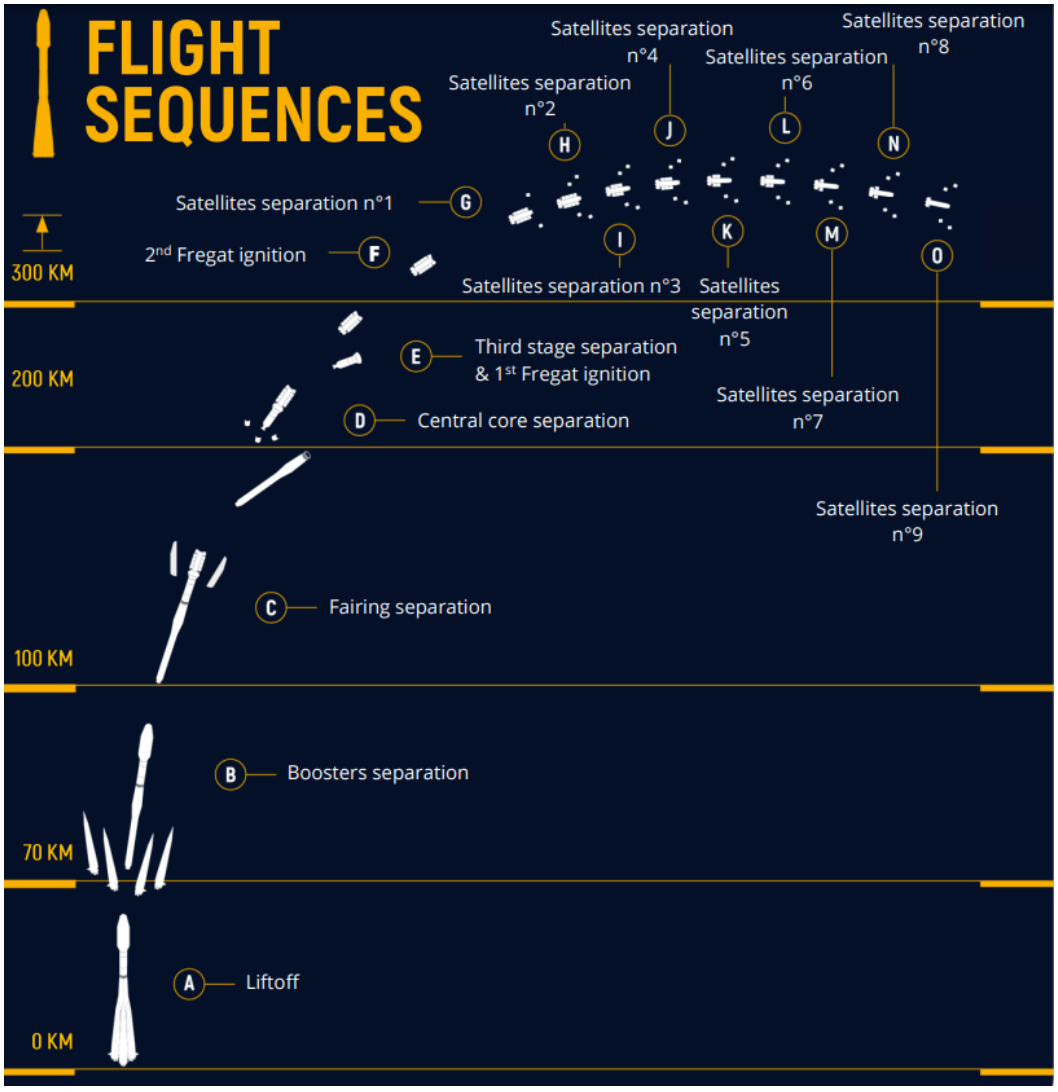

Figure 4.8: Soyuz flight sequence.
Extracted from: [38]

7.2 Constellation characteristics

Although full global coverage is planned throughout 2022, by mid-2022 OneWeb will be capable to deliver stable real-time connection to the area above 50 degrees north, which crosses Europe, Asia, North America and the Atlantic and Pacific ocean, by means of the satellites fleet. After total constellation deployment, OneWeb will be able to provide LTE, 3G, 4G, 5G and Wi-Fi coverage worldwide.

The final constellation is projected to reach a total number of 648 satellites, located at Low Earth Orbit (LEO) of 1200 km, reaching an inclination of 87.4 degrees. Total-fleet satellites will be divided in 18 circular planes, as shown in figure 4.9.

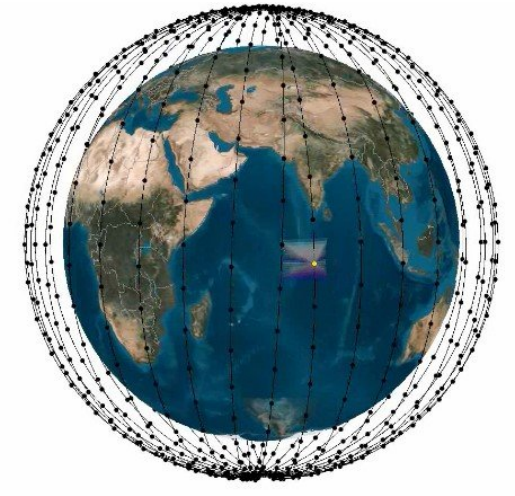

Figure 4.9: OneWeb's system architecture.
Extracted from: [13].

Accordingly, latency is on the order of 5 to 10 times lower than for GEO satellites, assuming a latency between 50 and 100 ms in OneWeb's satellites in front of 560 ms average from GEO satellites.

Even in the most recondite location, OneWeb will be able to encrypt data through a terminal and deliver it to the satellites network. The maximum transmitted data to these satellites is up to 32 Mbps, and the maximum data received is until 188 Mbps. The continuous satellite movement at a speed of 11,227 km/h implies that in a mere 92 minutes, each satellite completes its entire orbit.

These satellites are programmed to automatically de-orbit once they are approaching the end of its expected lifetime (5 years approximately), thanks to an stored fuel inside the spacecraft.

7.3 Processing data system (Ground stations)

Traditionally, satellites have been monitored by parabolic-dish antennas. However, these are not suitable for LEO constellations since multiple spacecraft can rapidly cross the field of view of a terrestrial receiver simultaneously. To be able to track the large number of satellites, it is

necessary to deploy a terrestrial network composed of several ground stations.

OneWeb hosts 2 Satellite Operations Centre (SOC), located in Virginia and London, from where it will manage its 43 ground stations. Currently, in January 2022, OneWeb has deployed 6 ground stations for its first 50^{o} north coverage mission. Each ground station, operating with Ka-band frequency, allocates a maximum of 10 antennas of 2.4 m diameter each, whereas user terminals, using Ku-band spectrum, just need 30-75 cm antennas [13]. OnWeb expects to provide worldwide coverage with its ground stations by the end of 2024.

8 Online Platform

8.1 Internet Delivery

OneWeb will deliver Internet to its end-users through two different pathways, either directly and/or indirectly. To enable direct user connectivity, the company has created the OW1 terminal. On the other hand, OneWeb will indirectly supply its customers with internet through its Distribution Partners.

To provide directly internet to consumers, OneWeb along with a leader in satellite dish technologies, Intellian Technologies, and Collins Aerospace, have developed the OW1 terminal, a 50 x 43 x 10 cm briefcase designed to provide high-speed and wide-bandwidth Internet to its customers. OW1 reduced dimensions allow an easy user installation.

Figure 4.10: OW1 terminal designed by OneWeb, Intellian Technologies and Collins Aerospace.
Extracted from: [31].

The flat antenna OW1 incorporates OneWeb's satellite modem within an isolated exterior unit. Installation of this equipment via an optional stabilized J-bracket is possible and it can be connected to its internal module through a combination of data cable. [31]

Online demonstrations sites have been also enabled to allow the costumers experiment with the offered service and to test their connectivity requirements.

8.2 Value-Added Services (VAS)

To facilitate user management, the company has created a web application and APIs (Application Programming Interface) which feature different digital products and services to ensure a satisfying user experience through the automated processes of platforms. The digital products and services that the company offers:

- **Service Hub**: To offer continuously support to the user and to respond to possible incidents.
- **Account Hub**: To handle customer's aspects as contracts, orders and bills.
- **Device Hub**: To monitor user terminals and to access real-time data.
- **Developer Hub**: To enable networking to satellite business operators via web applications and APIs.

9 Financial Status and Risks

9.1 Financial status

The year 2020 was marked by a lack of funding that caused the company to fall into bankruptcy. Today, after many challenges, OW is stronger than ever with a fully funded constellation and more than half of the constellation deployed. Although OneWeb envisions effective revenue from its service, it is still in a preliminary stage of revenue generation [35]. Once OneWeb begins to provide actively its service, expected in 5 or 6 months, its income will grow and the profitability of the business will be demonstrated. The initial constellation of 648 satellites is already funded, as well as ground network, thanks to the investors' contribution described previously.

9.2 Economical risks

One of the main issues that OneWeb, and companies with similar projects in general, may face is financing and liquidity. This is due to the high cost of deploying the project, and the

lack of revenue for at least the first few years. In addition, during project development and deployment of both the constellation and ground systems, real expenditures may differ from expected capital expenditures. Currently, the company has managed to raise the full amount of funds required to complete the first generation satellite constellation and ground network, and has also contracted the full amount of major expenditures with respect to its major costs. Furthermore, in order to anticipate any potential cost concerns, OneWeb periodically reviews its cost forecasts, and the latest review, as of October 2021, confirms that the company is fully funded [35].

As OneWeb has, for the time being, the necessary funding to roll out its initial constellation, the biggest risk it faces is failing to acquire and retain customers. The company may fail to precisely evaluate the market opportunity for satellite broadband services and implement its business strategies, thereby failing to achieve the sales required to meet its revenue forecasts. Even if the market materialises as expected, OneWeb may still not achieve adequate sales to match its revenue projections. Nevertheless, OneWeb has already generated significant excitement in the market and has initiated and completed negotiations with several potential customers around the world.

The main cause for OneWeb to fall into the above risk is the inability to offer user terminals at sufficiently low prices to facilitate widespread consumer adoption and building a sufficiently solid supply chain for a mass-market user terminal [35]. Although the price to be paid for its services is not yet known, the government affairs manager of Pacific Dataport, OneWeb's distributor in Alaska, stated that "wholesale prices are extremely competitive compared to what is being offered now" [29]. For benchmark, Starlink, OneWeb's main competitor, will sell its service for a fee of USD 99 per month to its direct consumers (B2C), in addition to the USD 500 upfront payment for the equipment and an extra USD 60 for shipping and handling [30]. This fee is targeted at the direct consumer segment, but for businesses it may be necessary to pay more than one fee to ensure the smooth operation of the service.

10 Environmental philosophy

Company's commitment to the environment has been remarkable since its inception, as its philosophy is to "leave no trace" in LEO environment while implementing the necessary changes to ensure undamaged space for future generations. OneWeb's satellites comply with both nationally mandated de-orbiting requirements and the United Kingdom Government's UNOOSA

(United Nations Office for Outer Space Affairs) commitments. The company's commitments to preserve space are as follows:

- **Responsible procedure**: OneWeb relies on sustainable business procedures to maintain its environmental goal. Therefore, the satellites are purposely-built for de-orbiting and incorporate a "grappling hook" to assist in coupling with recovery satellites if active de-orbiting is not possible.
- **Space environment development**: The company recognizes that the task of preserving the space ecosystem is shared between industry and governments. Both must facilitate the further advancement of new technologies and industries.

Key actions undertaken by the company to reduce its environmental footprint are the following:

- **Constellation impact:** OneWeb together with a debris modelling specialist, Dr Hugh, conducted a study based on the constellation's plane layout to reduce the environmental impact of constellation deployment.
- **Carbon footprint reduction:** Since 2019, one of the company's goals has been to initiate a transition towards zero carbon consumption. OneWeb has undertaken both reduction and abatement measures. The employment of renewable energy powered data centres, remote working and a significant reduction in business travelling are just a few measures that have led to a reduction in carbon consumption. The replacement to non-ozone-depleting gases has allowed to eliminate the impact especially in offices [7].

Chapter 5

Business Model CANVAS

By definition, a business model is a description of the elements that drive the company's profitability. However, there are several methodologies to describe a business model, in this case, the tool that will be used to analyze OneWeb's framework is the Business Model Canvas (BMC), created by Alexander Osterwalder and Yves Pigner [41]. The CANVAS methodology is based on a representation of the business model, integrated by 9 interrelated building blocks and divided between the value side and the cost side. The self-made CANVAAS layout is shown on the figure 5.1. The blocks belonging to the cost side are highlighted in red and those pertaining to the value side in green.

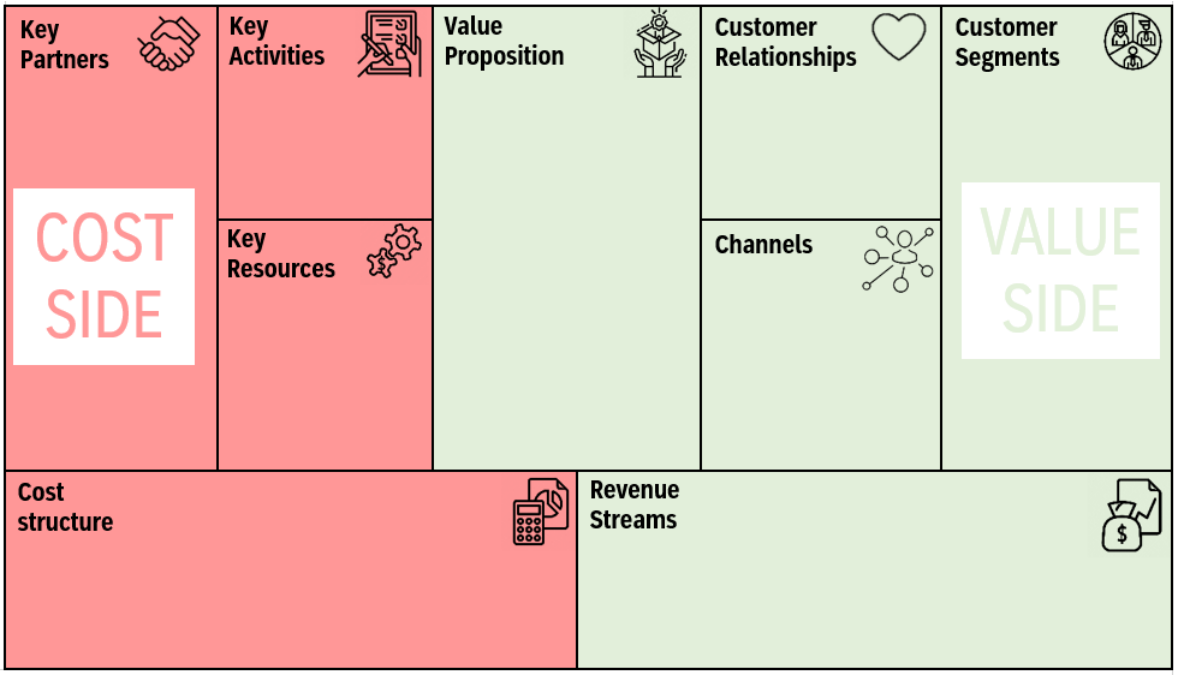

Figure 5.1: Cost and Value sides on Business Model Canvas template

A brief description of each block is given bellow, followed by an in-depth description of each block to create a specific business model for OneWeb. On the one hand, the value side is integrated by the following five blocks:

- **Customer Segment:** Describes the target group of individuals or companies that are intended to be reached with the service or product, considering that they share common characteristics or needs.
- **Value Proposition:** Represents the competitive advantage of your product/service which motivates the customers to choose it in front of the competitors.
- **Channels:** Communication method between the customer and the company to offer business Value Proposition.
- **Customer Relationship:** Express the avenues and attention that will be provided to customers to attract and retain customers to increase revenue.
- **Revenue Stream:** Depicts the price that the costumer is willing to pay to acquire the product/service.

On the other hand, the cost side is composed of the following 4 blocks:

- **Key Resources:** Fundamental assets, both financial and tangible, that create and deliver the Value Proposition.
- **Key Activities:** Identified as those necessary to achieve the Value Proposition through the successful transformation of resources into products/services.
- **Key Partners:** Essential players that enable the company to develop its business, minimizing risks and gaining access to key resources.
- **Cost Structure:** Identifies all the costs, fix and variables, and the proportion of each activity incurred to operate a business model.

1 Value side

1.1 Customer Segment

The potential market that OneWeb wants to access is very broad as it will not only focus on offering its service to businesses (B2B) but also to governments (B2G). OneWeb will not restrict its market by limiting it to a single target customer, but it rather aims to reach a wide range of potential customer segments which currently lack reliable and high-speed Internet connections. Geographically, when the constellation will be full deployed, the company will not have limitations as it intends to provide service anywhere, whether by land, sea or air. However, currently both government and business customers apply only to those located above the 50 degrees North area. To meet the requirements of each of the segments, it is necessary to identify them separately.

- **Business to Business (B2B):** Companies represent an important target public since, according to a study conducted by OneWeb, between a 15 and 25% of organizations currently use satellite connectivity as their primary or back-up access technology, a service that can be enhanced by LEO constellations [23]. OneWeb targets SMEs to a greater extent, as they are frequently located in remote areas, unlike multinationals and large enterprises, which tend to be located in urban areas where connectivity problems are scarce.

  OneWeb also aims to support telecommunications companies, by transmitting the Internet directly to ground stations and expanding the coverage areas of next-generation services (4G and 5G). The terminals may not only perform on a standalone basis but may also become part of a miscellaneous network connectivity solution, acting as a back-up when the primary link crashes or when a capacity boost is needed during time periods of backhaul congestion.

  Maritime, Air and Land transportation industries are potentially eligible to benefit the most from the service offered. Although some airlines and large commercial ships already have in-flight internet connection for their users, they could also consider the service offered by OneWeb for a reliable and faster navigation.

  This segment also includes educational institutions and health centers, as well as environmental and emergency services, among others.

- **Business to Government (B2G):** The company's platform underpins terrestrial, maritime, aerial and spatial communications to provide fast and secure deployability to mil-

itary missions and government networks. Therefore, this segment includes not only governments but all those organizations that are part of them. In particular, the government agencies that will be most eligible to use this service are those located in isolated areas where no reliable Internet connection is currently available. Likewise, the naval and air fleet, as well as land-based forces in remote locations, will be supported by a high-level security service to prevent leaks and resilient connectivity to take decisions and mission changes in real time.

1.2 Value proposition

The service offered by OneWeb in the emerging LEO satellite telecommunications market represents a revolutionary value proposition over the traditional one. The set of elements that render it interesting to consumers are as follows:

- **Reliable global connectivity:** Worldwide internet access has been a problem so far, however, Oneweb's truly global, 5G-ready network aims to solve this problem. Signal loss is far reduced in LEO compared to further orbits, so a reliable connectivity is established. Therefore, through its fleet of LEO satellites, the company will provide reliable connectivity to every business and government related agency, everywhere on land, sea and air.

- **Affordable prices:** Due to the altitude, placing successfully a satellite in LEO requires less energy, less powerful launchers and smaller satellites, which is traduced in significantly lower costs for the company versus traditional companies. Moreover, OneWeb's philosophy is to offer the service to a reasonable price in order to reach as many costumers as possible. As OneWeb handles the satellite production through its own company, Airbus OneWeb Satellites, satellites cost less to manufacture than to purchase elsewhere, thus enabling the company to offer the service cost-effectively.

- **Value-added services:** To facilitate user management, the company has created a web application and APIs which feature different digital products and services to ensure a satisfying user experience. Users will always be able to access real-time data and manage its contracts, with a continuous support from the company to respond to possible incidents.

- **Well-recognized partners:** OneWeb is supported by world-renowned companies in the aerospace and telecommunications sector, as Airbus and AT&T, respectively. In such cases, the impact of prestigious partner companies can be leveraged by OneWeb

to expand its customer base, its distribution network and, indeed, its revenue. Thanks to these collaborations, the value of the company is strengthened, since customers will associate the quality offered by the company with the same magnitude as that offered by well-known companies.

- **Cloud services:** Cloud services are software infrastructures, platforms or systems hosted by external providers which facilitate the flow of user data over the Internet. AWS (Amazon Web Services) and Microsoft Azure are some of the cloud providers that OneWeb can connect to and establish the fastest and most secure connection for latency-critical applications [34]. Using cloud services allows continuous data availability, flexibility and scalability for OneWeb.

- **Priority spectrum:** A key issue for a well-functioning network is to have the right spectrum to deliver high-speed and low latency connectivity worldwide. OneWeb has secured Ku-band and Ka-band frequencies after meeting the requirements of the Interational Telecommunications Union (ITU).

1.3 Channels

The communication channels used by OneWeb to interact with its customers are completely digital, since there are no physical facilities or third party establishments offering the service.

- **OneWeb website:** The main and initial platform through which the company communicates with customers is through its official website (link). Through the website, companies and governments are able to contact directly with OneWeb to define the suitable service according to their requirements and circumstances. This site acts as a source of information for those potentially interested, providing detailed information concerning the service offered, as well as data affecting the consumer (latency data, download times, etc.).

- **Airbus website:** Due to Airbus' alliance with OneWeb for satellites creation, within Airbus' official homepage several sections and news about OneWeb can be found (link).Despite being a secondary channel, the impact on the company is significant because of Airbus' renown, as mentioned in the previous section. For full company information and to contact them, interested customers will have to access OneWeb's website.

- **Web application and APIs:** To facilitate user management, the company has created a web application and APIs (Application Programming Interface) which feature different

digital products and services to ensure a satisfying user experience. Through this application, the user will be able to contact with OneWeb if any incident is produced and manage its preferences.

- **Social media:** OneWeb has an account on several social networks such as Twitter, Linkedin, Youtube and Facebook. Social media communication is more likely to occur with companies than with governments. Of those mentioned, Linkedin is the most formal and business-oriented network, therefore it is considered the main social network for communication with business customers.

1.4 Customer Relationship

For OneWeb and any company, being able to establish durable and long-term relationships matters the most. Such relationships tend to be developed easily between governments and big companies. However, OneWeb will maintain strong committed and personal relationships with any client.

OneWeb aims to attract and capture the costumers with its affordable broadband, low-latency Internet service, as well as with the added services mentioned above.

1.5 Revenue Stream

The biggest question mark for OneWeb concerns the price to pay for its services. The head of government affairs of Pacific Dataport, OneWeb's Alaska distributor, stated that "wholesale prices are extremely competitive compared to what is being offered now" [29]. For benchmark, Starlink, OneWeb's main competitor, will sell its service for a $99 per month fee to its direct consumers (B2C), besides the upfront payment of $500 for the equipment. The aforementioned fee is aimed at the direct consumer segment, but for businesses it may be necessary to pay more than one charge to ensure proper operation of the service.

The price to be paid by companies and governments is unknown since it depends on several factors such as the contractual duration and the type of organization, among others. The contracts entered into with businesses will be multi-year agreements to provide the service. In contrast, to provide connectivity to governments, OneWeb will need to meet the requirements of public concessions.

2 Cost side

2.1 Key Resources

Key resources enable the company to create and deliver the Value Proposition, access markets, establish customer segment connections and generate income. We can divide these into 4 subgroups: physical, financial, intellectual and human.

- **Physical resources:** OneWeb Airbus Satellites' facilities at Cape Canaveral (Florida) enable the production of satellites. Therefore, the buildings where the satellite is developed, as well as the vehicles and machinery used, are considered physical assets. Satellite itself becomes an essential and irreplaceable physical resource, mainly because it allows the company to offer the service and deliver the Value Proposition. Finally, we also consider physical internet distribution systems, such as ground stations.

- **Financial resources:** Currently, OneWeb is debt-free and the constellation is fully funded, thanks to the participation of the UK government along with Bharti Global, as well as the powerful investors that trust the company. A wide range of participants invest in OneWeb, meaning that the company's funding relies on several investors, not just a single one.

- **Intellectual resources:** The high technology behind OneWeb has led to its intellectual property being covered of 28 patents, mostly under the category of "Electrical Communication Technology" [10].

- **Human resources:** A crucial and indispensable element of OneWeb is the human side, otherwise it would be impossible to progress. All the employees contribute to the successful development and operation of the activity. From engineers to scientists, as any other employee, they are fully qualified specialists key to the company's success.

2.2 Key Activities

With the resources defined, the activities that transform them into value and allow the company to deliver its Value Proposition are as follows:

- **Development and production:** The cycle between satellite development and production is always continuous, as any changes to fix issues and/or improve certain aspects directly impact on the satellite manufacturing process. By development, we mean all those

activities aimed at innovation and continuous research of possible technologies to implement, thus improving satellites performance and quality in order to constantly strive for cutting-edge technology. OneWeb's philosophy is to mass manufacture satellites, reaching a rate of two satellites per day. Therefore, to ensure optimal production it is essential to logistically organize, in an efficient way, the resources involved in the satellite manufacturing process, minimizing possible time losses.

- **Constellation management:** Once the satellites reach their operational orbit, the OneWeb team is responsible for continuously monitoring them for proper operation, both individually and the overall constellation.

- **Ground stations management:** The two OneWeb-enabled Satellite Operations Centers (SOC) are designed to process and control the incoming satellite signal to deliver high-speed, broadband Internet access to users. Regular checking and monitoring of the received signals enables the company to rapidly identify potential hazard situations and avoid major consequences.

- **Data management:** Good data management and processing is essential to ensure the security and smooth running of the service, as well as constant monitoring of data transfer to cloud services.

2.3 Key Partners

A fundamental part that allows the business model to succeed is the alliances formed between companies and organizations. All of the partners described below are external to the company and some of them have already been described in-depth in the Case Study.

- **Launching partners:** The company is supported by three partners that enable the entire space mission, from preparations to the launching of satellites into orbit. As seen in the case study, this three organizations are Arianespace, Starsem and ROSCOSMOS & Russian partners. It would be impossible to offer neither the service or the Value Proposition to the costumers without launching partners, since OneWeb on its own lacks required elements to launch a rocket.

- **Distribution partners:** Similarly to launching partners, OneWeb lacks the necessary infrastructures for delivering Internet, hence the need to form alliances with distribution companies. Pacific Dataport, BT Group and Rock Networks are some examples of the companies described in the previous chapter.

- **Manufacturing partner:** OneWeb together with a well-recognized space company, Airbus, have set up the company OneWeb Airbus Satellites, for the creation and production of the constellation's satellites.
- **Investors:** A key pillar in getting OneWeb out of bankruptcy and back on track has been investors. The company is now fully funded and debt-free thanks to a $2.7 billion investment from its investors.
- **Regulatory agreements:** On the one hand, the Federal Communications Commission (FCC) is the U.S. government agency in charge of processing and approving licenses for satellites launching into constellations. Therefore, without the approval of the agency, OneWeb would not be able to launch satellites and, consequently, would be unable to provide its service. On the other hand, NASA runs the official debris program, which is in charge of regulating outer space junk. For this reason, OneWeb will have to follow the rules and comply with the restrictions and regulations imposed.

2.4 Cost structure

Once defined all the previous building blocks, the cost associated with them can be quantified. The costs related with the business model development are the following:

- Satellite production and all costs related to the activity, from the supply of raw materials to the infrastructures required.
- Launch services
- Ground stations and Value-added services
- Equipment and infrastructures
- Employees
- Website and web application maintaining costs
- Patents

3 Business Model CANVAS - Case OneWeb

Finally, after having described in detail each and every block, we can build the CANVAS model together with the template shown in the figure 5.1.

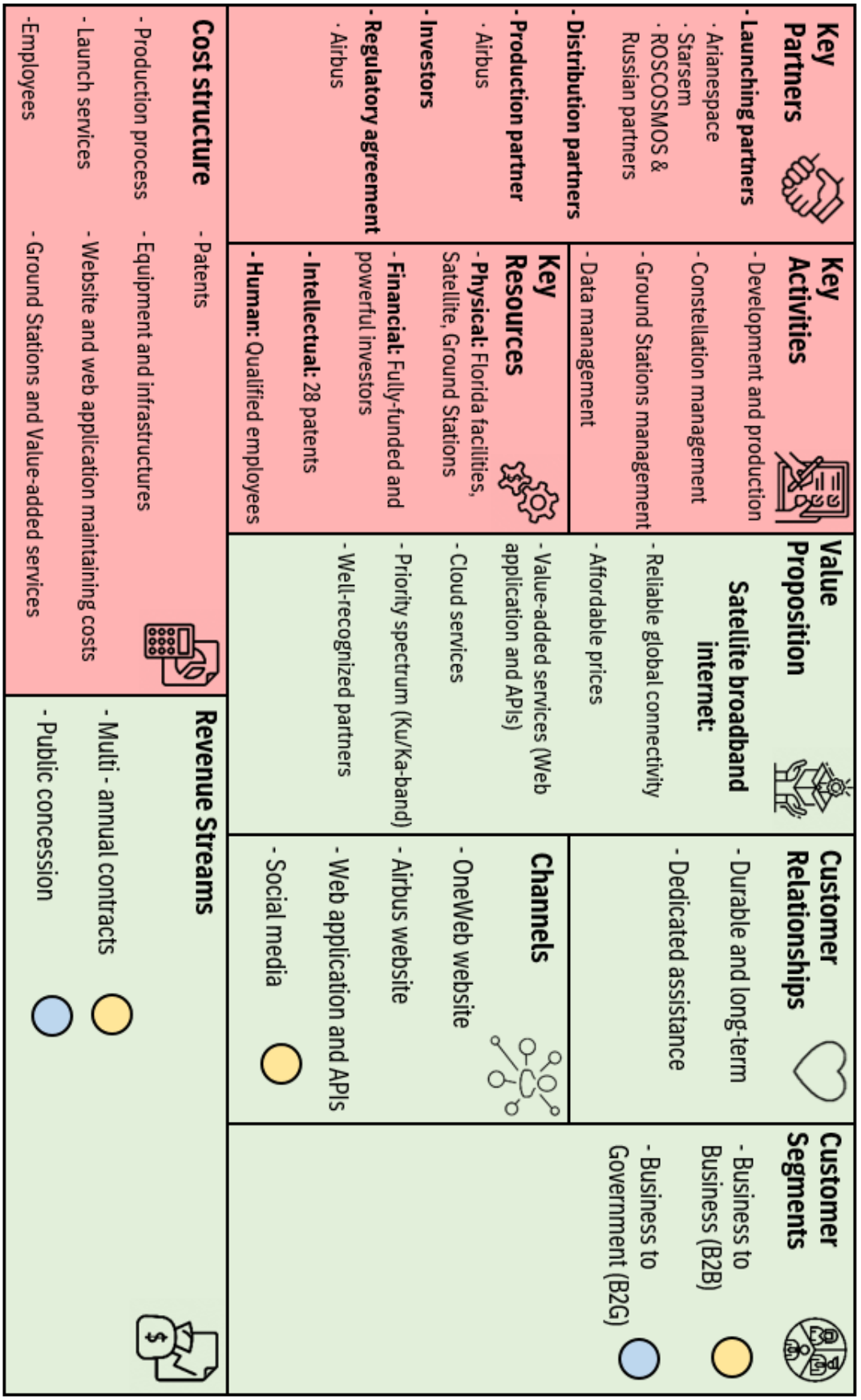

Figure 5.2: OneWeb's Business Model CANVAS

Chapter 6

SWOT Analysis

After having thoroughly examined OneWeb's case study and having designed its business model CANVAS, a SWOT analysis must be performed. SWOT is an acronym that stands for Strengths, Weaknesses, Opportunities, and Threats. Such a visual strategic tool permits analyzing, both internally and externally, the company's advantages and disadvantages in order to take an overview of its competitive position. The SWOT analysis of OneWeb is shown on figure 6.1.

On the one hand, the internal analysis will list the strengths and weaknesses of the company, analyzing aspects such as financial resources, tangible and intangible assets, and key staff. Such factors can be controlled and influenced by the company to improve them, if applicable.

On the other hand, the analysis of opportunities and threats will provide an overall scenario of the competitors - thus the external factors that can affect the company's success. Examples include government regulations, suppliers, and market trends. Unlike internal factors, the enterprise is unable to influence them, however it can take advantage of its opportunities and protect itself from threats.

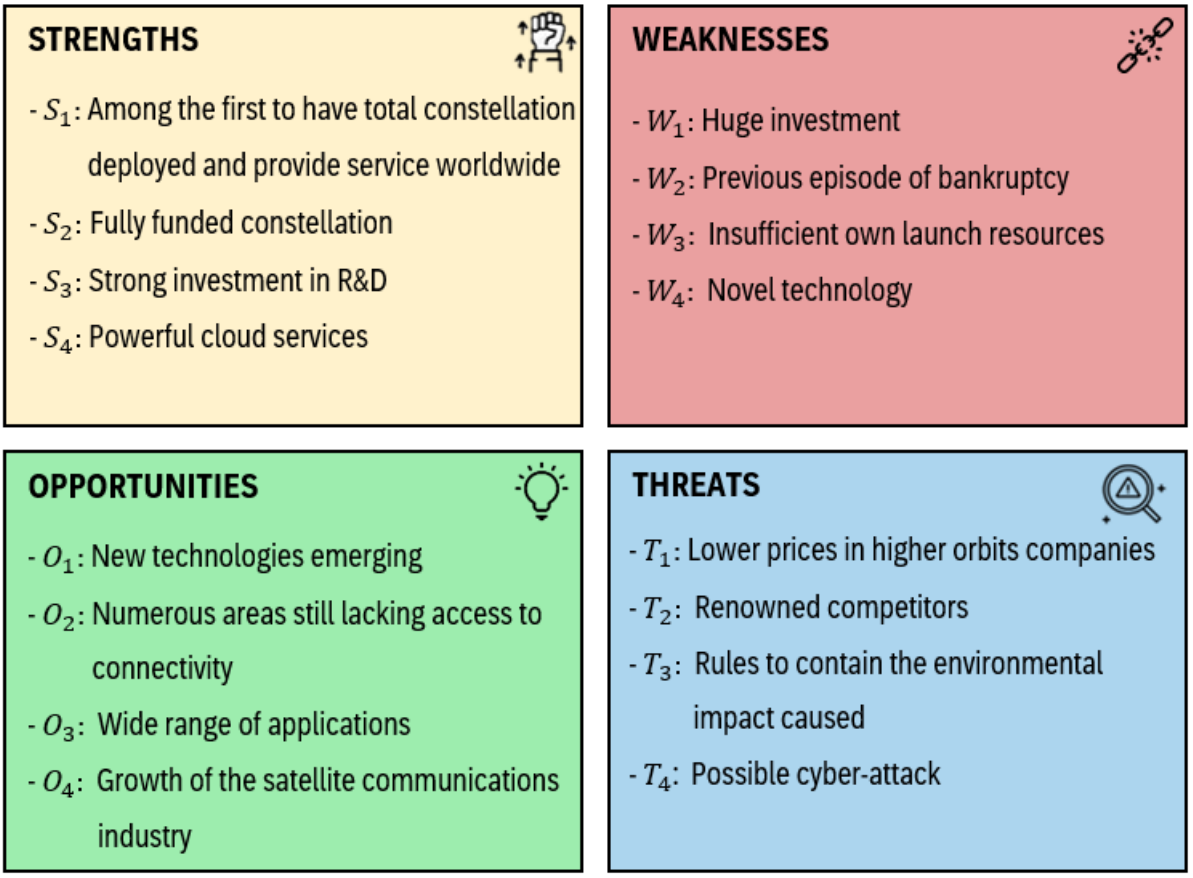

Figure 6.1: SWOT analysis of OneWeb

Strengths

- S_1: A major competitive advantage over other companies in the sector is that OneWeb will become one of the first companies, along with Starlink, to complete its constellation and be able to offer broadband Internet worldwide.
- S_2: Even though the constellation has not been fully deployed, it is already financed, meaning that economically, there will not be any setbacks in the process that would impede the completion of the constellation.
- S_3: OneWeb's strong investment in RD has enabled it to hold a high number of 28 patents and to be able to continuously apply innovative technology in its satellites.
- S_4: The company is able to connect to Cloud Services and establish the fastest and most secure connection for latency-critical applications.

Weaknesses

- W_1: Although the market demand from users is large, the investment required to deploy the satellite constellation with its associated costs is enormous. As a result, the benefits of the service are slow to materialize.
- W_2: Going through such a serious business crisis as bankruptcy, may cause a negative appearance and reputation of OneWeb in the eyes of many users, difficult to repair in some occasions.
- W_3: The company does not have sufficient resources to be able to deploy the satellites itself, so it has to rely on external launch companies.
- W_4: Technology used by OneWeb is the first of of its kind, so it may face technical issues that impact negatively on the service performance. Satellites or ground stations not functioning as intended are an example.

Opportunities

- O_1: 5G technology has already reached society and is being deployed worldwide. The actual satellites, based on this architecture, will integrate mobile networks with satellite communication to manage the connectivity of IoT devices even in areas that are currently inaccessible. In addition, the advancement of technology is enabling the improvement and development of technologies related to communication systems. Indeed, OneWeb has the potential to become a major force in the IoT revolution.
- O_2: Internet demand is strong in many areas which currently lack internet access, therefore, the only businesses that will be able to overcome such problems are those operating within the LEO segment.
- O_3: As potential consumers of the service, a wide range of sectors exist. The R&D areas, industrial manufacturing and defence communications are just a few of the varied industries where the company could penetrate.
- O_4: The satellite internet market remains growing and forecasts of upcoming market trends predict that it will further expand in the coming years.

Threats

- T_1: Traditional and current internet service providers are affordable than LEO companies. Therefore, in urban areas with high-quality internet access, it may be more difficult to integrate the service, resulting in a loss of potential costumers.

- T_2: The company is up against world-renowned and prestigious firms such as Amazon, or SpaceX, whose owner is also world famous for his ownership of the succesful company Tesla.
- T_3: Laws and regulations regarding the environmental impact caused by mega constellations are not yet in place. However, many environmental organisations already have open debates on this issue, which could result in future regulations that could impede the service or be costly to implement.
- T_4: The network may suffer a cyber-attack or other unexpected incident that could damage the system.

Chapter 7

Risk Analysis

After having studied the Business Model CANVAS of OneWeb and its SWOT analysis, it is interesting to analyse the risks and opportunities that may arise during the development of the project, to design a response towards these potential scenarios.

The risk matrix is a qualitative tool based upon the association of possible scenarios according to their likelihood of occurrence together with the expected impact on the company. The probability of an event occurring is divided into 5 groups, each comprising a 20%; from very low (0-20)% to very high (81-100)%. Similarly, the impact caused in the company by each scenario is quantified in a scale from 1 to 5, meaning a negligible, minor, moderate, significant and severe impact, respectively. The matrix distribution is shown on figure 7.1.

RISKS MATRIX										
PROBABILITY ↓	THREATS					OPPORTUNITIES				
Very high (81-100)%	Low	Moderate	High	Extreme	Extreme	Extreme	Extreme	High	Moderate	Low
High (61-80)%	Minimum	Low	Moderate	High	Extreme	Extreme	High	Moderate	Low	Minimum
Medium (41-60)%	Minimum	Low	Moderate	High	High	High	High	Moderate	Low	Minimum
Low (21-40)%	Minimum	Low	Low	Moderate	High	High	Moderate	Low	Low	Minimum
Very low (0-20)%	Minimum	Minimum	Low	Moderate	High	High	Moderate	Low	Minimum	Minimum
IMPACT →	1	2	3	4	5	5	4	3	2	1

Figure 7.1: Risks matrix template

1 Risk rating methodology

1.1 Risk identification

On the one hand, we will analyse the opportunities and threats extracted from the SWOT analysis, detailed in the previous chapter and following the same nomenclature given (O_x for opportunities and T_x for threats). On the other hand, some additional risks (R_x) that are adjacent to the OneWeb study have been defined:

- R_1: OneWeb may fail to precisely assess the market opportunity and implement its business strategies, thereby failing to achieve the sales required to meet its revenue forecasts.
- R_2: As there are a large number of satellites in LEO orbits, OneWeb satellites may collide with other spacecrafts or space debris.
- R_3: Rocket explosion and loss/damage of satellite cargo.
- R_4: OneWeb relies entirely on partners to launch its satellites. Therefore, trusting an external company and being unable to manage their factors can lead to a delay in the deployment of the constellation. Likewise for satellite material suppliers.
- R_5: The service may become congested due to an overload of users accessing it.

1.2 Risk rating calculation

In order to estimate the overall impact of the different scenarios on the project's development, a weighting system will be established considering three different impacts: Quality Impact Score (I_Q), Schedule Impact Score (I_S) and Cost Impact Score (I_C). The equation that will allow us to obtain the Total Impact Score (I_T) is as follows:

$$I_T = 0.3I_Q + 0.3I_S + 0.4I_C \tag{7.1}$$

The weighting related to the cost impact is greater than the rest owing to OneWeb's financial past along with the intention of making the service now viable and profitable, whilst not forgetting the quality and schedule impact of the service.

1.3 Risk preliminary actions summary

As soon as the risk situation or opportunity arises in the company, it must react and undertake a preliminary action. Possible measures to be taken in the face of a possible risk fall into the following four categories:

- **Avoidance:** Eliminate the risk by taking measures that can be as severe as the cancellation of the project.
- **Mitigation:** Take active measures to reduce the likelihood of the threat occurring.
- **Transfer:** Transfer the consequences of the risk and the ownership of the response to a third party.
- **Acceptance:** Recognise the hazard, without taking any action until the risk arises.

On the other hand, the possible response strategies to be followed in front of an opportunity, can be divided into the following three groups:

- **Share:** Joint ownership with a partner can raise the likelihood and/or impact of the opportunities.
- **Enhance:** Increase the chances or benefits associated with an opportunity to exploit it.
- **Acceptance:** Like risk acceptance; Recognise the opportunity without taking any action unless it occurs.

2 Risk identification and assessment

The table below has been generated with the various aforementioned risks and opportunities. For these scenarios, the range of impacts and probabilities of occurrence have been quantified to analyse the associated impact and possible response.

Risk ID	**Probability**	I_Q	I_S	I_C	I_T	**Risk associated**	**Responses**
O_1	High	3	2	4	3	Moderate opportunity	Share
O_2	Very high	2	2	3	2	Moderate opportunity	Enhance
O_3	High	3	2	4	3	Moderate opportunity	Acceptance
O_4	High	1	3	4	3	Moderate opportunity	Enhance
T_1	Very high	1	2	4	3	High risk	Mitigation
T_2	Very High	2	2	3	2	Moderate risk	Acceptance
T_3	Low	1	4	3	3	Low risk	Mitigation
T_4	Very Low	5	4	5	5	High risk	Mitigation
R_1	Low	2	3	4	3	Low risk	Mitigation
R_2	Very low	5	4	5	5	High risk	Avoidance
R_3	Very Low	2	3	4	3	Low risk	Mitigation
R_4	Low	1	5	4	3	Low risk	Mitigation
R_5	Low	4	1	4	3	Low risk	Mitigation

Table 7.1: Risk identification and assesment

Allocating the results obtained to their corresponding positions, we obtain the following matrix:

RISKS MATRIX										
PROBABILITY ↓	**THREATS**					**OPPORTUNITIES**				
Very high (81-100)%		T_2	T_1						O_2	
High (61-80)%								O_1, O_3, O_4		
Medium (41-60)%										
Low (21-40)%			T_3, R_1 R_4, R_5							
Very low (0-20)%			R_3		R_2, T_4					
IMPACT →	1	2	3	4	5	5	4	3	2	1

Figure 7.2: Risk matrix with allocated scenarios

Once the possible scenarios have been identified, it is interesting to discuss the actions that allow the company to minimise the risks and maximise the opportunities.

- O_1: Share - To be part of the IoT revolution and to be able to distribute 4G and 5G widely, OneWeb will need to build powerful partnerships with mobile network operators.

- O_2: Enhance - To exploit market demand, OneWeb could undertake marketing strategies and advertising campaigns, leveraging its service against competitors, to gain visibility and reach a larger customer segment.
- O_4: Enhance - The company must continue investing in R&D to constantly innovate technologically in order to keep pace with the market and have a strong presence in it.
- T_1: Mitigation - Continuous research by the R&D team plays an important role in reducing the costs associated with the service. Therefore, OneWeb shall invest in research and development to seek new technologies and/or cost-saving materials.
- T_3: Mitigation - The company should closely follow the intentions of environmental organisations and conferences, in order to be aware of possible future regulations and to have scope to work towards implementing them in its service.
- T_4: Mitigation - OneWeb must implement blocking measures and/or measures to minimise the impact of cyber-attacks, as well as constant monitoring of its network. In addition, suppliers are required to provide sufficient and standardised guarantees of quality and security.
- R_1: Mitigation - OneWeb must continuously study the market in order to be able to react to any possible changes in market and consumer trends.
- R_2: Avoidance - Oneweb should ensure that its satellites are prepared to detect objects and avoid collisions between them. Failure of the system would require strengthening of the areas of the satellite most susceptible of being damaged by collision.
- R_3: Mitigation - The company must demand from its launching partners guarantees of quality and safety to avoid any technical failure that could lead to the loss or damage of the cargo. The fact of relying on a company specialised in the launching of rockets and with great experience, significantly reduces this risk.
- R_4: Mitigation - The company must commit to suppliers with solid forecasts, schedules and/or orders to simplify the supply chain. Increasing the number of suppliers also increases the ability of the provider to supply.
- R_5: Mitigation - The greater the number of satellites deployed, the lower the probability of congestion by concurrent users. Therefore, an increase in the number of operational satellites would reduce this issue.

After identifying contingency measures for risks and managing opportunities, it is possible to re-examine the impact of these on the development of the project by implementing the above-mentioned actions.

Risk ID	**Probability**	I_Q	I_S	I_C	I_T	**Risk associated**
O_1	Very High	3	2	4	3	High opportunity
O_2	Very high	2	2	4	3	High opportunity
O_3	High	3	2	4	3	Moderate opportunity
O_4	High	4	3	4	4	High opportunity
T_1	Medium	1	2	3	2	Low risk
T_2	Very High	2	2	3	2	Moderate risk
T_3	Low	1	3	3	2	Low risk
T_4	Very Low	4	4	4	4	Moderate risk
R_1	Very low	2	3	4	3	Low risk
R_2	Very low	4	4	4	4	Moderate risk
R_3	Very low	2	3	4	3	Low risk
R_4	Very Low	1	5	4	3	Low risk
R_5	Very low	3	1	3	2	Very low risk

Table 7.2: Scenarios reassesment

Finally, by positioning the previous situations into the risk matrix, the representation obtained is presented in the figure 7.3. Unlike the prior matrix obtained, before the application of the different measures, the impact of the risks has generally decreased whilst the opportunities have been exploited. It is worth noting that if the range of probabilities taken for each partition was smaller, assuming probability intervals smaller than 20%, shifts in some risks would be more substantial and visible in the matrix.

RISKS MATRIX										
PROBABILITY ↓	**THREATS**					**OPPORTUNITIES**				
Very high (81-100)%		T_2						O_1, O_2		
High (61-80)%							O_4	O_3		
Medium (41-60)%		T_1								
Low (21-40)%		T_3								
Very low (0-20)%		R_5	R_1, R_3, R_4	R_2, T_4						
IMPACT →	1	2	3	4	5	5	4	3	2	1

Figure 7.3: Definitive risk assessment matrix

Chapter 8

Environmental Impact

All economic activity generates, to a greater or lesser extent, an impact on the environment. This chapter will analyse the footprint of OneWeb and, implicitly, of the rest of the LEO telecommunications companies. Not only the adverse effects will be analysed, but also the beneficial social outcomes, by means of the analysis of the seventeen Sustainable Development Goals (SDGs).

1 OneWeb constellation impact

Company's commitment to the environment has been remarkable since its inception, as its philosophy is to "leave no trace" in LEO environment while implementing the necessary changes to ensure undamaged space for future generations. OneWeb's satellites comply with both nationally mandated de-orbiting requirements and the United Kingdom Government's UNOOSA (United Nations Office for Outer Space Affairs) commitments. Although the company emphasises its concern towards a responsible space, implicitly, its commercial practice produces the following negative effects on the environment:

- **High energy usage**: The annual energy used globally in the telecommunications sector amounts to 3% of the total energy consumption. In addition, the energy consumed by the data centres used by the company accounts for 2% of annual greenhouse gas emissions [7]. It is worth emphasising that although such significant values are not only attributable to the company under study, the high consumption caused by the companies as a whole generates an important impact on the environment.

- **Rocket pollution**: The environmental damage caused by a rocket significantly begins at the moment of liftoff. Soyuz fuel is based on the use of kerosene and liquid oxygen, mainly emitting carbon dioxide (CO_2) and monoxide (CO), hydroxyl (OH), nitrogen oxides (NO_X), water vapour (H_2O) and black carbon (BC) [22].

  It is estimated that 66% of the entire fuel is released between the stratosphere and the mesosphere, remaining there between 2 and 3 years. Both nitrogen oxides and water vapour emissions undergo chemical reactions in the stratosphere leading to ozone depletion, thereby deteriorating the ozone layer shielding humans from damaging UV rays. Although at first glance cloud formation may not seem harmful, clouds reflect the solar flux back into space, while black carbon absorbs it, causing a radiative forcing that results in stratoshpere's cooling or warming [4].

  Unlike other rockets used by competitors, such as Space X's Falcon 9, the Soyuz rocket has neither reusable first stages nor controllable second stage re-entries. Extracted fragments from the first stage accumulate in the oceans, disrupting the ecosystem and causing a negative impact on it due to the accumulation of debris.

  The formation of mega constellations involves the continuous launching of rockets to deploy the satellites, thus increasing the environmental impact of the above-mentioned aspects compared to recent years.

- **Light pollution**: Light pollution is a growing reality faced by more than 80% of the world's population [61]. Ecosystems may be among the damaged scenarios arising from polluted skies, affecting certain aspects such as insect reproduction and bird migration. Astronomy, astrophotography and ground-based observation are also in the spotlight. During recent years, this problem has been exacerbated by the formation of mega constellations of satellites in Low Earth orbits (LEO), leading to continuously travelling lights and glints in the night sky. The image below shows a picture taken by the 4-metre Blanco Telescope at the Cerro Tololo Inter-American Observatory. Nineteen Starlink satellite trails crossed the image during the six-minute exposure.

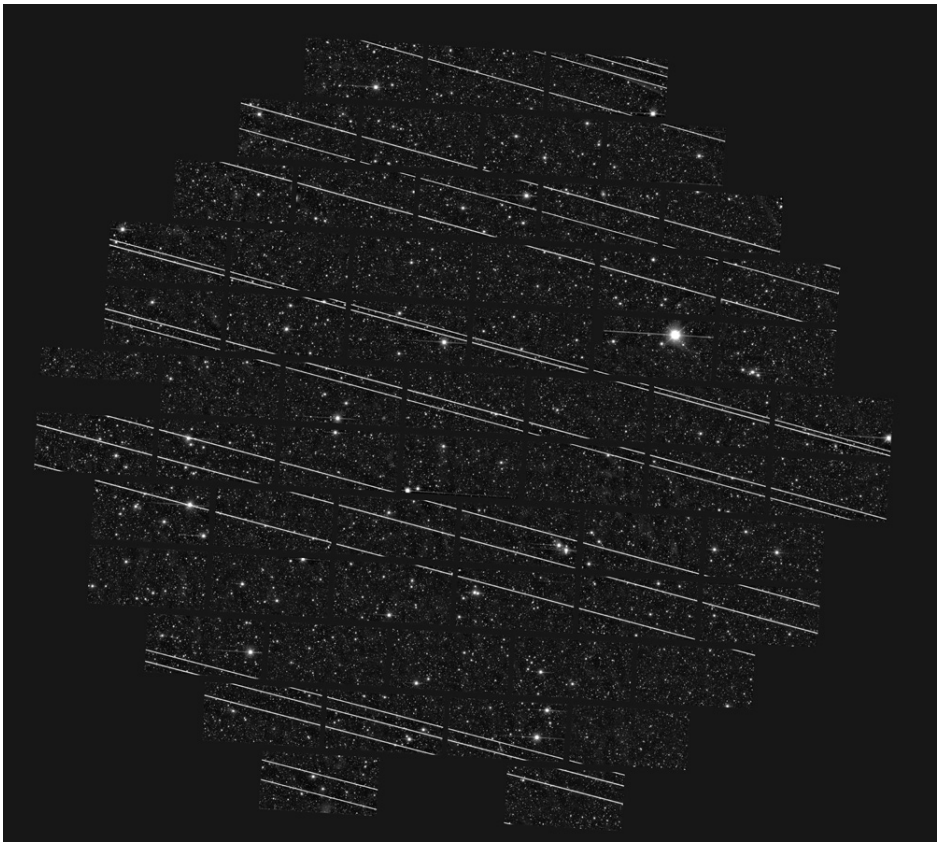

Figure 8.1: Blanco Telescope image of Starlink satellites during six-minute exposure. Extracted from: [62]

SATCON 1 was a workshop held in June 2020, aimed at discussing and quantifying the impact of constellations in the night sky, jointly attended by astronomers, satellite operators and other interested parties. It was advocated that satellites positioned at 500 km altitude orbits should be no brighter than the 7th magnitude, in order to be unobservable to the naked eye. Higher altitudes imply a further dimming of the magnitude as satellites are visible for longer in the night, leading to a recommendation to not deploy constellations in orbits higher than 600 km. Unfortunately, OneWeb satellites do not meet these measurements so far; despite having an average magnitude of 7.9, spacecrafts travel at a slower speed and appear more focused to telescopes [3]. The following graph shows the visibility of the satellites at 500 and 1.000 km in a summer night period, between the red lines. For this purpose, it has been assumed that each of these orbits accommodates 10.000 satellites divided into 100 planes and inclined at $35^{\underline{o}}$.

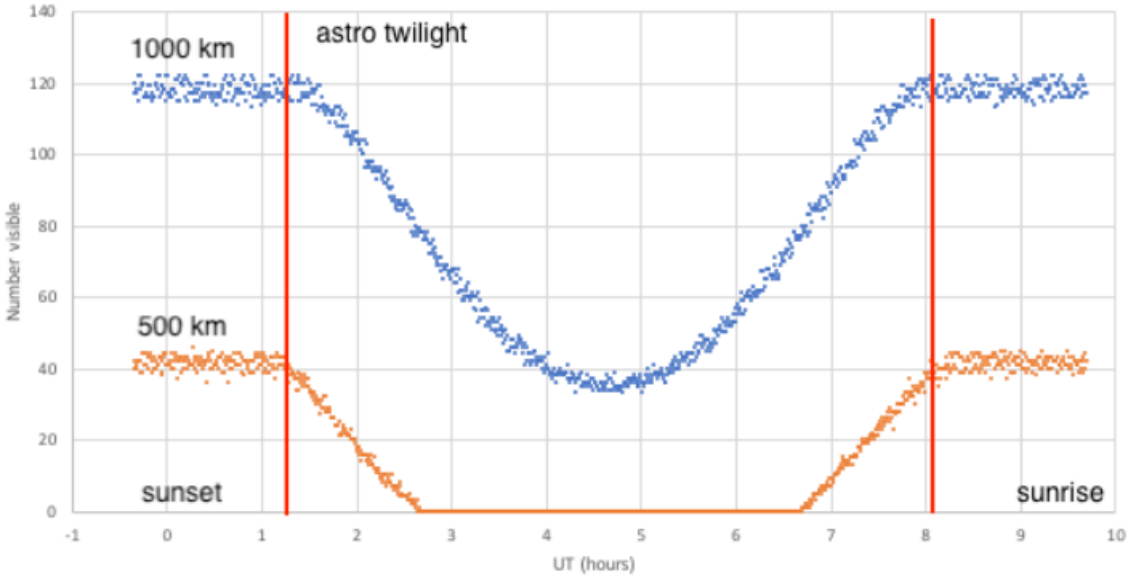

Figure 8.2: Visibility differences between satellites at 500 and 1.000 km altitude. Extracted from: [50]

Even if all satellites managed to comply with these guidelines, it would still not be enough to mitigate the consequences of LEO satellites concentrations. The path from pro-dark sky measures through to regulation and compliance will be clearly challenging.

- **Space debris**: The unstoppable increase in launches of LEO space objects is bound to leave the region crowded and with difficult traffic management. Satellites are considered space junk at the end of their operational life and are required to trigger the de-orbiting process . However, the process is not instantaneous; it takes approximately 6 months to complete it with the consequent risk of collision. If a collision occurs in the process, it could perforate the objects, causing significant degradation of their functionality. Impacts between them can generate even more fragments of space debris, creating a dangerous domino effect, also known as Kessler's syndrome [**8**]. Although the probability of collision is low thanks to continuous tracking of these fragments, it is not unprecedented. Recently, in May 2021, a small object hit and punctured a robotic arm of the International Space Station (ISS) [59].

2 Sustainable Development Goals contribution

The Sustainable Development Goals were declared in 2015 by the United Nations to ensure a path to global peace and equality by 2030. It is integrated by 17 states addressing social, economic and sustainability issues. A block analysis will be carried out to find out the positive impact that OneWeb's service has on the planet.

Figure 8.3: Sustainable Development Goals.
Extracted from: [15].

2.1 SGD 4 - Quality education

Sustainable Development Goal 4 is based on "Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all" [15].

OneWeb's constellation clearly contributes to this goal, as its service not only enables connection to schools located in remote areas, but also offers high speed and quality internet. In addition, one of the consequences of the health pandemic has been the adoption of a new teaching method, a non-contact and virtual format. OneWeb's constellation would allow any student to have access to education, reducing the inequalities that exist between isolated and urban areas.

Figure 8.4: SDG 4: Quality education.
Extracted from: [15].

2.2 SGD 8 - Good jobs and economic growth

Figure 8.5: SDG 8: Good jobs and economic growth.
Extracted from: [15].

Sustainable Development Goal 8 is based on "Promoting sustained, inclusive and sustainable economic growth, flat and productive employment and decent work for all" [15].

OneWeb not only employs nearly 500 people at its offices in London and Virginia, but also creates approximately 300 workplaces to support satellite production at Airbus OneWeb Satellites. In addition, its service enables to work from remote locations, allowing the creation of jobs in places hitherto unreachable due to a lack of connectivity. Economic development and growth, especially in rural and isolated communities, can thus be stimulated.

2.3 SGD 9 - Industry innovation and infraestructure

Sustainable Development Goal is based on "Building resilient infrastructure, promoting inclusive and sustainable industrialisation and fostering innovation" [15].

The Low Earth orbit (LEO) satellite telecommunications service is novel in terms of technology and development. Since the service is not offered by any company to date, continuous research for improvements and new technologies to implement will be ongoing to position itself in front of its competitors and become a market leader.

Figure 8.6: SDG 9: Industry innovation and infraestructure
Extracted from: [15].

2.4 SGD 10 - Reduce Inequalities

Figure 8.7: SDG 10: Reduce inequalities
Extracted from: [15].

Sustainable Development Goal 10 is based on "Reducing inequality within and between countries" [15].

There are still many places in the world where internet connectivity remains a challenge, either due to lack of connectivity or slow connectivity. It is estimated that approximately 50% of the world's population suffer from a lack of reliable connectivity. This digital divide is particularly pronounced in emerging continents, such as Africa, India and many Western countries. The percentage of the population living outside the reach of a 3G or 4G signal amounts to a 25%. However, the gap is also evident in rural and remote regions of the United States and Europe.

OneWeb's main objective is to deliver good quality and affordable internet to any place in the world, so the service offered contributes to reducing existing inequalities and digital divide.

Chapter 9

Conclusions

The main objective of this thesis was to study the benefits and potential that Low Earth Orbits (LEO) provide in the field of global telecommunications, based on the analysis and development of the OneWeb business model, troughout the CANVAS methodology.

In the state of the art, the study of the current situation of the telecommunications market together with the key players has been carried out. With this study, we have been able to understand the huge market opportunity; rapidly growing for years and promising to keep expanding during the next decade, thanks to the new emerging technologies and the development of projects to exploit the lowest orbits. In addition, OneWeb plans to adapt its infrastructure and establish trust relationships with mobile network operators to join the IoT revolution and spread 5G coverage worldwide, potentially becoming a key player on the sector. Then, the PESTEL analysis has allowed us to understand the global external situation facing the company.

In the case study, all the characteristics of the company and its constellation have been analysed in detail. With all the information gathered in the two aforementioned chapters, it has been possible to graphically design OneWeb's business model thanks to the CANVAS methodology. From the cost side, it should be noted that partners represent a very restrictive element for OneWeb; the company relies heavily on them to be able to deliver its service to consumers. From the value side, it is worth noting that OneWeb's value proposition is unique and different from that of its competitors, thanks to the value-added services created for the consumer, as well as the use of Cloud services, among others.

Subsequently, thanks to the SWOT and risk analyses, we have been able to analyse internally and externally, the factors that affect (or have the potential to affect) the company both positively and negatively. The importance of managing these risks proactively, to eliminate the impact of the risks and to exploit the opportunities to their maximum, has also been observed.

Finally, the environmental impact caused by OneWeb's service has been studied. Despite demonstrating that, through the Sustainable Development Goals, OneWeb's constellation complies with 4 out of the 17 building blocks entitled to generate a positive social impact, negative effects generated by the constellation are notable and must be regulated and minimized by all companies in the sector in a near future.

The contribution of each of the previously mentioned sections has made possible to achieve the initially planned goal of the thesis.

Disconnection and poor connectivity is a major problem affecting nearly half of the world's population. Developing countries, and rural and isolated areas suffer the greatest effects, resulting in a blockage in the progress of the economy in this area. OneWeb's constellation will contribute significantly to the bridging of the digital divide and to the economic advancement of many areas. In addition, the high-speed Internet connectivity delivered by these satellites will benefit human factors, such as faster medical assistance and access to education.

With globalization, air and sea traffic is increasingly frequent, coupled with a persistent lack of connectivity. Regardless of the location, air and sea passengers will benefit from reliable connectivity as OneWeb's project will connect all devices on airplanes or ships, delivering fast, low-latency broadband internet, thus allowing users to enjoy real-time applications for both business and entertainment purposes.

If one thing is clear, is that OneWeb's service and its disruptive technology will mark a before and after in science and technology. The company has the potential to become an icon, because if the viability of its business model is fulfilled, hundreds of communities, companies and governments will be connected to its network. Unprecedented and innovative projects such as OneWeb, Starlink or Amazon, are those that involve the progress and global evolution of the human species in this digital era.

Bibliography

[1] ArianeGroup. *Soyuz - The medium launcher*. URL: https://www.arianespace.com/vehicle/soyuz/.

[2] Arianespace. *About us*. URL: https://www.arianespace.com/about-us/.

[3] *Beyond Starlink: The Satellite Saga Continues - Sky Telescope - Sky Telescope*. URL: https://skyandtelescope.org/astronomy-news/beyond-starlink-the-satellite-saga-continues/.

[4] Aaron C Boley and Michael Byers. "Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth". In: *Scientific Reports | 11* (123), p. 10642. DOI: 10.1038/s41598-021-89909-7. URL: https://doi.org/10.1038/s41598-021-89909-7.

[5] Yannick Borthomieu. "Satellite Lithium-Ion Batteries". In: *Lithium-Ion Batteries: Advances and Applications* (2014), pp. 311–344. DOI: 10.1016/B978-0-444-59513-3.00014-5.

[6] A.G. Burns and T.L. Killeen. "Polar Thermosphere". In: *Encyclopedia of Atmospheric Sciences* (Jan. 2003), pp. 1768–1777. DOI: 10.1016/B0-12-227090-8/00319-5.

[7] "Carbon Report 2020 OneEarth's annual Net Zero and sustainability benchmark Connect with Purpose". In: (2021).

[8] Union of Concerned Scientists (UCS). *Satellite Database | Union of Concerned Scientists*. Sept. 2021. URL: https://www.ucsusa.org/resources/satellite-database.

[9] N.H. Crisp et al. "The benefits of very low earth orbit for earth observation missions". In: *Progress in Aerospace Sciences* 117 (Aug. 2020), p. 100619. ISSN: 0376-0421. DOI: 10.1016/j.paerosci.2020.100619. URL: http://dx.doi.org/10.1016/j.paerosci.2020.100619.

[10] Crunchbase. *OneWeb - Tech Stack, Apps, Patents Trademarks*. URL: https://www.crunchbase.com/organization/oneweb/technology.

[11] DCD. *OneWeb partners with BT to provide connectivity to rural UK*. URL: https://www.datacenterdynamics.com/en/news/oneweb-partners-with-bt-to-provide-connectivity-to-rural-uk/.

[12] DCD. *OneWeb partners with Rock Networks to serve Canadian Armed Forces*. URL: https://www.datacenterdynamics.com/en/news/oneweb-partners-with-rock-networks-to-serve-canadian-armed-forces/.

[13] Download Scientific Diagram. *Constellation pattern for OneWeb's system*. URL: https://www.researchgate.net/figure/Constellation-pattern-for-OneWebs-system_fig1_331795087.

[14] eoPortal Directory. *OneWeb Minisatellite Constellation for Global Internet Service*. URL: https://directory.eoportal.org/web/eoportal/satellite-missions/o/oneweb.

[15] ESA. *ESA and the Sustainable Development Goals*. URL: https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/ESA_and_the_Sustainable_Development_Goals.

[16] ESA. *Mitigating space debris generation*. URL: https://www.esa.int/Safety_Security/Space_Debris/Mitigating_space_debris_generation.

[17] ESA. *Plasma propulsion for small satellites*. URL: https://www.esa.int/ESA_Multimedia/Images/2020/09/Plasma_propulsion_for_small_satellites.

[18] ESA. *Satellite frequency bands*. URL: https://www.esa.int/Applications/Telecommunications_Integrated_Applications/Satellite_frequency_bands.

[19] Theodore D.Swansonb Gajanana C.Birura Georg Siebesa. *Encyclopedia of Physical Science and Technology*. Third. 2003, pp. 485–505.

[20] USA Gov. *Federal Communications Comision*. URL: https://www.usa.gov/federal-agencies/federal-communications-commission.

[21] UK Government. *UK involvement in the EU Space Programme - GOV.UK*. Aug. 2021. URL: https://www.gov.uk/guidance/uk-involvement-in-the-eu-space-programme.

[22] *How much air pollution do rocket launches cause? - Breeze Technologies*. URL: https://www.breeze-technologies.de/blog/how-much-air-pollution-do-rocket-launches-cause/.

[23] GSMA Intelligence. "Connectivity from the sky". In: (2021). URL: www.gsmaintelligence.com.

[24] *Investing in space companies hits record $8.9 billion in 2020: Report*. URL: https://www.cnbc.com/2021/01/25/investing-in-space-companies-hits-record-8point9-billion-in-2020-report.html.

[25] Col E John Keesee. "Satellite Telemetry, Tracking and Control Subsystems". In: (2003).

[26] Steinar Lag. *Mega-constellation satellites on the horizon - DNV*. Ed. by Tiffany Hildre. URL: https://www.dnv.com/to2030/technology/mega-constellation-satellites-on-the-horizon.html.

[27] Adam Mann. *Starlink: SpaceX's satellite internet project*. May 2021. URL: https://www.space.com/spacex-starlink-satellites.html.

[28] McKinsey. *Large LEO satellite constellations: Will it be different this time?* URL: https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/large-leo-satellite-constellations-will-it-be-different-this-time.

[29] Alaska Public Media. *Satellite internet promises fast, cheap service in rural Alaska, but remains out of reach so far*. URL: https://www.alaskapublic.org/2021/03/05/satellite-internet-promises-fast-cheaper-service-to-rural-alaska-but-technology-remains-untested/.

[30] Starlink media. *Key information about us*. 2021. URL: https://www.starlink.com/.

[31] BusinessCom Networks. *OneWeb, Physics and FPAs*. URL: https://www.bcsatellite.net/blog/oneweb-physics-and-fpas/.

[32] Cision PR Newswire. *Satellite Communication Market size worth 131.68 Billion, Globally, by 2028 at 9.10% CAGR: Verified Market Research®*. URL: https://www.prnewswire.com/news-releases/satellite-communication-market-size-worth--131-68-billion-globally-by-2028-at-9-10-cagr-verified-market-research-301394253.html.

[33] OneWeb. *ATT and OneWeb plan Satellite Access for Business in Remote Areas across the US | OneWeb*. URL: https://oneweb.net/media-center/at-t-and-oneweb-plan-satellite-access-for-business-in-remote-areas-across-the-us.

[34] OneWeb. *Enterprise*. URL: https://oneweb.net/enterprise.

[35] OneWeb. "Financial Statements Mission accelerates". In: (2021). URL: https://oneweb.net/assets/news/media/OneWebFinancialStatements_March2021.pdf.

[36] OneWeb. *Launches | OneWeb*. URL: https://oneweb.net/launches.

[37] OneWeb. *OneWeb Secures Global Spectrum Further Enabling Global Connectivity Services*. URL: https://oneweb.net/media-center/oneweb-secures-global-spectrum-further-enabling-global-connectivity-services.

[38] OneWeb. *PRESS KIT - ST35*. Sept. 2021. URL: https://oneweb.net/assets/news/PRESS-KIT-ST35-EN.pdf.

[39] *OneWeb and Airbus transform space industry with world's first high-volume satellite production facility in Florida*. July 2019. URL: https://www.airbus.com/en/newsroom/press-releases/2019-07-oneweb-satellites-and-partners-oneweb-and-airbus-transform-space.

[40] *OneWeb commercial launch delayed 'five or six months'*. URL: https://www.capacitymedia.com/articles/3830435/oneweb-commercial-launch-delayed-five-or-six-months.

[41] Alexander Osterwalder and Yves Pigner. *Business Model Generation*. Ed. by John Wiley Sons Inc. 2010. URL: https://www.strategyzer.com/books/business-model-generation.

[42] "Outlook for the US telecommunications, media, and entertainment industry". In: (2021).

[43] DISCOVERER project. *Facts and Figures*. 2021. URL: https://discoverer.space/about-discoverer/facts-and-figures/.

[44] DISCOVERER project. *Why it matters*. URL: https://discoverer.space/about-discoverer/why-it-matters/.

[45] Maxime Puteaux and Alexandre Najjar. *Are smallsats entering the maturity stage?* Aug. 2019. URL: https://spacenews.com/analysis-are-smallsats-entering-the-maturity-stage/.

[46] Cristian Rus. *Estas son las antenas que Amazon utilizará para Project Kuiper, la alternativa a Starlink de Elon Musk*. Feb. 2021. URL: https://www.xataka.com/espacio/estas-antenas-que-amazon-utilizara-para-project-kuiper-alternativa-a-starlink-elon-musk.

[47] Via Satellite. *GEO, MEO, and LEO - Via Satellite*. URL: https://www.satellitetoday.com/content-collection/ses-hub-geo-meo-and-leo/.

[48] Airbus OneWeb Satellites. *About Us*. URL: https://airbusonewebsatellites.com/about-us/.

[49] Airbus OneWeb Satellites. *Global Supply Chain*. URL: https://airbusonewebsatellites.com/global-supply-chain/.

[50] Patrick Seitzer. "Large Constellations of LEO Satellites and Astronomy". In: (2020). URL: www.amostech.com.

[51] Space. *Air pollution from reentering megaconstellation satellites could cause ozone hole 2.0*. URL: https://www.space.com/starlink-satellite-reentry-ozone-depletion-atmosphere.

[52] SpaceNews. *OneWeb Completes its 'Five to 50' Mission to Cover Regions North of 50 Degrees Latitude including UK, Canada, Alaska and Arctic Region*. URL: https://oneweb.net/media-center/oneweb-completes-its-five-to-50-mission.

[53] SpaceNews. *Telesat preparing for mid-2020 constellation manufacturer selection*. URL: https://spacenews.com/telesat-preparing-for-mid-2020-constellation-manufacturer-selection/.

[54] *SpaceX lofts 49 Starlink internet satellites to orbit in 1st launch of 2022*. URL: https://www.space.com/spacex-starlink-launch-success-january-2022.

[55] James G. Speight. "Water systems". In: *Natural Water Remediation* (Jan. 2020), pp. 1–51. DOI: 10.1016/B978-0-12-803810-9.00001-2.

[56] Amazon Staff. *Amazon receives FCC approval for Project Kuiper satellite constellation*. July 2020. URL: https://www.aboutamazon.com/news/company-news/amazon-receives-fcc-approval-for-project-kuiper-satellite-constellation.

[57] Starsem. *Who is Starsem?* URL: https://www.starsem.com/starsem/starsem.html.

[58] Statista. *Smallsats launched worldwide 2020*. URL: https://www.statista.com/statistics/1267439/small-satellites-launched-worldwide/.

[59] Ashley Strickland. *Basura espacial golpeó la Estación Espacial Internacional*. URL: https://cnnespanol.cnn.com/2021/06/01/basura-espacial-golpeo-la-estacion-espacial-internacional-danando-un-brazo-robotico/.

[60] Telesat. *Telesat Lightspeed LEO Network*. URL: https://www.telesat.com/leo-satellites/.

[61] Sky Telescope. *Streetlights to Satellites: Taking Light Pollution to the United Nations*. URL: https://skyandtelescope.org/astronomy-news/taking-dark-skies-to-the-united-nations/.

[62] Sky Telescope. *The Starlink Situation*. URL: https://skyandtelescope.org/astronomy-news/starlink-satellites-astronomy/.

[63] *Types of orbits*. URL: https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits#GEO.

[64] UNOOSA. *Online Index of Objects Launched into Outer Space*. 2021. URL: https://www.unoosa.org/oosa/osoindex/search-ng.jspx?lf_id=.

[65] Alun Williams. *Further batch of OneWeb satellites nears constellation to service*. URL: https://www.electronicsweekly.com/news/further-batch-of-oneweb-satellites-nears-constellation-to-service-2021-04/.

[66] Xin Yang. "Low Earth Orbit (LEO) Mega Constellations-Satellite and Terrestrial Integrated Communication Networks". In: (2018).