UNIVERSITAT POLITÈCNICA DE CATALUNYA
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STUDY OF THE BENEFITS AND APPLICATIONS OF LEO FOR COMMUNICATIONS AND DEFINITION OF SPACE NEW BUSINESS MODELS: PROJECT KUIPER - AMAZON

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REPORT

Study of the benefits and applications of LEO for communications and definition of space new business models: Project Kuiper - Amazon

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"If there is one trait that differentiates human beings from other species, it is that in addition to being able to observe reality and analyze it, we are also capable of imagining it"

Blai Pallisé Perelló

Abstract

Project Kuiper is the new constellation of satellites to be deployed by Amazon over the next few years and placed in LEO with the primary goal of providing high-speed, low-latency broadband connectivity to unserved and underserved communities around the world.

This project aims firstly to study this new constellation in order to know the benefits that its low terrestrial orbit will bring and then to develop its business model through the Business Model CANVAS to extract its key success factors. In addition, the new business opportunities that will emerge from the deployment of constellations of these characteristics have also been studied.

El Project Kuiper és la nova constel·lació de satèl·lits que serà desplegada per Amazon durant els propers anys i que estarà emplaçada a LEO amb l'objectiu principal de proporcionar connectivitat de banda ampla, d'alta velocitat i de baixa latència a les comunitats no ateses o mal ateses de totes les parts del món.

Aquest projecte té com a objectius, primerament, estudiar aquesta nova constel·lació per tal de conèixer els beneficis que li aportarà la seva baixa òrbita terrestre i després, desenvolupar el seu model de negoci a través del Model de Negoci CANVAS per extreure els seus factos clau d'èxit. A més a més, també s'han estudiat les noves oportunitats de negoci que sorgiran gràcies al desplegament de constel·lacions d'aquestes característiques.

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To my friends who have made me feel loved, who have encouraged me to achieve my goals and with whom I have shared unforgettable experiences.

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Chapter 1

Introduction

1.1 Aim of the project

The objective of this project is to study the Project Kuiper, the new satellite constellation to be deployed by Amazon in the coming years, and to develop its business model in order to show the advantages of its LEO location as well as to study its benefits and extract the key success factors of this new project.

1.2 Scope of the project

The project will include

- The state of the art of the of the current systems of broadband internet satellite constellations.
- The study of the main characteristics and the potential applications of the Very Low Earth Orbits (VLEO).
- A PESTEL analysis to identify the external factors that will surround and affect the Project Kuiper.
- A study of the main characteristics of the Project Kuiper
- A complete Business Model CANVAS of the Project Kuiper.
- A risk analysis to detect the threats and opportunities that may arise from the development of the project and to propose actions to respond to these events.
- A study of the environment impact of the project Kuiper.

The project will not include:

- A complex and exhaustive analysis of the telecommunication system used by the project Kuiper.
- The detailed study of the most optimal option on how to place the satellite constellation in the very low earth orbit.
- The analysis of the components and the blueprints of the satellites of the Project Kuiper.
- The technical study of the launchers that will take the satellites to the desired orbit.

1.3 Requirements

The main requirements of this project are the following:

- This project is part of DISCOVERER research group [1] [2].
- The companies that will be studied must meet the USA and UE satellite and telecommunications regulation.
- The restrictions imposed in the field of telecommunications by the Federal Communication Commission (FCC) will be taken into account and no procedure outside the framework imposed by the International Telecommunication Union (ITU) will be proposed.
- This project must comply with the UPC regulations for bachelor's degree final projects.

1.4 Justification

If there is one thing that defines humanity is the desire to known and to explore everything that surrounds us in order to learn how it works and why it does in that way. This genuine curiosity has made us explore our planet in depth and gradually discover its peculiarities. Little by little we have been changing and shaping the Earth to make it as comfortable for us as possible. We have built roads, highways and dams; we have built great cities, bridges and skyscrapers; we have moved the Van Allen rings with our radio emissions; we have modified the planetary atmosphere and we have connected oceans and added islands to them. But the human ambition and the desire to know and discover has not stopped here, and over the last century we have taken a step forward, leaving our warm and familiar planet and venturing out to discover and learn about the huge and vast expanse of universe. Since the Soviet Union launched the Sputnik 1 satellite in 1957 more than 10000 objects have been sent into space. But this is a relatively small number compared in what's to come in the next years. With the rapprochement and vastly improved accessibility of space in recent years, a new era in the world of telecommunications is dawning.

We have been able to evolve and develop the society as we have and in such a "short time" thanks to the joint work of all human beings. We are a specie characterized by cooperation between creatures, and it is for this reason that technological developments in the field of communication have been key and decisive. Distances that were once enormous have been gradually narrowed by the development of technology and communications. Since the invention of the telephone in the 19th century, nothing has been the same in human-to-human communications. We went from communicating by letter or at best by telegraph to being able to talk to a person thousands of kilometers away. Communications have progressed from wired networks to fully wireless networks. The invention of the Internet has brought another major revolution in the sector and has become the defining technology of the information age in the same way that the steam engine became the vector of technological transformation in the industrial revolution. Despite this, the expansion of the internet was restricted for some time due to the difficulty of installing terrestrial telecommunications infrastructure in rural areas, in wild and remote environments and in some developing countries. For this reason, internet satellite constellations have been born. These large constellations of artificial satellites in Low Earth Orbits would have seemed like science fiction a little more than a decade ago, but today they are a reality. Their main purpose is to provide high throughput satellite communication to deliver low latency broadband internet services to any location on the surface of the Earth. Big companies like Amazon, SpaceX or OneWeb are already creating or in the process of creating these constellations that will undoubtedly change communication between people around the world.

This project aims to cover the specific case of the project Kuiper , the satellite constellation to be deployed by Amazon in the coming years. A business model will be drawn up to evaluate the viability of the business idea and to analyse the opportunities in the sector. It will also allow to document the state of the company and the current state of its direct competitors. Moreover, it will be studied the opportunities and benefits that will provide its position in these low orbits.

Chapter 2

Framework of the project

This chapter will present the DISCOVERER project and explain what it consists of, since it will be the framework of reference for this final thesis.

The DISCOVERER project is a European research project whose objective is to find a way to commercially exploit the Very Low Earth Orbits or VLEO (the terrestrial orbits below 400 km) which have significant technological and market challenges that need to be solved. The official name of the project is "Disruptive Technologies for Very low Earth Orbit platforms" [1]. This project has been under development since 2017 and its expected duration has been 51 months although it may be extended due to the Covid-19 pandemic.

Currently, the DISCOVERER consortium is composed of eight institutions of five different countries. Of these eight, four are universities: the University of Manchester (UNIMAN),the University College London (UCL), the University of Stuttgart (USTUTT), the Universitat Politècnica de Catalunya (UPC). Two of them are companies related to the space sector: Elecnor Deimos Satellite Systems (DEIMOS) and Gomspace APS (GS). And finally, two are consultancies: Euroconsult (ECONSULT) and Concentris Research Management GMBH (CONCENTRIS).

The DISCOVERER project currently has three fields of study in which it is trying to solve some of the most relevant problems associated to the Very Low Earth Orbits. These are:

- The research of new materials with good performance to resist the rapid degradation of the materials of which the satellites are currently made due to the high concentration of atomic oxygen in these regions.
- The development of new propulsion technologies that will be able to take advantage of the existing residual atmosphere to combat the rapid orbit decay of satellites placed in these orbits.
- The development of aerodynamic control systems for satellites to take advantage of the light atmosphere at these altitudes.

In addition to these three fields of study, there is a market challenge. It is in this aspect where the UPC is involved since it is in charge of finding new business models that can exploit and take advantage of VLEO from a commercial point of view.

In this sense, the project is open to students who can contribute with new knowledge by carrying out their end-of-studies projects in this area of the search for new possibilities and business models. As of today, 45 final projects have been carried out, including final degree projects and final master's projects, and there are 7 ongoing projects, including this one. Thus, this final thesis aims to add value to the DISCOVERER project by studying the benefits and applications of LEO for communications and defining the new space business model that Amazon is already developing with its Project Kuiper.

Chapter 3

State of art

This chapter presents first of all a brief review of geocentric orbits and then a study of the background and the analysis of the current status and future plans of the satellite constellations that will provide broadband satellite internet services to a geographically global demographic. It also includes a study of the VLEO industry sector, taking a look at its main characteristics, its benefits and disadvantages, its current status and plans and opportunities for the near future. Finally it also includes a study of the external environment that will affect and influence the Project Kuiper.

3.1 Review of Earth orbits

For as long as there have been historical records, human beings have always dreamed of leaving the planet and knowing what lies beyond it into space. The Greek philosopher, Socrates wrote: "Man must rise above the Earth, to the top of the atmosphere and beyond, for only thus will he fully understand the world in which he lives"[3]. But where can the beginning of outer space be defined? The Fédération Aéronautique Internationale (FAI), the international standardization and registration body for aeronautics and astronautics, defines the Kármán line as the boundary between the Earth's atmosphere and outer space and places it at an altitude of 100 kilometers above the Earth's mean sea level [4].

Once the altitude at which outer space "begins" has been determined, different orbits that satellites can follow around the Earth can be defined.

Geosynchronous orbit (GSO)

Geosynchronous orbits are Earth-centered orbits with an orbital period equal to Earth's rotation period on its axis, 23 hours, 56 minutes, and 4 seconds. A circular geosynchronous orbit has a fixed altitude of 35786 km (22236 mi). A special type of geosynchronous orbit is the geostationary orbit (GEO) which is also circular but it's always placed above Earth's equator and following the direction of Earth's rotation.

Medium Earth Orbit (MEO)

The Medium Earth Orbits are that orbits which their altitudes are between 2000 and 35786 km. The orbital periods of MEO satellites range from about 2 hours to nearly 1 day. This type of orbit hosts numerous artificial satellites used for navigation, communication, geodetic and space environment science.

Low Earth Orbit (LEO)

The Low Earth Orbits are orbits that are normally at an altitude of less than 1,000 km but could be between 160 km and up to 2000 km above Earth. LEO satellites do not always have to follow a specific trajectory around the Earth since their plane can tilt. It is the orbit used by the International Space Station (ISS) located at about 488 km, since it is the most optimal option due to its shorter distance to the Earth's surface and it is the most comfortable option for astronauts to travel to and from Earth.

Very Low Earth Orbit (VLEO):

The Very Low Earth Orbit are a subcategory of the LEO which are defined as all the orbits with a mean altitude below 450 km [5]. Satellites at VLEO are at very low altitudes and this means that they fly through a denser part of the atmosphere and therefore the aerodynamic forces they receive are greater than those they would experience in higher altitude orbits. These higher aerodynamic forces can be seen as a challenge, but they can also represent some opportunities [6].

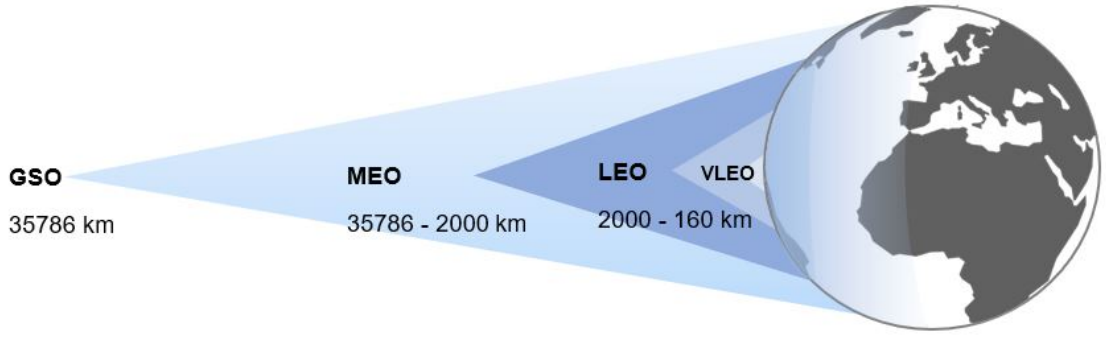

Figure 3.1: Diagram of geocentric orbits.

3.2 Background

The successful launch of the Sputnik I, the first artificial satellite in history, by the Soviet Union in 1957 marked the beginning of the space race and opened the door to the exploration of both the solar system and deep space. This new need for knowledge, research and exploration has brought new opportunities and challenges unimaginable just a few decades ago.

One sector of the space industry that has been growing steadily and is expected to grow exponentially in the coming years is the satellite market. The current trend is to create lighter and lighter satellites because the less heavy they are, the less money it will cost to put them into orbit. Nowadays, satellites are essential in many aspects of the technological development, such as scientific research, naval and air navigation, weather forecasting and communication.

The telecommunications satellites are already playing a key role in the new era of communication. They retransmit and amplify radio communication signals through a transponder and create a communication channel between a source transmitter and a receiver at different locations on Earth [7]. They are highly useful for communicating remote areas of the Earth effectively and quickly. Historically, satellite communications have been carried out with geosynchronous (GEO) spacecraft, large infrastructures that have grown in capacity and efficiency over the years. But now non-geosynchronous orbit (NGSO) communications constellations, which include very low Earth orbit (VLEO), low Earth orbit (LEO) and medium Earth orbit (MEO) satellites, are already taking to the skies, and their numbers could explode in the near future. This can be seen in the following chart 3.2 that shows the growth forecast of the US payload market differentiated by type of orbit (GEO, MEO and LEO).

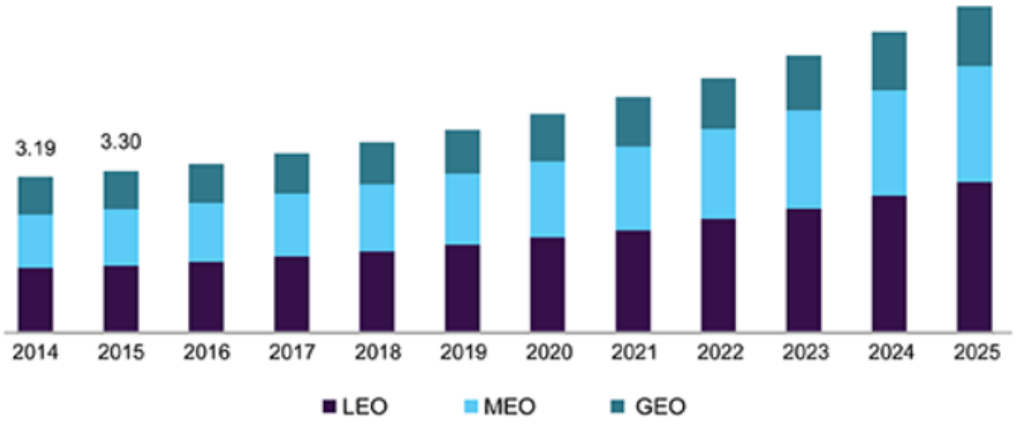

Figure 3.2: Growth forecast of the US payload market differentiated by type of orbit (in USD billion). Source: [8]

If the current Internet-over-satellite proposals become reality, some 50000 active satellites[9] will be orbiting overhead within ten years. Even if the most ambitious plans do not come to fruition, satellites will be manufactured and launched on an unprecedented scale. The global satellite communications market size was worth $62,19 billion in 2019 and is expected to grow at a compound annual growth rate of 9,2% from 2020 to 2027[10].

A very important type of communications satellites are those that offer satellite internet. The market for satellite broadband is clearly on the rise thanks to its ability to reach the unserved or rural areas where the wired or other connectivity fails to reach. Traditionally, this service was provided by geostationary satellites offering moderate connection speeds. However, in recent years some important multinational corporations are creating new constellations of satellites placed in Low Earth Orbit (LEO) or in Very Low Earth Orbit (VLEO) in order to provide low-latency satellite internet services to all regions of the world.

These ambitious new constellation projects in LEO may be remind of some projects that emerged in the 1990s, when several firms tried to offer global connectivity. Companies such as Globalstar, Iridium, Odyssey and Teledesic had impressive plans. In the end, however, all of them, except Iridium, scaled back or cancelled their constellations as all suffered financial problems due to high costs and low demand [9].

However, much has changed in the last 20 years. Accessibility to space has increased strongly, satellite technology has advanced, demand for bandwidth has skyrocketed everywhere in the world with no slowdown in sight and companies have developed creative new business models to generate profits through their services.

3.3 Satellite internet constellations

Over the last decades, the scientific and technological sectors have made great efforts to design, build and deploy satellites in different Earth orbits for such relevant purposes as deep space exploration, telecommunications or geolocation. Satellite constellations are groupings of satellites of the same type in the same or complementary orbits designed to achieve a common purpose and which have a common control.

These constellations have revolutionised people's daily lives as, for example, constellations such as GPS have made it possible for everyone to know very accurately their geographical location almost anywhere on Earth with just a mobile phone.

In recent years, space has become increasingly accessible as new, much more efficient and cheaper methods of sending material out of Earth have been designed and built. Since 2019 the number of satellites orbiting the Earth has been rapidly increasing, with plans to deploy potentially tens of thousands of them crating big satellite constellations. In that event, the new satellite constellations will soon outnumber all previously launched satellites. Most of them are expected to be deployed in low Earth orbits (LEO).

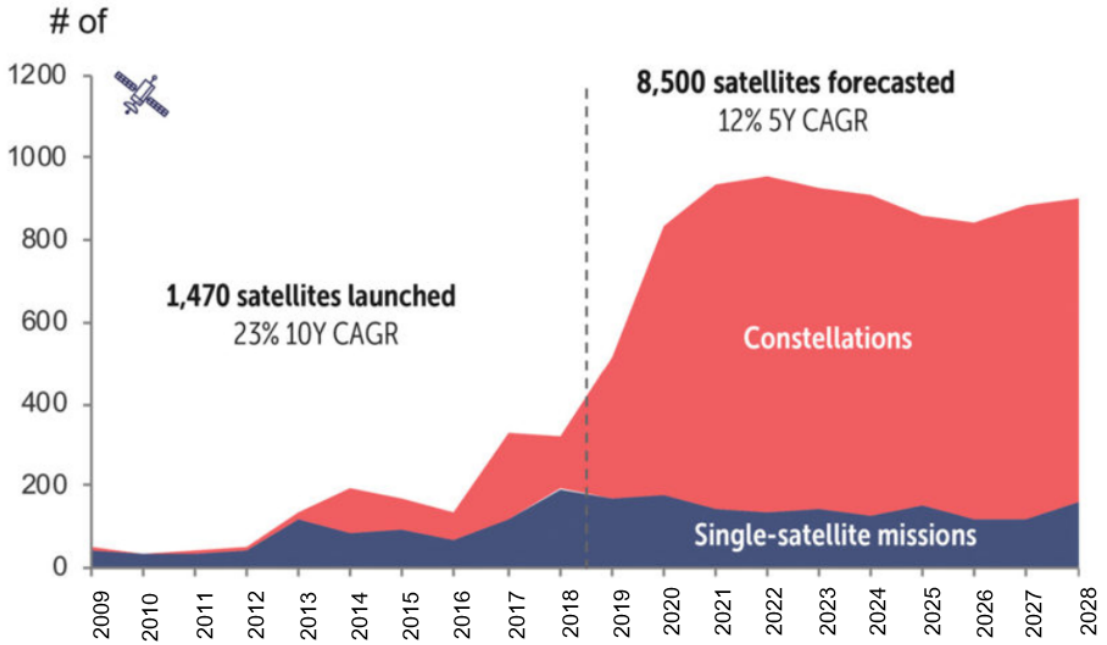

Figure 3.3: Forecast of satellites of 500 kg or less launch mass between 2009 and 2028. Source: [11]

Some of these constellations will offer low-latency satellite internet services to all regions of the world. They will offer faster communications due to lower latency and will often provide higher bandwidth per user than GEO satellites, even more than cable, copper and fixed wireless technology prior to 5G. As is obvious, these LEO satellite constellations will require a large number of satellites to provide global coverage. These concepts will require major changes in satellite operations, including manufacturing and supply chain. In addition, their average lifetime turns out to be much shorter than traditional communication satellites located in geostationary orbits.

These satellite internet constellations are born to meet the demanding requirements of users all over the world. Today, consumers not only routinely watch online high-definition movies and series but also play video games and shop online, consuming vastly more bandwidth than a few years ago. Furthermore, entirely new demand segments have emerged, such as in-flight connectivity for airlines. Other markets, such as the telecommunications sector, have expanded enormously with the exponential increase in mobile usage.

Today's customers are much more demanding with their Internet connection services. Both businesses and individual consumers are looking for high bandwidth and low latency connections. It is significant that these expectations have extended beyond technologically sophisticated users to almost all consumers in developed economies and in many emerging markets.

Currently, the vast majority of consumers rely on terrestrial solutions, and business-to-business (B2B) use of satellites is limited to a few sectors where terrestrial solutions do not work: for example, in-flight Internet, Internet in maritime locations, remote oil and gas extraction and various military applications. This is largely because satellite connectivity options are very expensive and offer low quality services. But if providers of new constellations offer competitive prices and quality services, demand could skyrocket.

This project aims to study the business model of the ambitious constellation of satellites to be deployed by Amazon in the next years that will provide broadband internet to all places on Earth. Therefore, it's interesting to study its direct competitors in order to know their differential traits and their plans for the near future.

3.3.1 Study of direct competitors

In this section the main competitors of the Project Kuiper will be analyzed. Only satellite constellations with similar characteristics and that occupy the same market segment will be studied. Neither traditional satellite Internet providers with geostationary orbits nor Internet service providers through different terrestrial technologies will be studied.

Starlink

Figure 3.4: Starlink logo. Source: [12]

Starlink is one of the most recognised satellite constellation projects that will provide high-speed, low latency broadband internet connectivity to all places on Earth. It's now delivering initial beta service both domestically in the United States of America and internationally, and will continue expansion to near global coverage of the populated world in 2022 [12].

It is a project of SpaceX, the US company that is currently revolutionising the aerospace industry and will try to conquer the new market of spaceflight. It was founded in 2002 by Elon Musk with the main objective of reducing space transportation costs to enable the colonization of Mars. SpaceX has designed and manufactured some different launch vehicles as the Falcon 9 and the Falcon Heavy and several rocket engines. It is developing other projects as the Dragon cargo and crew spacecraft and the mentioned Starlink satellites.

Starlink services are still in beta and users can expect data speeds to vary from 50 Mbps to 150 Mbps and latency from 20 ms to 40 ms in most locations over the next few months

while the Starlink system is being improved.

SpaceX ensures that Starlink will provide low-latency broadband internet to all regions of the world [12]. Latency is the time it takes to send data from one point to the next. When satellites are far from Earth, latency is high, resulting in poor performance for activities like video calls and online gaming. Starlink satellites are placed 60 times closer to Earth than conventional GEO satellites. This ensures that a lower latency will be achieved and some services that are not typically available with traditional satellite internet as video calls, online work or online gaming will be supported.

Table 3.1: Main characteristics of Starlink. Source: [13]

Characteristics		
Coverage	Expected	Worldwide
	Currently	South Canada and upper parts of the US
Number of Satellites launched	Expected	12000
	Currently	1300 [14]
Orbit		LEO: 350-550 km
Service offered		Low-latency broadband internet

OneWeb

Figure 3.5: OneWeb logo. Source: [15]

The OneWeb satellite constellation will be a constellation of satellites with the main objective of provide global satellite Internet broadband services to people everywhere on Earth, initially aiming to start global services in 2021. OneWeb is a global communications company founded by Greg Wyler and based in London, UK and McLean, Virginia, U.S.A. It is a joint venture with Airbus Defence and Space and was formerly known as WorldVu Satellites [15].

The company has not had the best of times in the recent past as it went bankrupt in March 2020 but managed to keep the 68-satellite operations centre already in orbit while the court determined the disposition of OneWeb's assets. In November 2020, OneWeb emerged from bankruptcy thanks to an investment of more than $1 billion led by the UK government and Bharti Global, an Indian multinational Conglomerate Company headquartered in New

Delhi, India.

In the same way as Starlink, OneWeb aims to offer a low-latency, high-bandwidth, high quality internet service that enables tasks to be performed everywhere on Earth that could not be performed with existing satellite internet services. One of the differences is that the satellites designed by OneWeb will be smaller and will be located in orbits further away from Earth than those created by SpaceX.

Table 3.2: Main characteristics of OneWeb constellation. Source: [15]

Characteristics		
Coverage expected		Worldwide
Number of Satellites launched	Expected	650 on phase one and 6372 on phase two
	Currently	146 [16]
Orbit		LEO: 1200 km
Service offered		Low-latency broadband internet

Telesat Lightspeed

Figure 3.6: Telesat Lightspeed logo. Source: [17]

In February of 2021 the Canadian satellite operator, Telesat finally came forward with the long-awaited announcement of the details of its new Low Earth Orbit constellation, a venture away from its traditional satellites on Geostationary Orbit [17].

Its constellation, called Lightspeed, will focus on providing high-speed fiber-like internet around the globe to enterprise, serving Mobile Network Operators, Internet Service Providers (ISPs) along with aviation, maritime, and government markets. In this way, the company would be interested in focusing on business-to-business customers and would move a little away from the intentions of SpaceX and Oneweb that will focus mainly on offer broadband Internet services to private customers.

The company expects its constellation will cost around $5 billion to be build, including the cost of the satellites, building their ground infrastructure, buying the launchers and developing the software platforms to operate the network [17]. Telesat has contracted the European satellite manufacturer Thales Alenia Space to build the 298 initial satellites of its constellation.

Table 3.3: Main characteristics of Lightspeed Telesat constellation. Source: [17]

Characteristics	
Coverage expected	Worldwide
Number of Satellites expected to be launched	298
Orbit	LEO: 1000 km
Service offered	Low-latency broadband internet for business

3.4 Very Low Earth Orbits

This section will analyze in more detail the VLEOs as they are the field of study of the DISCOVERER project. Its main characteristics, its main fields of application and the advantages and disadvantages they can provide will be studied.

3.4.1 Characteristics

As mentioned in the previous section 3.1, VLEOs are a subcategory within LEOs. It is important to know the characteristics that make this subdivision relevant and to know a little more about its features and the applications they can have.

The Very Low Earth Orbits, are typically classified as orbits below approximately 450 km in altitude [18]. Nevertheless, the altitude range is characterized by the presence of aerodynamic forces that can significantly affect the orbital dynamics and behavior of a spacecraft. An altitude between 450 km and 500 km is usually determined as the upper range for VLEO. However, in reality this can vary significantly with solar cycles and depends on some atmospheric conditions.

VLEO are located in the region of the Earth's atmosphere known as the thermosphere. This region is the layer in the atmosphere directly above the mesosphere and below the exosphere. Temperatures in the thermosphere increase with altitude due to the absorption of highly energetic solar radiation. This means that the temperatures are very changeable. The daytime temperature in the thermosphere is usually about 200°C higher than the nighttime temperature [19]. As a result of these high temperatures and the ultraviolet solar radiation, the existing molecules are broken into highly reactive atomic oxygen (the most abundant gas), atomic nitrogen and helium.

VLEO orbits are, of course, the easiest orbits to reach because they are the closest to the Earth's surface. Spacecraft placed in VLEO are capable of orbiting the Earth several times a day. They have the shortest periods of all types of orbits in orders of magnitude of only minutes. However, the fact that they are at such low altitudes causes the atmospheric density to be higher. This causes the satellites to be affected by a significant atmospheric drag which, if not compensated with a periodic re-boost, causes the satellites to fall and reduces their orbital lifetime [6].

3.4.2 Main applications

The two main applications of VLEO nowadays are Earth Observation (EO) and satellite communications.

Earth Observation (EO)

Earth observation bases its activity on observing the Earth's surface and its atmosphere for the collection and extraction of images and information about its physical, chemical and biological systems through remote sensing (RS) technology by means of satellites and aircraft. Earth observation is used to monitor and assess the state and changes of both natural and built environments on Earth. It is because of this fact that it has many concrete applications. For example some of its specific applications are: weather forecasting, detection of potential natural disasters and assessment of the availability of natural resources.

Thanks to the low altitudes at which LEOs, and specifically VLEOs, are located, they are very useful for obtaining high definition images and information of the Earth's surface, since the cameras can capture more quality data due to less interference with the atmosphere [6].

Satellite communication

Due to the proximity of satellites in VLEO and LEO to the Earth's surface, the signal strength do not need to be as high as in other orbits to be of good quality as the signal strength decreases with the square of the distance from the source [5]. Because of this, satellites placed in this low orbits can provide much better broadband internet services, in terms of speed and low latency, than satellites placed in other orbits with higer altitudes such as GEO and MEO [20]. However, since satellites in VLEO and LEO orbit the Earth much faster, they do not remain visible in the sky to a fixed point on Earth continuously as GEO satellites do. Therefore, to provide continuous communication capability with these lower orbits it is required a larger number of satellites so that at least one of them is always visible in the sky. For this reason, satellite constellations for communications are born.

3.4.3 Benefits, disadvantages and challenges

Once the main characteristics of this type of orbits are known, the main benefits and the disadvantages and the challenges that satellites have to face when are placed in them can be determined.

Benefits

A clear benefit of this type of orbit is that the satellites placed in VLEO need less energy than those to be inserted in other types of geocentric orbits. This implies that less propellant is needed and therefore smaller launchers can be used, thus significantly reducing the launch costs. In addition, this also means that the number of launch vehicles that can put the mission into orbit is greater, potentially reducing the risks of launch delays associated

with reliance on a single launch [5].

Another important benefit of this type of orbit is that satellites in such orbits do not need any additional thrust to de-orbit. This can be seen as a benefit because ESA directives, following the recommendations of the Inter-Agency Space Debris Coordination Committee (IADC), state that spacecraft that are no longer operational must leave orbit and de-orbit within a maximum of 25 years. These regulations are intended to control and manage existing debris and to try to reduce future space pollution. As an example, a satellite placed in a LEO orbit of between 600 and 700 km will take between 15 and 78 years to de-orbit, depending on factors such as solar activity or the shape of the satellite, which means that an additional impulse will be required to ensure that the spacecraft de-orbits within the required period. In contrast, a satellite placed in a standard VLEO of about 400 km will take no more than 3 years to fall back to Earth [5].

As mentioned above, VLEOs are very good options for EO missions. This is because the spatial resolution of the cameras is directly related to the distance to the target. Switching EO satellites from higher orbits such as MEO or LEO to VLEO allows either obtaining higher resolution for the same satellite or reducing the sensor aperture and spacecraft size without reducing the resolution [18]. In addition, mapping errors associated with satellite attitude (azimuth and elevation) and pointing accuracy are reduced at lower altitudes, improving the geospatial accuracy of ground imagery and location-based services [18].

Finally, it should be noted that VLEOs are orbits in which there is less risk of collision between satellites and space debris than in higher orbits. This is because being at a lower altitude orbit, where the atmospheric density is significantly "high", the debris will fall fast and, therefore, the orbit will be cleared of debris much faster than in higher altitude orbits. Predictions indicate that the VLEO range will remain clean and free of space debris over next several years. This fact may represent that VLEO may become an alternative to traditional orbits as they are very resilient to space debris accumulation.

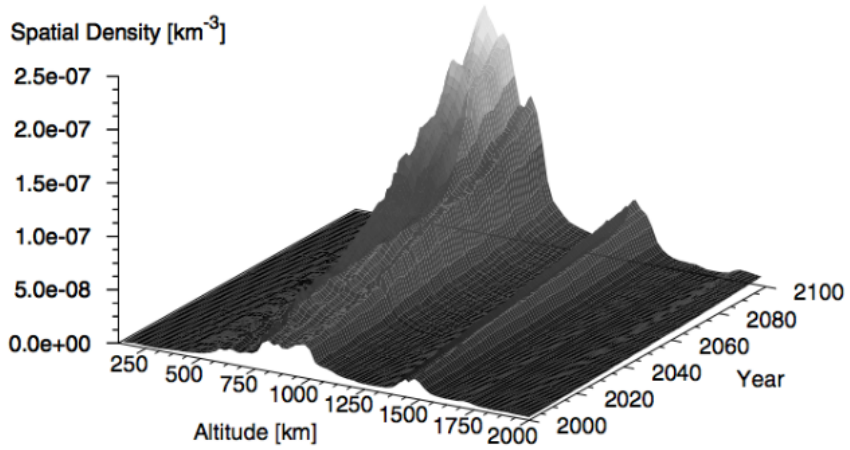

Figure 3.7: Prediction of the evolution of spatial density altitude profiles in LEO for objects with a diameter bigger than 10 cm during a 100-year timespan. Source: [21]

Disadvantages and challenges

One of the main disadvantages of VLEO is that at these low altitudes the aerodynamic forces caused by the Earth's atmosphere acting on the satellites are remarkable. As previously mentioned, drag is the most notable force that causes the orbit of the spacecraft to decay and, therefore, the mission lifetime to be short. In addition, due to the increase of atmospheric drag, some turbulence may appear, causing a decrease in the stability of the satellite and affecting the correct development of its functions. For these reasons, the aim is to reduce drag as much as possible. To achieve this it's necessary to have a very good knowledge of spacecraft aerodynamics in order to produce good and optimized designs with the most precise shapes and configurations possible [5].

Another drawback that has also been discussed above is the presence of the atomic oxygen. This element is very reactive and can affect and degrade material performance, in particular sensitive sensor surfaces and thermal coatings [18].

An intrinsic characteristic of this type of orbit is that the communication windows between satellites and ground stations are very short due to the high orbital velocity of the satellites. The satellites in VLEO have a very short orbital period, which means that the communication windows are reduced and, therefore, a data transmission problem appears. This is a challenge in Earth Observation missions but not so much in communications projects such as satellite internet because the ideas of creating constellations of satellites are already conceived.

The DISCOVERER project aims to reduce these disadvantages as much as possible by looking at them as opportunities while maximizing the unique benefits of this type of orbits.

3.5 External environment analysis

The external environment of a company consists of all those factors external to the company itself that affect and influence its ability to function. This includes all external political, legal, economic, social and technological actions that influence the company and its competitors. In aerospace projects it's relevant to make a careful study of the external environment as this projects are usually highly influenced both by new opportunities that arise and by the strong pressures from governments and civil society.

This section will analyze the external environment that affects the Project Kuiper by means of a PESTEL analysis (Political, Economic, Social, Technological, Environmental and Legal).

Political

- The United States seems to be entering on a period of relative harmony with the new President Joe Biden after his victory over Donald Trump in the 2020 national elections. The atmosphere in the North American country was very tense and polarized but currently it seems that the general tension is already de-escalating.
- Currently, in many Latin American countries there are huge social and political conflicts. Colombia, Chile or Venezuela are the clearest examples of the social tension in these countries. It is also relevant to comment the insecurity and the problems they have with crime in some of these countries such as Mexico or Panama [22].
- Nowadays, some governments around the world are investing strongly in new space programs of their space agencies, such as the USA with NASA, European countries with ESA or Japan with JAXA. At the same time, these agencies are involving new actors in their plans: private companies that will be their partners and will play a key role in the new space era [23].

Economic

- The COVID-19 pandemic has affected many western societies and many are going through an economic crisis. However, it seems that the health situation is starting to improve thanks to massive vaccination campaigns and it is expected that in the coming years the economic levels prior to this crisis that has shaken the world can be recovered. However, some countries will be forced to give economic aid to different sectors in order to recover from their current situation and this fact could slow down investments in space programs [24].
- Some companies that could play a key role in the future of the space sector have found in the health crisis an opportunity and have managed to increase their profits. Amazon is the most clear example of this situation [25].
- The global satellite communications market is clearly on the rise. It size was worth $62.19 billion in 2019 and is expected to grow at a compound annual growth rate of 9.2% from 2020 to 2027 [10].

Social

- Societies are increasingly moving towards a highly interconnected world. In this new paradigm, the communications sector, and especially internet, will be the key to further progress.
- Citizens are becoming more and more exigent with their internet connections. They want fast and efficient connections everywhere but they want them at affordable prices.

- Societies in western countries are becoming more and more aware of the importance and the benefits of the space industry and the opportunities that satellites can offer in the daily lives of the persons. In addition, great personalities such as Elon Musk or Jeff Bezos have openly introduced the world to the space sector, which was previously considered to be very select and complicated, and have awakened new passions in people with scientific and technological concerns in all parts of the world.

Technological

- SpaceX is currently leading the technological development of LEO satellite constellations. The Elon Musk's company is already implementing new technologies to its satellites such as laser cross-links for better communication between satellites [26].
- Western societies are growing technologically speaking. In many countries governments are making efforts to bring quality connections, such as fiber optics, to rural areas. This in theory, but in practice it will take many years before the majority of rural areas are supplied, since the deployment mentioned above is being carried out very slowly.

Environmental

- Currently, there are few laws concerning space pollution, and space debris. However, with the creation of the giant constellations of satellites, the importance of establishing stringent regulations has increased enormously, especially pushed by the astrophysical community.
- Developed societies in the first world are becoming increasingly aware of all aspects related to the environment and sustainability. As a result, companies are striving to offer products that have the least possible impact on the environment and that are respectful with the planet.

Legal

- The laws that try to legislate the space issues are really complex and difficult to implement in many cases because the technological developments are always one step ahead of the existing legislation.
- The Federal Communications Commission (FCC) is an independent U.S. government agency that regulates interstate and international telecommunications by radio, television, wireless, telephone and satellite. It is therefore the regulatory agency for the new constellations that will provide satellite internet and will be responsible for ensuring fair competition among the new constellations [27].

Chapter 4

Business model

In this chapter all the information necessary to develop the Business Model will be detailed. First, the methodology followed to build the business model will be explained, followed by the in-depth study and search of all the information about the Project Kuiper needed to develop a reliable and correct business model.

4.1 Business model methodology

A business model is a conceptual tool that describes the different parts of an organization or company and how they relate to each other in order to deliver and create value in economic, social or cultural contexts. This definition is quite general and can include several different business model methodologies [28].

For this project, the business model CANVAS developed by Alexander Osterwalde a Swiss business modelist has been used. This methodology consists of describing all the relevant factors of the company through nine building blocks. It shows information about the customers of the business, about the relationships that will be established with them and about the channels through which these will be realized. It also shows the value propositions of the business, the key activities and resources as well as the cost structure and how the company will generate profits.

These nine blocks that conform and structure the BM CANVAS will be briefly presented next according with the Osterwalde definitions [28].

- **Customer segments**

  Alexander Osterwalder defines the Customer Segments Building Block as the block that identifies the different groups of people or organizations an enterprise aims to reach and serve [28]. These are all the segments that the organization wishes to target and add value to.

  There are different types of customer segments to which the company can aim to appeal: mass market, niche market, segmented groups or diversified groups. In turn, these segments can be segmented or diversified.

  On the other hand, another division can be made about customer segments depending on the type of customer to whom the company will offer services. It will be called B2B (business to business) if the company intends its customers to be other companies, B2G (business to governments) if the company intends its customers to be governments, and B2C (business to customers) if the company intends its customers to be private users.

- **Value Proposition:** According to Alexander Osterwalder definition this block describes the different products or services that the company offers and which create value for a specific customer segment [28].

  Each customer segment will appreciate a specific value proposition. The value propositions have to be unique and differential as it is the reason why customers choose the services or products of one company over those of another. They are those services or products that solve the customer's problems or satisfy their needs. Some value propositions may represent a disruptive offer if the products or services offered are innovative. If they already exist in the market, value propositions should have added features and attributes. An organization's value proposition typology can fall into one of the following three categories:

  Quantitative Category: if the organization creates new value by improving the speed of its service, improves the price of it, or adds new features or upgrades.

  Qualitative category: if the organization creates new value with products or services that improve the customer experience through new designs or new interfaces.

  Game-changing category: if the organization creates new value with a product or service that truly revolutionizes its field. This new product or service is capable of being a paradigm shift in the industry.

- **Channels:** This building block describes all the mechanisms that the company uses to reach and to communicate to its customer segments and to deliver its value proposition according to Osterwalder definition [28].

  These channels can be of two types: direct (when the company interacts directly with the customer) or indirect (when intermediaries exist between the company and the customer).

- **Customer Relationships:** Osterwalder defines this building block as the block that describes the types of relationships that the company will establish with its specific customer segments.

  There is a wide range of possible interactions between the company and its customers: from personal relationships to impersonal or automated relationships. The company's goal has to be always to attract and retain customers by building strong, quality relationships.

- **Revenue Streams:** This block represents the revenue that the company manages to obtain from all its customer segments [28].

  Revenue sources can be of two main types: recurring revenues (revenues resulting from ongoing payments to either deliver a Value Proposition to customers or provide post-purchase customer support) or transaction revenues (revenues resulting from one-time customer payments. The companies have several ways to generate revenue streams such as subscription fees, asset sales and licensing among many others.

- **Key resources:** Osterwalder defines the key resources as the building block that describes the most important assets that a company needs to make its business model work and deliver its value proposition to the customers [28].

  These assets can be categorized into tangible resources (financial or physical), intangible resources (technology or reputation) and human resources.

- **Key activities:** This building block describes the necessary activities that the company needs to do to to make its business model work, according to Osterwalder definition [28].

  These are the most important actions that the company must do to operate successfully. Key activities can be divided into 3 categories: production, problem-solving and network activities.

- **Key partnerships:** Osterwalder defines this block as the building block describes the network of suppliers and partners that make the business model work [28].

  A differentiation can be made between internal partnerships (if the partners are part of the company itself) or external partnerships (if these partners are totally external to the company itself).

- **Cost structure:** This last building block is defines by Osterwalder as the block that shows all the costs that the company must assume for its business model to work properly [28].

  These costs can be classified into two general types depending on their regularity over time: the fixed costs, which do not depend on the quantity of products or services generated, and the variable costs, which vary proportionally with the quantity of products or services generated by the company.

The blocks corresponding to the Value proposition and Customer segments are the most relevant of the 9 total blocks since they are the basis of the business, they are the "what" the company offers and the "who" it wants to reach.

A significant feature of the CANVAS BM is that it is a very graphical tool in which the design and how the information is organized, unlike other BMs, is very relevant. Once the nine different building blocks have been explained it is important to know the layout of these in the design of the CANVAS. The general layout can be seen in the figure 4.1 that is the self-made template that will be used in this project.

Figure 4.1: Business Model CANVAS template. Source: [28]

The layout is designed in such way because the different blocks can be grouped in bigger parts. The layout can be separated into two parts or into four different zones.

First, the division of the CANVAS into two main parts will be explained. The blocks that are on the right-hand side of the CANVAS form what is known as the "Value-side". These blocks are all those that describe the activities performed by the company or organization and that are visible from a position outside the company itself. The left hand side is the "Cost side" and involve all the blocks related to the internal efficiency and functionality of the company or organisation. It is worth noting that the two sides are strictly related and that changing elements on the right-hand side will have implications for the left-hand side.

The image 4.2 shows the layout of the two sides and the blocks that belong to each of them.

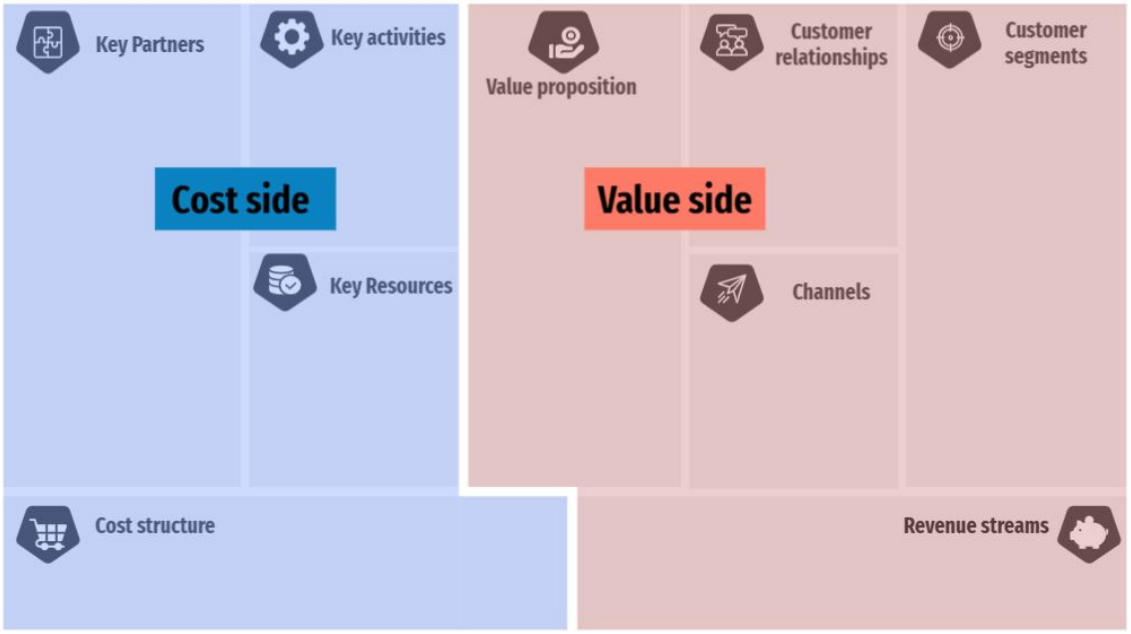

Figure 4.2: Two sides of the Business Model CANVAS. Source: [28]

As mentioned, the CANVAS template can also be divided into four different areas: the value proposition, the customers, the business structure and the financial viability. These distinctions are relevant because they are the four main areas that every organization must take into account in order to make its business model viable. The distribution on the CANVAS of this four parts can be seen in the figure 4.3

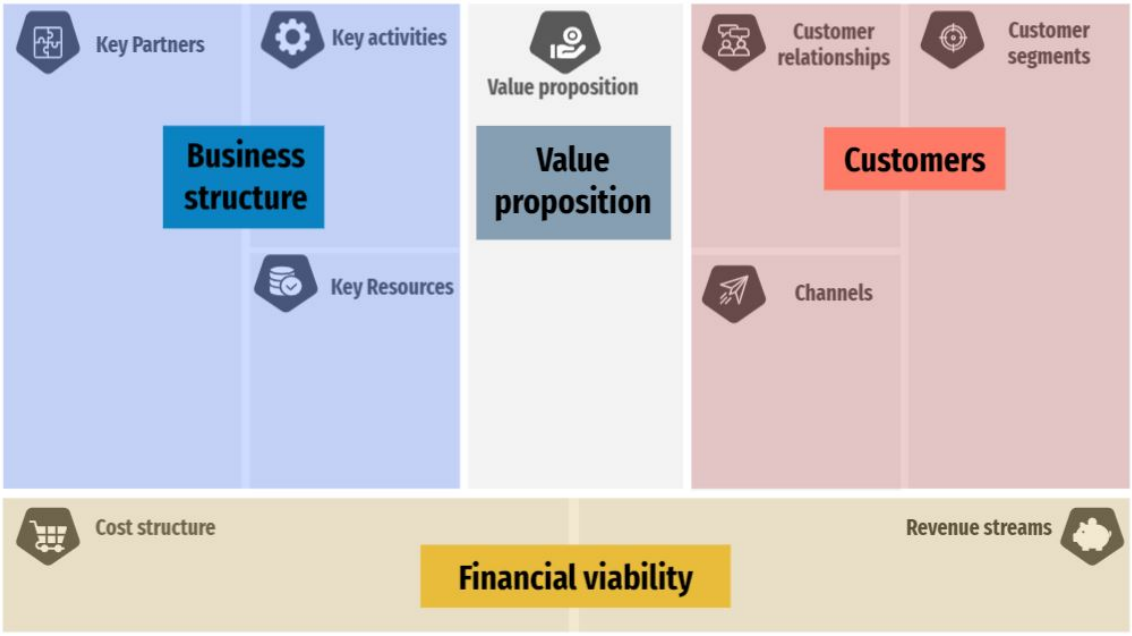

Figure 4.3: Four areas of the Business Model CANVAS. Source: [28]

4.2 Case study: Project Kuiper

Kuiper Systems LLC is a subsidiary of Amazon that was created on April of 2019 with the primary objective of deploying a large broadband satellite internet constellation to provide quality and reliable Internet connectivity to all places around the world. The deployment is commonly known by its project name: the Project Kuiper [29].

In this section the the most relevant aspects of the constellation and the activities related to them will be analyzed. It is important to note that the project is still in the development phase, so Amazon still keeps many data confidential (especially economic and technical data) and there is some information about other areas that is not yet known because it is still under development.

For further information, a complementary study has been carried out, which can be found in section 2 of the Annexes titled: "Extension of the case study: Amazon overview". Amazon is analyzed in this study since it is the company in charge of developing the project. Therefore, Kuiper Systems will use its resources and services to carry out the project. The aim is to obtain all the relevant extra information about its history, its work philosophy and its environmental philosophy.

Figure 4.4: Project Kuiper logo. Source: [29]

4.2.1 Employees

The Project Kuiper has a staff dedicated of more than 500 people [30], although 187 additional project-related jobs are currently available at different locations in the United States mainly related to the scientific and technical fields [31].

The main project facilities are located in Redmond, Seattle near the company's headquarters and include dedicated offices and large research and development facilities. The main visible face of Project Kuiper is Rajeev Badyal who is the current VP of technology of the project. He is a computer engineer who has extensive experience in the industry. He was working for Microsoft, then became the vice president of Starlink when the project was in development phase until finally in 2018 he joined Project Kuiper.

4.2.2 External partneships

Amazon has not yet announced any information on when its constellation will be available or the dates on which it will start launching its satellites. However, the Federal Communications Commission (FCC) decreed that by 2026 the company must have put into orbit at least half of the total satellites that will make up the constellation. For this reason, Amazon will have to accelerate the rest of the design process, and then prepare a fairly intense launch schedule.

On April 19, 2021, the U.S. company revealed who would be one of its launch partners to send its first satellites to the desired orbits. Amazon has agreed to use the United Launch Alliance (ULA) Atlas V as the first of many launch vehicles for deploying the full constellation of satellites. ULA will provide nine Atlas V rockets for its first launches from Space Launch Complex 41 at Cape Canaveral Space Station in Florida [32].

United Launch Alliance is a U.S. provider of spacecraft launch services that was established in December of 2006. The company is a joint venture of Lockheed Martin Space and Boeing Defense, Space & Security and currently manufactures and operates rockets able to launch spacecraft and satellites into Earth orbits and to other bodies in the Solar System.

Amazon has not yet disclosed details on contract pricing. It has also not yet detailed which versions of the Atlas V will be used for the nine launches and how many satellites will be deployed on each mission.

The Atlas V is a highly reliable rocket that has a 100% success rate in the 85 launches it has performed. This rocket has been used in several NASA missions. Among these there is the "Mars 2020" mission, which has been incredibly successful and has managed to place the Perseverance rover on the surface of the red planet and to fly a helicopter, the Ingenuity, being the first flight in history on a planet which is not the Earth.

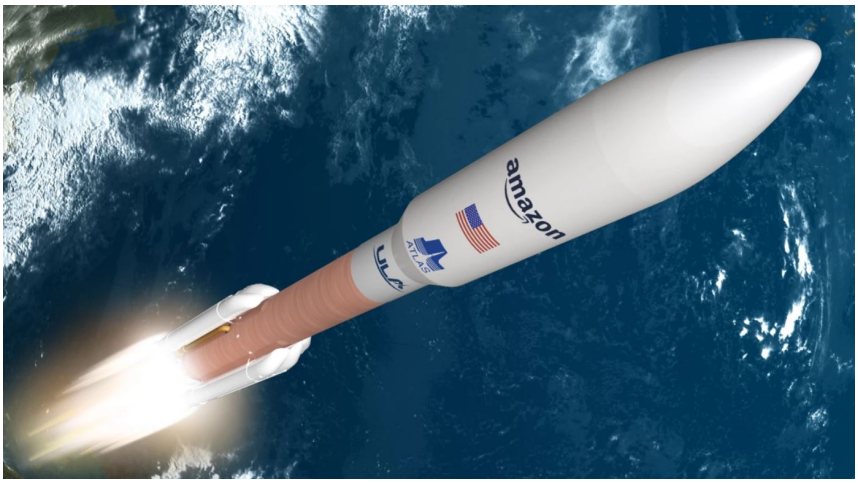

Figure 4.5: Conceptual Rendering of a ULA Atlas V rocket carrying Project Kuiper satellites. Source: [30]

However, Rajeev Badyal, VP of technology of the Project Kuiper, clarified that they have designed the satellites and the dispenser system to be able to accommodate to multiple launch vehicles [30]. This means that the company will work with many launch vehicles and launch partners to deploy all the constellation's satellites on time and to replace them at the end of their useful life, leaving the door open to potential future partners such as Blue Origin, or the European space company Arianespace.

Blue Origin could develop a key role in Amazon's future plans. It could be one of the main partners in Project Kuiper thanks to the existing close relationship with Amazon. Although the rocket company does not currently have a heavy-lift rocket capable of placing the Kuiper satellites to the desired orbit, this could change in the near future. The company has one rocket of this type which will also be reusable, the New Glenn, under development. Amazon is expected to spend the next few years developing the satellites that will compose the Project Kuiper constellation. This could give Blue Origin time to have a heavy-lift option with which Amazon could put some of its satellites in orbit or, at least, replace them when they complete their useful life [33].

In addition to all this, Amazon will have to establish relations with NASA as it is the organization in charge of regulating the standards regarding surviving space debris that all space missions must comply with [34].

4.2.3 Telecom satellite market segment & Requirements

This section will analyze the current situation of the satellite internet providers market segment, its current trends and its requirements.

The satellite communication market is clearly on the rise. Companies are increasingly using satellite communications to collect operational data in order to improve efficiency and achieve the best possible ways to conduct their business. There are companies whose business operations extend to geographically remote locations and are therefore highly dependent on satellite communications to carry out all their activities correctly and efficiently. In addition, individual users are increasingly demanding to enjoy the benefits of fast and efficient connections wherever they wish. Moreover, the Covid-19 pandemic has generated changes that are here to stay. One of them is teleworking. In order to make teleworking a viable and effective option in all rural areas, it is essential that quality Internet connections are available in these regions.

For these reasons, satellites are an increasingly important part of the digital infrastructure that can provide connectivity to rural and remote areas. They have already become an integral part of the wireless ecosystem, as they connect a multitude of systems used on a daily basis, from providing broadband to airplanes to providing broadband to homes.

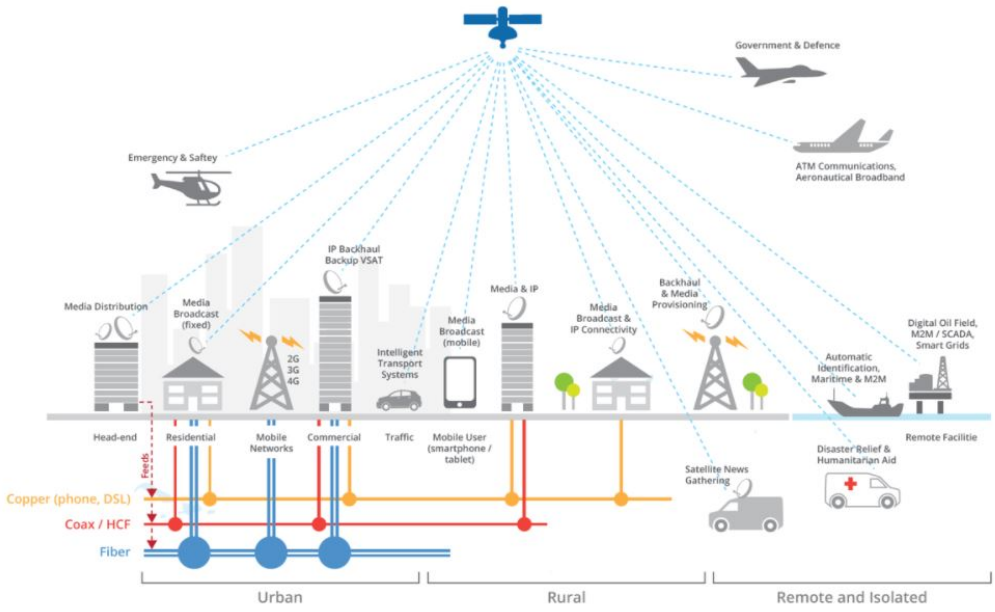

Figure 4.6: Different ways in which users typically receive a broadband connection for internet access. Source: [20]

Today, key developments such as the rise of small satellites, the launch of reusable rocket vehicles and the use of the Low Earth Orbits have enabled the satellite communication industry to take a step forward, both in its military and commercial sides. These developments have made it possible that today the internet constellations that will provide internet are no longer a fantasy.

Currently, Starlink is clearly the company most advanced in its plans to deploy its full constellation. On April 7, 2021, Elon Musk's company had already managed to place more than 1300 satellites in orbit [14]. OneWeb was also well on track but due to its collapse into bankruptcy in 2020 it has fallen further behind. However, it has already deployed 146 of the 650 expected in the first phase [16]. On the other hand, Amazon has opted to go more slowly. In August 2020, it received FCC approval to deploy its 3236-satellite constellation, which must be complete by 2029. Currently, as previously mentioned, the company is focusing on the development process.

Having analyzed the current situation of the satellite Internet provider sector, it is necessary to determine what requirements Amazon's new constellation will have to meet.

Amazon intends to provide broadband Internet to all types of customers who currently do not have it. This is why its potential customers are so diverse, as they will be individual users, as well as schools or hospitals, businesses, and transportation systems, including airplanes, ships and land vehicles. In addition, it is expected to play a role in expanding coverage areas for mobile network operators in the future and thus contribute to the IoT revolution. From here the first and most important requirement is extracted: to reach all parts of the world with its services. In order to reach the consumers described before, it is necessary that the services offered will be of high quality. For this reason the second

requirement is that the broadband internet provided will be both fast and secure. It is important that the internet service offered manages to be fast so that users can work conveniently but it is also necessary that it manages to be reliable even if many users connect to the system at the same time.

The last requirement is also related to the previous ones; if broadband Internet is desired to be offered to all the people who do not currently have it, it's necessary to offer it at affordable and reasonable prices. Amazon is fully aware of this and wants to offer lower prices than its direct competitors.

4.2.4 Satellites characteristics

Since Project Kuiper is still in the development phase and due to the company's own confidentiality policies, no specific data on the satellites that will conform the constellation have been disclosed yet. However, it is interesting to at least have a reference on how these satellites could be. For this reason the Starlink satellites will be taken as a reference and their main characteristics will be studied [12]. The characteristics of the satellites of the two constellations will not vary too much and Amazon will have to take into account some technological advances that SpaceX is already incorporating to its satellites in order not to be left behind in its particular dispute to offer broadband Internet to all regions of the world.

Starlink's operational satellites have a mass of 260 kg and therefore belong to the group of small satellites (all satellites with a mass of less than 500 kg). Their design consists of a flat panel with multiple high-performance antennas and a single solar array. These satellites incorporate hall effect thrusters that use krypton as reaction mass for orbit position adjustment, altitude maintenance and end-of-life de-orbit. They also incorporate a star-tracking navigation system for precision targeting and can access space debris data provided by the Department of Defense for autonomous collision avoidance. Starlink has designed its satellites so that 100% of their components burn up quickly in the Earth's atmosphere at the end of their useful life.

In addition, as previously discussed at the PESTEL analysis (section 3.5), SpaceX is incorporating a new technology into its satellites: laser cross-link [26]. These new elements were installed for the first time in the satellites launched on January 24, 2021, so few satellites currently have incorporated this technology. The laser cross-link allows the connection between satellites. These connections allow communications to be transferred from one satellite to another, either in the same orbital plane or in an adjacent orbital plane. These links make it possible to reduce the number of ground stations to a minimum, since the ground station no longer has to be in the same satellite footprint as the user stations. In addition, they allow coverage to be extended to remote areas where there is no possibility of installing ground stations as the middle of the sea. They can also reduce latency, as the number of hops between satellites and ground stations is substantially reduced.

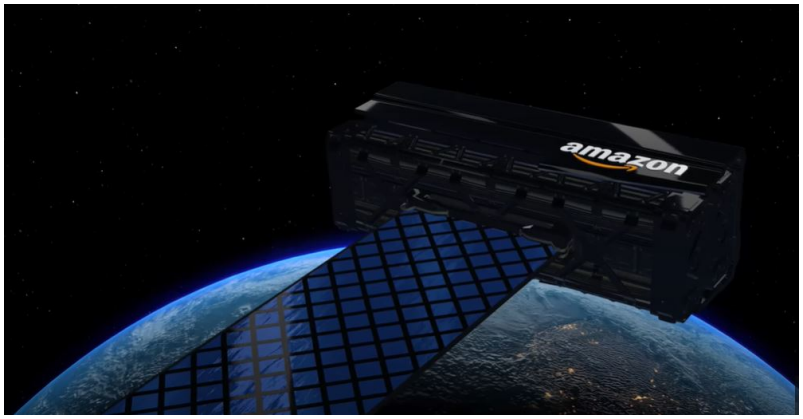

Figure 4.7: Conceptual Rendering of a Project Kuiper satellite. Source: [35]

4.2.5 Operations

4.2.5.1 Constellation Characteristics

In this section the main characteristics of Amazon's satellite constellation will be analyzed and the main architecture of the system will be presented.

Kuiper System Space Segment

The constellation that will be deployed by Amazon will have a total of 3236 satellites. These satellites will be placed in three layers of satellites, at different altitudes and inclinations all of them located in the lower range of low Earth orbits (LEO). The first layer will be located at 590 km, the second at 610 km and the upper layer at 630 km [36]. The table 4.1 describes how the Kuiper satellites will be distributed within the planes of each of the three orbital layers .

Table 4.1: Constellation Design: altitudes and inclinations. Source: [36]

Altitude (km)	Inclination (º)	Planes	Satellites per plane	Number of satellites
590	33	28	28	784
610	42	36	36	1296
630	51,9	34	34	1156

The satellites are expected to be launched in 5 waves. The first wave will consist of 578 satellites which will provide internet service in two large horizontal bands; the first will be between 39 degrees north and 56 degrees north (approximately from the Strait of Gibraltar to Moscow) and the second will be between 39 degrees south and 56 degrees south (approximately from Hastings, New Zealand, to the South Sandwich Islands of Great Britain in the Atlantic Ocean). The remaining 4 waves will fill all the remaining latitudes between the two initial wide bands until reaching the equator. Therefore, all latitudes from

56 degrees north to 56 degrees south will be covered, which is the area of the plant where approximately the 95% of the population lives [37].

It is estimated that the satellites that will conform the constellation will have a useful life of seven years. This is less than half the lifetime of a traditional geostationary communications satellite. Amazon predicts that due to their low orbit, the Project Kuiper dead satellites would naturally deorbit on average between five to seven years. Moreover, the company expects that if a satellite fails on entering on its orbit it would deorbit within a maximum of 10 years [37].

As previously mentioned, the FCC determined that by 2026 Amazon must have placed half of its satellites in orbit and that by 2029 the constellation must be complete.

Table 4.2: Main characteristics of Project Kuiper constellation. Source: [29]

Main characteristics overview	
Coverage expected	"Worldwide" (between 56º N and 56º S)
Number of Satellites expected to be launched	3236 in 5 waves
Orbit	LEO: 590 to 630 km
Service offered	Low-latency broadband internet
Completion of the constellation	50% at 2026, 100% at 2029

System architecture

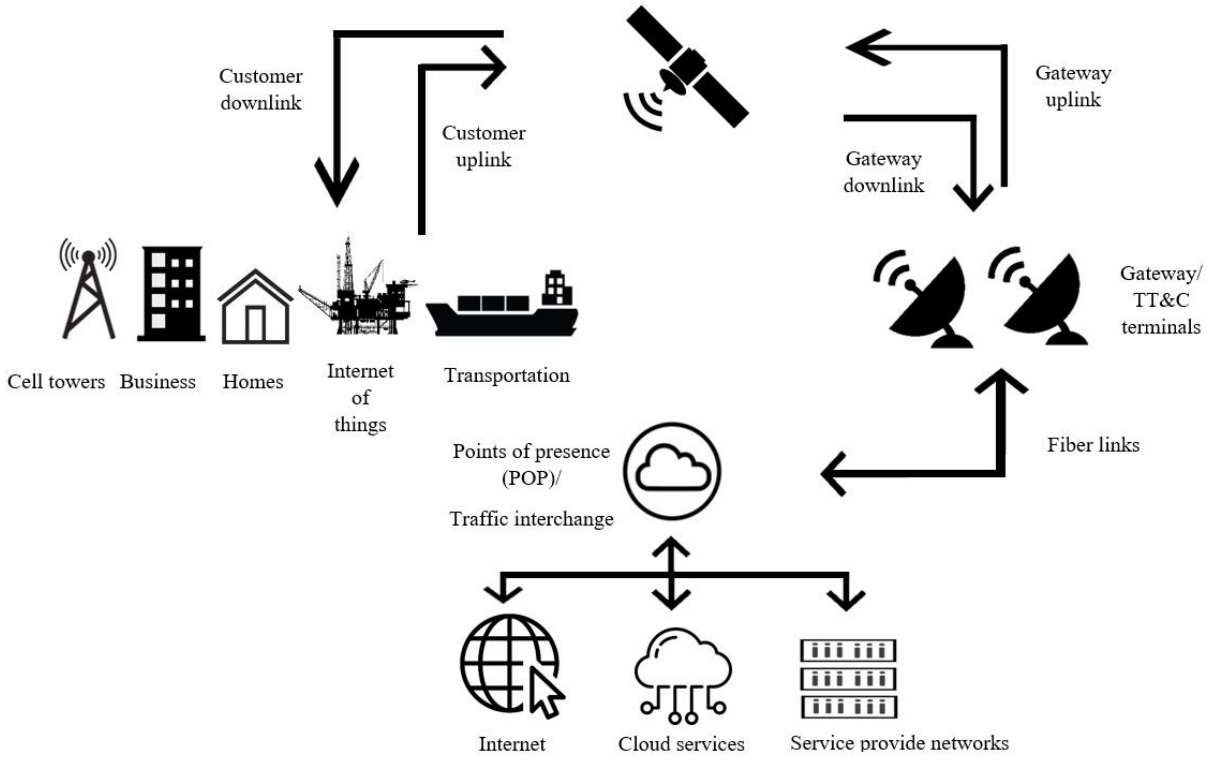

Figure 4.8: Architecture of the project Kuiper system

The system is composed of three main elements: the user terminal, the satellites and the gateway antennas of the ground stations.

The first element, the user terminal, will be a small antenna that that all users must acquire and will require simple installation without the need for a technician, just point it at the sky and plug it in. These terminals will have to be located outdoors and outside the buildings. They will be electrically steered to ensure connection to the appropriate satellite of the constellation moving across the sky. To reach the internet the terminal will send its request to one of the satellites crossing the sky [37].

The satellites will use the Ka-band spectrum to process the request of the user terminals [20]. The main frequency bands authorized for satellite networks are Ku-band, from 12 to 18 gigahertz, and Ka-band, from 27 to 40 gigahertz. These bands have been identified as the frequencies with the most suitable resources and performance for satellite transmissions. The satellite, in turn, will transmit the instructions to the gateway antennas.

The gateway antennas will be connected by high-speed fiber to global Internet exchange points and point-of-presence sites to interchange traffic and reduce network hops and latency. To highlight the importance of digital infrastructure, it is important to note that specifically fiber and data centers enable satellite connectivity to the internet.

Once the instructions are received by the gateway terminal meaning that the website has been reached the process is reversed. The gateway antenna then will send the necessary data to the satellite through what is known as gateway up-link and then to the user terminal through what is known as customer down-link. The satellite will provide both the front haul to the customer and the back haul to the data center.

4.2.5.2 Ground stations and user terminals

Ground stations

Developing, building and launching satellites is certainly expensive, but the ground stations that connect those satellites and that make them operational also have considerable costs. For this reason the ground segment is a fundamental part of these new projects.

Amazon has a differential advantage over its direct competitors with respect to the ground facilities, it has the AWS Ground Stations. Project Kuiper is expected to work in conjunction with Amazon Web Services' large network of 12 satellite ground station facilities (the "AWS Ground Stations unit"). AWS is already working on ways to expand cloud computing to the next level. On 2019 Amazon Web Services rolled out its Ground Station service for controlling satellites and downloading data from space. AWS Ground Station is a fully managed service that allows customers to control satellite communications, process data, and scale their operations without having to worry about building or managing their own ground station infrastructure. These ground stations will not only work for Project Kuiper, but are expected to work for projects of other external companies.

Each ground station usually consists of multiple input antennas and is located in valley areas because this geography benefits less interference from other radio signals in the radio spectrum. Currently AWS Ground Stations are placed in the US West (Oregon), US East (Ohio), Middle East (Bahrain), EU (Stockholm), Asia Pacific (Sydney), EU (Ireland), Africa (Cape Town) and in Hawaii [38]. However, in the near future more antenna will be installed in different locations around the world.

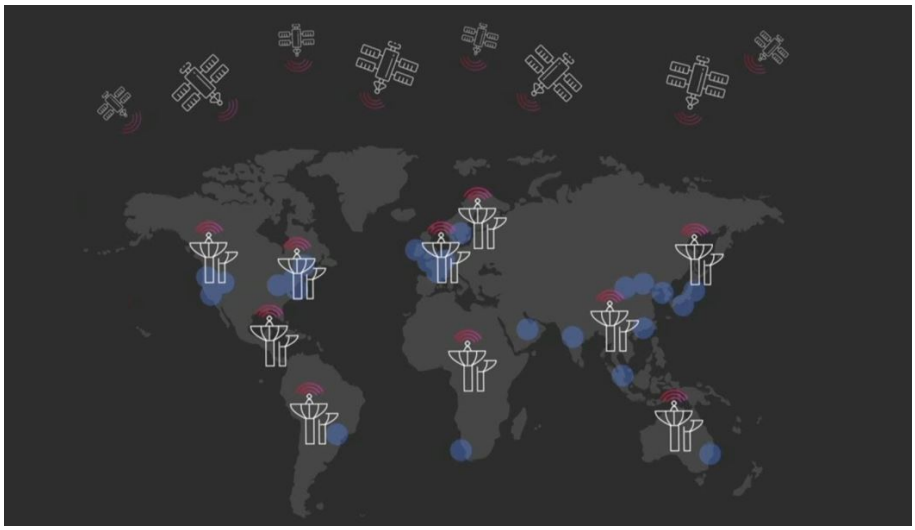

Figure 4.9: Location of AWS ground stations. Source: [38]

Additional ground stations will be installed in regions with the most signal fading due to rain to compensate the signal loss, as well as along coastlines to support offshore customers. Amazon ensures that each Kuiper satellite will be able to access to two ground stations to minimize downtime, to achieve the best system performance and reduce line interference. Customers will always see a persistent connection through a standard Ethernet interface in their homes and will be unaware of satellite switching, gateways or routing through the Kuiper system network [29].

User terminals

On the other hand, it is also relevant to analyze how the user terminals will be a key element of the system.

The Kuiper phased array antenna takes a different approach to conventional antennas. Instead of placing adjacent antenna arrays as is usually done, it has been chosen to use small structures of antenna elements to overlap them. This is a major breakthrough as it has never been achieved in Ka-band before. In addition, this has made it possible to reduce the size and weight of the entire terminal, while allowing it to operate on a frequency that offers higher bandwidth and better performance than other bands [39].

The main antenna breakthrough has been the combination of transmit and receive phase antennas in a single aperture by using tiny antenna element structures to overlay one on top of the other [40].

The terminal passed the development and testing phases during the fall of 2020. With a diameter of only 30 centimeters, the antenna is smaller and lighter than its competitors antenna designs. Amazon has said that the reduction in size compared to previous antenna designs will allow them to reduce production costs and offer customers a terminal at an affordable price, although the cost of the terminal for the average user has not yet been disclosed [40].

The prototype already achieves 400 Mbps, what are already very good speeds, but the company has assured that its performance will continue to improve in future iterations. The company has also done extra tests and proved that its prototype antenna can be used to transmit 4K-quality video from geostationary satellites [40].

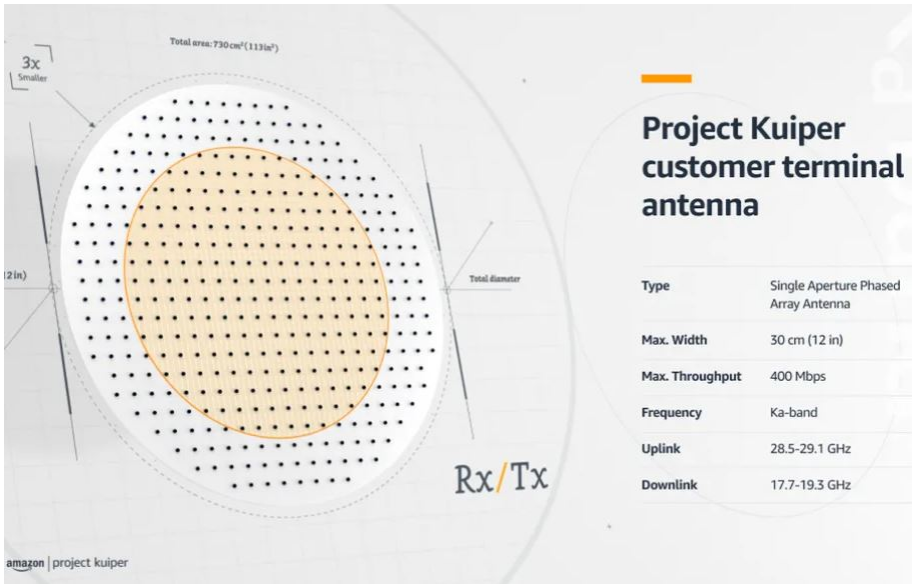

Figure 4.10: Amazon customer terminal prototype specifications. Source: [40]

4.2.6 Online Platform

This section will detail information related to the broadband internet service to be provided by Project Kuiper and a brief comparison will be made with the services currently offered by Starlink. In addition, it will analyze the added services that Amazon will be able to offer to its users that will add extra value and will help the company to differentiate itself from its direct competitors.

4.2.6.1 Internet Delivery

As mentioned in the previous section, Amazon engineers managed in December 2020 to obtain a download speed of 400 Mbps using the prototype of the user terminal they built. These speeds were achieved with a first prototype, so it is expected that the final speeds could be even higher [40]. These download speeds are really a very good performance to offer to users. If this data is compared with the download speeds offered by the most widespread terrestrial mobile network on the planet, which is still 4G, it can be seen that Kuiper services would offer higher download speeds than this. The best 4G connections offer real download speeds of between 40 and 60 Mbps [41]. Despite this, the download speeds offered by Kuiper are not higher than those of 5G, the new type of mobile network that is already spreading around the world, which are higher than 500 Mbps [41], nor those of fiber, which are typically around 1 Gbps [42].

However, the latter is not significant, since these new mobile networks and fiber connections will not be direct competitors, since the areas where Project Kuiper wants to provide services are those in which these services are not currently available. Therefore, what should be looked at is the speeds offered by the biggest direct competitor: Starlink.

Currently, Starlink is still a work in progress and it is offering a beta version of its services. Therefore, the current connections received by users are not yet definitive. SpaceX announced that download speeds were expected to range from 50 Mbs to 150 Mbs and that latency is expected to range from 20 ms to 40 ms during the first months of the beta version. However, the average Starlink download speed received by users in the U.S. is lower than expected and ranges from 40,36 Mbps to 93,09 Mbps [43].

This leads to the conclusion that Amazon has a service with a lot of potential and that Starlink will have to work to not fall behind in the area of connection speeds once Kuiper comes to market.

4.2.6.2 Value-Added Services (VAS)

Amazon has not yet announced any extra services that it will offer to its users with its satellite internet service. However, it is a company with very diversified activities and there are some of its sectors that could have a very good implementation with the Project Kuiper's internet services. Given that the users of Kuiper's Internet services will be from very different sectors, each customer segment may be interested in different extra services.

AWS is the most differentiating element that Amazon has at its disposal. As previously defined AWS is the world's most comprehensive and broadly adopted cloud platform that offers over 200 fully featured services from data centers globally. It could be that specific business sectors or governments, customers of Kuiper, may be interested in the resources of cloud computing, the machine learning or data analytics that AWS offers.

As far as individual customers are concerned, they could be very interested in all the services offered by the Amazon Prime subscription. Amazon Prime, as described before, is

a subscription service that gives members access to a variety of Amazon perks. Benefits include expedited 2-day shipping, access to exclusive Amazon deals, access to a wide catalog of movies and series in streaming and many other Amazon-centric benefits.

Undoubtedly, Amazon has the resources to offer extra quality services to its customers that will help to bring extra value to its services and will help them to stand out from its direct competitors.

4.2.7 Financial Status and Risks

This section will analyze the current financial status of the Project Kuiper and will briefly study the economic risks that it will have to overcome in order to make the business model viable and efficient.

4.2.7.1 Financial Status

Amazon has not yet disclosed any financial data related to its activities. The company has not yet wanted to make public any of the financial data of the activities and services that are already known, such as the cost of the launch services that ULA will provide for the 9 launches with the Atlas V rocket or the prices of the internet services and the cost of the user's terminal.

However, the company has disclosed that its planned an investment of $10 billion to develop the project [29]. This is the same amount that SpaceX announced it will invest in its Starlink project, so the direct competition between the two constellations is evident.

The industry has thus made combined commitments across all non-geostationary satellite broadband constellations that exceed the $20 billion, a spectacular level of financial support for companies that are currently generating almost no revenue (with the exception of Starlink, which is generating some revenue from its beta services). These investments are huge amounts of money so companies will need to have a strong enough financial structure to be able to support them without generating revenue for a certain amount of time.

Amazon has the financial resources to complete the project without seeking additional external funding. The e-commerce giant reported a 2020 net income of $21.3 billion, compared to the 2019 net income of $11.6 billion [25]. Even with the impact of the Covid-19 pandemic, the company has grown and could invest $1 billion or more per year over several years in a project as ambitious as Project Kuiper.

SpaceX on the other hand, has stated that when the Starlink services are fully operational the company will be able to generate around annual $30 billion of revenues as the communications market is already one of the most important sources of revenue in the space industry and is expected to continue to grow exponentially in the coming years [44].

4.2.7.2 Economical Risks

The main economic risks that Amazon and, in general, all satellite broadband Internet providers that will deploy their constellations in the coming years will face are firstly, to be able to sustain years of investing large amounts of money without generating significant income and secondly, to be able to offer their services at viable and realistic prices for all the markets currently unserved and underserved they want to reach.

As detailed in the previous section, Amazon has sufficient financial muscle to ensure that the first risk detailed will not be a major problem, so the second financial risk will be analyzed below.

This second economical risk that Amazon will have to face is being able to offer its services at affordable prices to individual users in different areas of the world. The company has not yet announced the fees for its internet services nor the price of their user terminal, although it has assured that they will be cheaper than those of its competitors. To put it in perspective, Starlink's prices can be analyzed since it is the only constellation that already offers services although it is only in beta phase. Currently, Starlink's fees are $99 per month in addition to the $499 one-time payment for its terminals and an extra $60 for shipping and handling [12].

As is logical, generally the countries in which there is less availability of quality Internet services and which have a higher percentage of population living in rural areas are those developing countries whose citizens are usually not very wealthy and it would be very difficult for them to acquire the services at these prices.

Researcher Meredith L. Rawls, along with other researchers and with collaboration with several universities and technological and scientific institutes from different countries around the world, including the Instituto de Astrofísica de Canarias and the Astrophysics Department of the University of La Laguna, carried out a study analyzing on the one hand the negative impact on astronomy of satellite constellations and on the other hand the necessity of offering satellite Internet services to populations where currently it is not affordable, not necessary, or both [45].

The study shows that the cost of Starlink's satellite Internet subscription remains out of reach for the communities that need it most and that services at current prices are only "necessary" and economically affordable for few countries. The report comments that the results obtained are also applicable to the other satellite Internet constellations. The detailed results are shown in the figure 4.11.

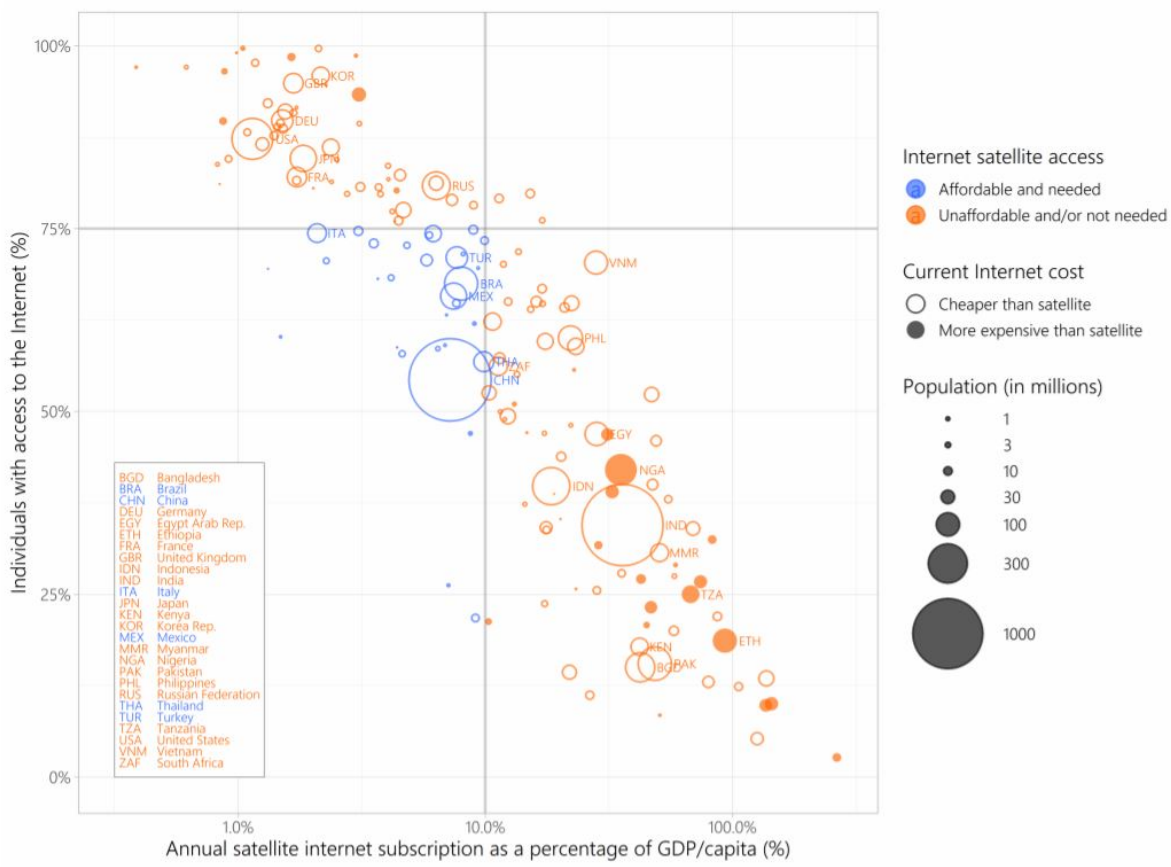

Figure 4.11: Analysis of the need and capacity to afford Starlink services in different countries around the world. Source: [45]

Project Kuiper is aware of this problem. Rajeed Badyal, noted that Project Kuiper wants to make a difference for unserved and underserved communities and therefore has to provide service at a price that makes sense for customers [40]. The first step in this trend will be to offer the user terminals at lower prices and with better features than the ones developed by the direct competitors. If Amazon manages to lower prices, it will be incredibly profitable because the global market for Internet demand is enormous and the business possibilities are unimaginable.

Chapter 5

Business Model CANVAS

Once all the information corresponding to the Project Kuiper and Amazon, the company to which the subsidiary belongs, has been gathered, it is now possible to develop the Business Model CANVAS of the Project Kuiper .

5.1 Value side

The value side of the CANVAS comprises the blocks of the customer segments, the value proposition, the customer's relationship, the channels used to communicate with them and the revenue stream.

5.1.1 Customer segments

The broadband Internet market is a very broad market that comprises many segments of users. Among Internet users, there are completely different segments that demand different services. For example, the wide range of internet users covers areas as diverse as private users who use the internet sporadically to governments and large companies with high demands. As mentioned in previous sections, Amazon does not want to target a single potential customer, instead it wants to cover as many potential customer segments as possible that do not currently have quality and reliable broadband internet connections.

For this reason, three main segments will be distinguished as the different types of customers that Project Kuiper will serve: businesses and companies (B2B), governments (BSG) and private users (B2C).

Business to business

Amazon aims to provide quality internet services to all those companies located in rural or remote areas with little or no access to broadband internet. This definition covers companies of very diverse natures.

One of the sectors that could benefit the most from Kuiper's services would be the maritime, air and land transportation systems [37]. The implementation of internet services in the transportation industry is already a reality and in the coming years the systems are expected to consolidate and improve allowing to transform the transportation sector. On the one hand, users of transportation systems could have internet services available everywhere on Earth. On the other hand, these internet services would profoundly change the way transportation systems collect data and information by bringing together the main technical and business trends of mobility, automation and data analysis. The collected data could be analyzed, firstly, to improve the traveler experience. Secondly, it could be useful to improve the safety of transportation systems by collecting and transmitting data in real time. Thirdly, the data could be used to avoid congestion (especially in terrestrial systems) saving time with an agile and fast capacity to change the traffic patterns. Finally, it could be useful to improve the operational performance of all services and play a decisive role in the development of autonomous vehicles [46].

Other business sectors that would benefit greatly from Kuiper's Internet services are companies that operate in rural or remote locations [37]. Examples of these would be agricultural companies and natural resource extraction facilities such as oil rigs, mines or quarries.

The last of the major business sectors that Kuiper expects to serve are the mobile network operators [29]. In addition to transmitting Internet directly to ground stations, Kuiper also wants to extend the coverage areas of 4G and 5G services by providing low latency backhaul solutions for different mobile network operators. This would expand coverage areas and expand broadband access in the United States and the rest of the world. With this expansion of coverage and with their large transmission capacity, satellites could support the development and become a key part of the IoT (internet of things) revolution. Moreover, The Project Kuiper will serve to complement the terrestrial 4G and 5G infrastructure and provide a backup in the event of natural disasters such as earthquakes, severe storms, hurricanes and floods [47].

Business to governments

The Project Kuiper aims to provide internet to government facilities located in rural locations where reliable broadband internet services are not available. Some of these facilities would be schools and high schools, medical clinics and hospitals or emergency services such as fire and police stations [37].

Currently, in developed societies, Internet services are already widely implemented in everyday tasks such as education, health services and, of course, emergency services. In addition, there is a move towards a less face-to-face model in some areas. This shift was already occurring earlier but in part thanks to the COVID-19 pandemic it has accelerated.

Tasks that were previously 100% face-to-face have been shown to be efficiently performed in a semi-face-to-face format or directly online. Rural sectors cannot be left behind in this change and technological development, so Kuiper wants to have an impact in these areas and provide them with quality internet services.

Business to customers

Finally, one of the most important sectors that Project Kuiper wants to address is that of the individual households. Nowadays, the use of the Internet has become an inevitable part of people's daily lives. Proper use of the Internet makes their lives easier and simpler in many different fields. The Internet helps consumers with information and knowledge for their personal, professional, social and economic development.

Private consumers have increased their demands in the coverage areas in the last years. They want quality connections everywhere they are. The Covid-19 pandemic has resulted in many people working from home and therefore needing reliable, quality Internet connections. Some people who do not need to go to the office on a daily basis have decided to move to more rural areas away from the daily hustle and bustle of the cities.

Along with the increased demand for connectivity, service expectations have risen. Consumers today perform a wide range of activities through the Internet, such as download HD movies on a regular basis, work, watch streaming TV, play games and shop online. This causes them to consume much more bandwidth than was the case just 5 years ago. Consumers are looking for high bandwidth and, for many applications, low latency connections. Significantly, these expectations have extended beyond technologically sophisticated users to virtually all consumers in developed economies and many emerging markets. Only those with limited connectivity options accept inferior performance.

5.1.2 Value proposition

Once the customer segments to be targeted by Kuiper have been studied, it is possible to analyze and study the value proposition that this new project will bring.

The services that Project Kuiper will provide are undoubtedly services that have the necessary strength to make a paradigm shift in a sector as booming as that of Internet services. For years, satellite communication has remained a stand-alone technology, independent of mobile networks. Now, with the next generation of satellites, they will be integrated with networks to manage devices and provide broadband internet services in remote and rural areas where conventional wired internet services do not reach. Therefore, the value proposition that Amazon's new project will bring will be a game changer.

The main characteristics of the Kuiper Systems value proposition are:

- **Internet services worldwide:** Project Kuiper's satellite Internet services will be available from latitudes 56°N to 56°S, the region of the world where 95 percent of the world's population lives. However, it is expected that service coverage may be extended to higher latitudes gradually as more satellites are launched in the future, although these plans are not yet confirmed.

- **Quality Internet services:** Users will receive quality Internet services. Download speeds are expected to exceed 400 Mbps thanks to the innovative design of the high-performance user terminal.

- **Reliable Internet services:** As mentioned in the section on customer segments, Amazon aims to supply the Internet to very different segments, ranging from private users to companies and government facilities. For this reason, its services will have to be reliable and be able to hold up without experiencing downtime even if many users are connected to the system at the same time.

- **Internet services at affordable prices:** Amazon is aware that if it wants its services to be purchased by a large part of the world's population currently underserved by quality internet services, its prices must be affordable. This fits perfectly with the company's philosophy of offering quality services and products at affordable prices for the bulk of the population.

- **Value-added services:** Project Kuiper has an extra valuable feature that can make it stand out from its direct competitors: being part of Amazon's extensive ecosystem. As has been discussed before, Amazon has AWS which is already an incredibly important tool but still has enormous potential for the near future. Project Kuiper and AWS could become strongly interconnected in the future and offer new possibilities and services to all its customers especially to companies and governments. Amazon Web Services can offer them many interesting services. The cloud computing, the machine learning and the data analytics could be key elements for these segments of customers taking into account the current tendency to move towards a completely interconnected world where all the business activities will be analyzed deeply to study their efficiency. Cloud computing provides a way for the business to manage their computing resources online and allows them to access their information virtually, creating a flexible and global way of accessing to their data any place, any time. The data analytics helps the organizations and the business to take advantage of their data and use it to identify new opportunities that, in turn, leads them to make smarter business moves, more efficient operations and higher profits. To individual users could be offered services such as Amazon Prime, that has already been defined before, that could fit perfectly on the demands and needs of them.

5.1.3 Customer relationships

Amazon is an experienced and professional company that has earned a great reputation for its good customer service. It is obvious that the company will maintain different types of relationships with its customers depending on the type of customer they are dealing with, but all of them will be personal and dedicated.

Amazon intends to create long-term relationships with all segments but especially with governments and large companies as these are the segments that will bring the most benefits in the medium and long term.

In addition, it is expected that the company will be able to offer the additional services mentioned in the Value Proposition section with Internet services. These quality services would serve to engage and retain customers.

5.1.4 Channels

Amazon has not yet announced which platforms or the specific channels it will use to communicate with its customers, but it will most likely use a similar configuration to the one used by Starlink. Through the official website, private customers will be able to contract the services and companies and governments will be able to contact Kuiper directly to explain their situation and requirements.

In addition, private customers will have an app that will offer them assistance once the services have been purchased. The app will offer, among other services: identification service of the installation location that will guarantee the best quality of service, run speed tests, hardware configuration and contact with the help assistance. For companies and governments, chat and telephone support services will also be available.

Another channel through which Amazon will be able to reach Project Kuiper the Business and Government customers if they are eventually able to access AWS services is through the cloud services.

5.1.5 Revenue streams

Kuiper's main source of revenue will be the monthly fees charged for the internet services. As previously mentioned, the exact prices are not yet known. Another source of revenue will be the one-time payments for customer terminals. In addition, Amazon will generate more revenue from agreements with mobile network companies to expand the coverage areas of 4G and 5G networks.

5.2 Cost side

The cost side of the CANVAS comprises the blocks of the key resources, the key activities, the key partnerships and the cost structure.

5.2.1 Key resources

This subsection will detail the most important resources available for Project Kuiper. They can be divided into 4 types:

Physical key resources:

- Development and production facilities in Redmond, Washington.
- Amazon Web Services ground stations.

Economic key resources:

- Strong financial situation of Amazon.

Technological and intellectual key resources:

- High-performance customer terminal with new technology.
- Patents for the new technologies developed.
- Amazon has one of the best logistics systems in the world.

Human key resources:

- High skilled scientists and engineers
- Directives with wide range of experience in the sector.

5.2.2 Key activities

The objective of Project Kuiper is to provide broadband Internet to the different areas of the world where quality services are not available. Therefore, some of the main key activities to be carried out by Kuiper are those that allow the development of these services in an optimal way. The most relevant of them are:

- Development and manufacture of the satellites and of the customer terminals on the Redmond facilities.
- Network control of the Kuiper system. The Kuiper System network will be managed via a global software defined networking (SDN) controller which among many other functions performs long-term resource allocation based on customer demand and type of service, including making short-term adjustments to resources based on time of day or peak capacity requirements.

- Control of Kuiper satellites through an independent network of TT&C ground stations, separate antennas and radios on board the satellite, and multiple satellite operations centers.

Kuiper will also have to realize other activities that are not strictly linked to the optimal functioning of the internet services but that will be equally key activities of the project. These are:

- Carry out marketing campaigns and work on branding to publicize Kuiper's entry into the market and to promote the new services offered and the advantages over the direct competitors.
- Project Kuiper will need to consider and work on logistics management as it is the fundamental part of the supply chain process that plans, implements and controls the efficient and effective flow and storage of goods, services and related information from the point of origin to the point of consumption. Amazon is known for being extremely efficient in this area and Kuiper isn't expected to be an exception.

5.2.3 Key partnerships

In order to properly develop satellite internet services and to be able to offer the value proposition described above, Project Kuiper will have to establish key partnerships with other companies and organizations. These strategic partnerships can be of two types: internal to the company itself and external to it.

Internal

As a partnership within the different sectors of the company, Project Kuiper will work together with Amazon Web Services and will have its own large network of satellite ground station facilities (the "AWS ground station unit"). In addition, Kuiper is likely to add AWS cloud computing services as an add-on service to its Internet services.

External

Amazon has already established an alliance with the Federal Communications Commission (FCC), the U.S. government agency in charge of regulating satellite communications, as it has been in charge of giving the approval to deploy the satellite constellation.

Amazon will have to work together with NASA as this organization is the agency in charge of regulating space debris. Kuiper will have to comply with all NASA rules and regulations regarding space debris.

The Project Kuiper will not have its own launch services, so it will have to establish strong alliances with external companies to provide these services. Currently, Amazon has already established alliances with United Launch Alliance (ULA), which has been contracted to perform the first launches. However, Project Kuiper plans to use several other private space launch providers in the future, including Jeff Bezos' space company: Blue Origin.

5.2.4 Cost structure

The Project Kuiper cost structure comprises the costs associated with the key resources available to the organization and the costs associated with performing the key activities. The main costs related to the Project Kuiper will be:

- Research and development.
- Human resources.
- Launch services.
- Equipment and infrastructure.
- Ground stations.
- Logistics.
- Marketing and branding.
- Patents.

5.3 Business Model CANVAS of the Project Kuiper

Finally, once the nine building blocks have been developed, they can be joined into a graphical CANVAS using the template that has been shown in the image 4.1. The figure 5.1 shows the Business Model CANVAS of the Project Kuiper developed for this project.

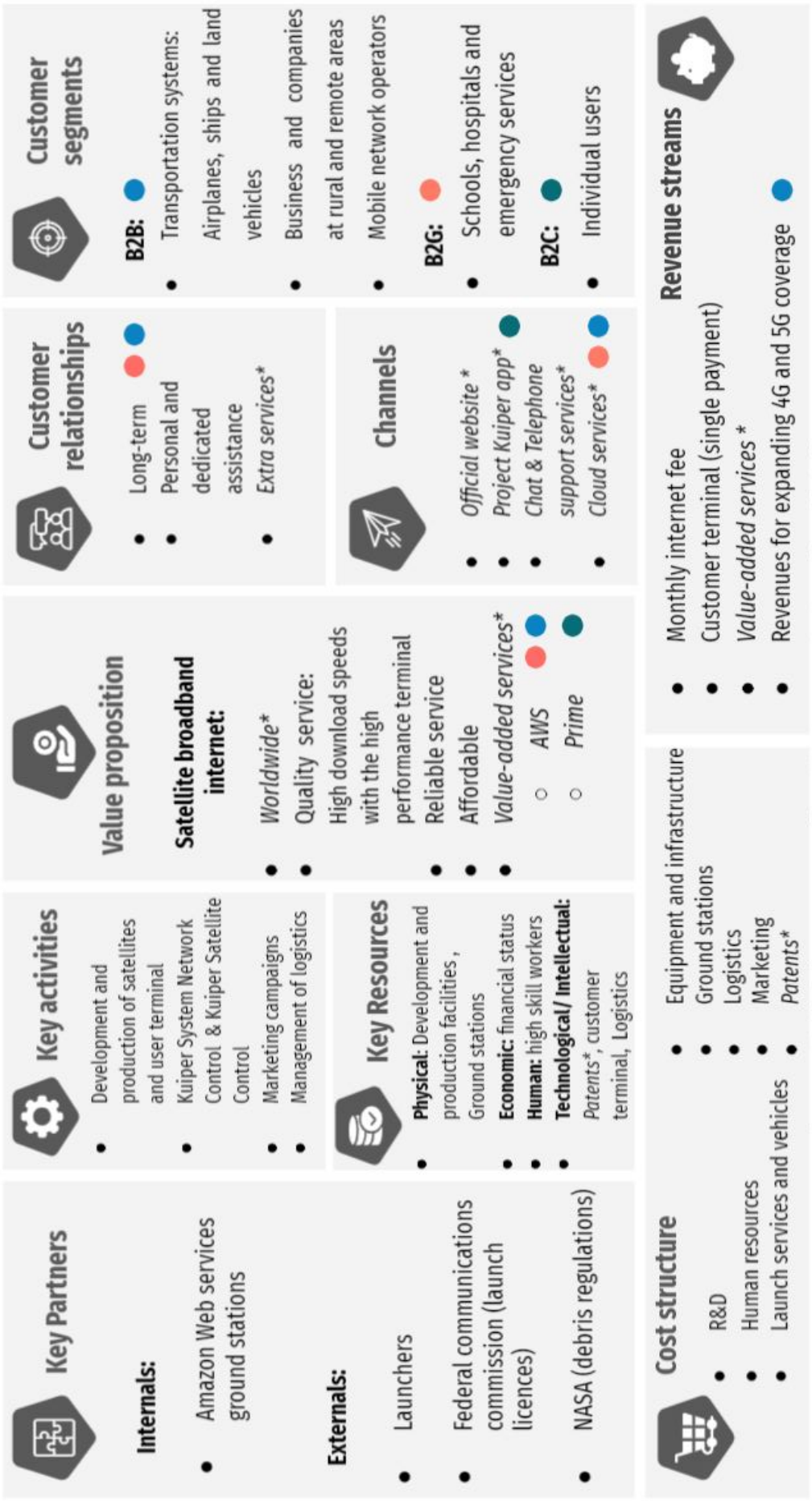

Figure 5.1: Project Kuiper business model CANVAS

Chapter 6

SWOT analysis

Once the internal structure of Project Kuiper has been analyzed, its business model has been developed, its external environment has been reviewed and the main competitors have been analyzed, the SWOT analysis can be developed. It is important to perform this analysis as it focuses on identifying external and internal factors that may impact the company's future performance.

SWOT is an acronym which stands for Strengths, Weaknesses, Opportunities and Threats. The strengths and weaknesses of a company are related to the analysis of its internal structure, while the opportunities and threats are related to its external analysis. Both positive and negative factors, from internal and external origins, are examined with the intention of analyzing how they can affect the company's success.

The main function of this analysis is to study the overall strategic position of a company or project and its environment. Moreover, It can also help companies to anticipate or predict changing trends that benefit the decision-making process. With its development can be identified the strategies that will create a company-specific business model that will best align the resources and capabilities of an organization with the requirements of the environment in which the company operates [48].

This analysis will provide details of Kuiper's main strengths and weaknesses, as well as of the opportunities and threats that will have an external origin but will undoubtedly affect the project. The SWOT matrix developed for Project Kuiper is shown in the figure 6.1.

Figure 6.1: Risk matrix

Strengths

- S_1: The company behind the development of the Project Kuiper is Amazon which is a technology giant with an incredible financial capacity and which has one of the best logistics services (if not the best) in the world.
- S_2: Project Kuiper will have the following strengths that will be an advantage over its direct competitors: a very powerful ground segment with AWS ground stations, it is expected that the services will be cheaper than those of its direct competitors, very good download speeds thanks to the designed customer terminal and in addition, it is expected that Project Kuiper will offer high quality additional services.

Weakness

- W_1: The constellation according to the current planning will not be completely global since for now the plans only include providing service to the area between latitudes 55ºN to 55ºS which is the area where the 95% of the world's population lives.
- W_2: Project Kuiper does not have its own launching systems. Therefore, will have to rely on the services of external companies to perform these tasks.

Opportunities

- O_1: Opportunity of global demand for broadband internet to grow even more than expected in the forecasts.
- O_2: Opportunity for AWS to grow further in popularity and demand and become an inherent part of the business ecosystem
- O_3: Opportunity to count with Blue Origin as a key partnership if it manages to develop its hevy-lift rocket in time and thus become a key player in the constellation's launch plans.

Threats

- T_1: Risk that direct competitors may steal intellectual property and technological breakthroughs.
- T_2: Risk of Project Kuiper becoming commercially available to individual customers too late, when Starlink has already established itself as the undisputed industry leader.
- T_3: Risk that a crisis of any kind could emerge that would slow down Amazon's financial and resource investment in Project Kuiper.

Chapter 7

Risk analysis

In this chapter the risk analysis of Project Kuiper will be developed. It's important to carry out this analysis to try to detect the main risks and opportunities that the project may encounter and to try to design the response to these events.

The risks and opportunities that will be studied in this section will be obtained from the SWOT analysis presented in the previous chapter (chapter 6), and from the study carried out in the Business Model CANVAS (chapter 5). The threats (risks) and opportunities extracted from the SWOT have been labeled as "T" and "O" respectively. On the other hand, the risks and opportunities extracted from the CANVAS will be labeled as "R" and "O" respectively.

The main opportunities and risks that have been extracted from the preparation of the CANVAS after gathering all the information in the case study are the following:

Opportunities

- O'_1: Opportunity to offer substantially lower prices than those of direct competitors.
- O'_2: Opportunity to become a key player in the IoT revolution of the coming years.

Risks

- R_1: Risk of collision of a Kuiper satellite with other satellites or with space debris.
- R_2: Risk of a Kuiper satellite not entering on the desired orbit.
- R_3: Risk of an explosion of a Kuiper satellite.
- R_4: Risk of delay in constellation launch plans by relying on external companies to perform these services.
- R_5: Risk of the service becoming overcrowded due to user overload.

In order to evaluate all risks and opportunities, each one of them will have associated numerical values to express its probability of occurring and to express the impact it would have on the project.

Probabilities are divided into five groups: very low (0-20%), low (21-40%), medium (41-60%), high (61-80%) and very high (81-100%). The impacts are also divided into five groups from 1, very little impact on the project, to 5, very important impact on the project. Three different types of impact have been considered depending on which part of the project will affect or benefit the different risks and opportunities: impact on quality (I_q), impact on schedule (I_s) and impact on costs (I_c). The total impact (I_T) will be obtained with the following expression in which the costs impact is given a little more importance, since Kuiper Systems is a business and its main objective is to make money, but without ignoring the impact on the schedule and on the quality of the service:

$$I_T = 0.3 \cdot I_q + 0.3 \cdot I_s + 0.4 \cdot I_c$$

It is important to note that the results of the total impact value will be rounded up.

Once the risks and opportunities are classified they can be represented using the risk matrix showed in the figure 7.1.

After associating numerical values of probabilities and impacts to the different risks and opportunities, preliminary actions will be proposed to try to mitigate or exploit them. The main possible responses to each risk and opportunity are the following:

- Avoidance: Different measures will be taken to avoid the risk as much as possible.
- Mitigation: If the risk is impossible to avoid, try to reduce either the probability or the impact, or if it's possible both, by applying active measures and actions.
- Transfer: Transfer ownership of the risk to another part or area of the company, or seek external help for managing the risk.
- Enhance: To carry out actions to maximize and try to exploit the opportunities that may arise.
- Acceptance: If none of the actions is feasible, accept the risk or the opportunity and take the necessary measures if it occurs.

Probability	Threats					Opportunities				
(81-100) % Very high	Low	Med	High	Ext	Ext	Ext	Ext	High	Med	Low
(61-80) % High	Low	Low	Med	High	Ext	Ext	High	Med	Low	Low
(41-60) % Medium	Low	Low	Med	High	High	High	High	Med	Low	Low
(21-40) % Low	Low	Low	Low	Med	High	High	Med	Low	Low	Low
(0-20) % Very Low	Low	Low	Low	Med	High	High	Med	Low	Low	Low
	1	2	3	4	5	5	4	3	2	1

Figure 7.1: Risk matrix

The table 7.1 shows the results of the risk analysis. The table includes the tags of the different risks and opportunities considered, as well as their probability of occurrence, the numerical values of the different impacts and proposed response.

Table 7.1: Risks assessment

ID	Probability	$\mathbf{I_q}$	$\mathbf{I_s}$	$\mathbf{I_c}$	$\mathbf{I_T}$**(rounded)**	Result	Response
T_1	Low	1	2	5	3	Low risk	Mitigate
T_2	Medium	1	4	4	3	Medium risk	Mitigate
T_3	Very low	1	5	1	2	Low risk	Acceptance
O_1	Medium	1	1	5	3	Medium risk	Enhance
O_2	High	4	2	5	4	High opportunity	Enhance
O_3	Low	4	3	5	4	Medium opportunity	Acceptance
R_1	Very Low	5	4	5	5	High risk	Avoidance
R_2	Low	2	1	4	3	Low risk	Mitigate
R_3	Very Low	3	5	5	4	Medium risk	Avoidance
R_4	Low	2	5	4	3	Low risk	Acceptance
R_5	Low	4	1	3	3	Low risk	Mitigate
O_1'	High	2	1	5	3	Medium opportunity	Enhance
O_2'	High	3	2	5	3	Medium opportunity	Enhance

The risk matrix showing the positions of each risk and each opportunity according the the results obtained is presented below in the figure 7.3

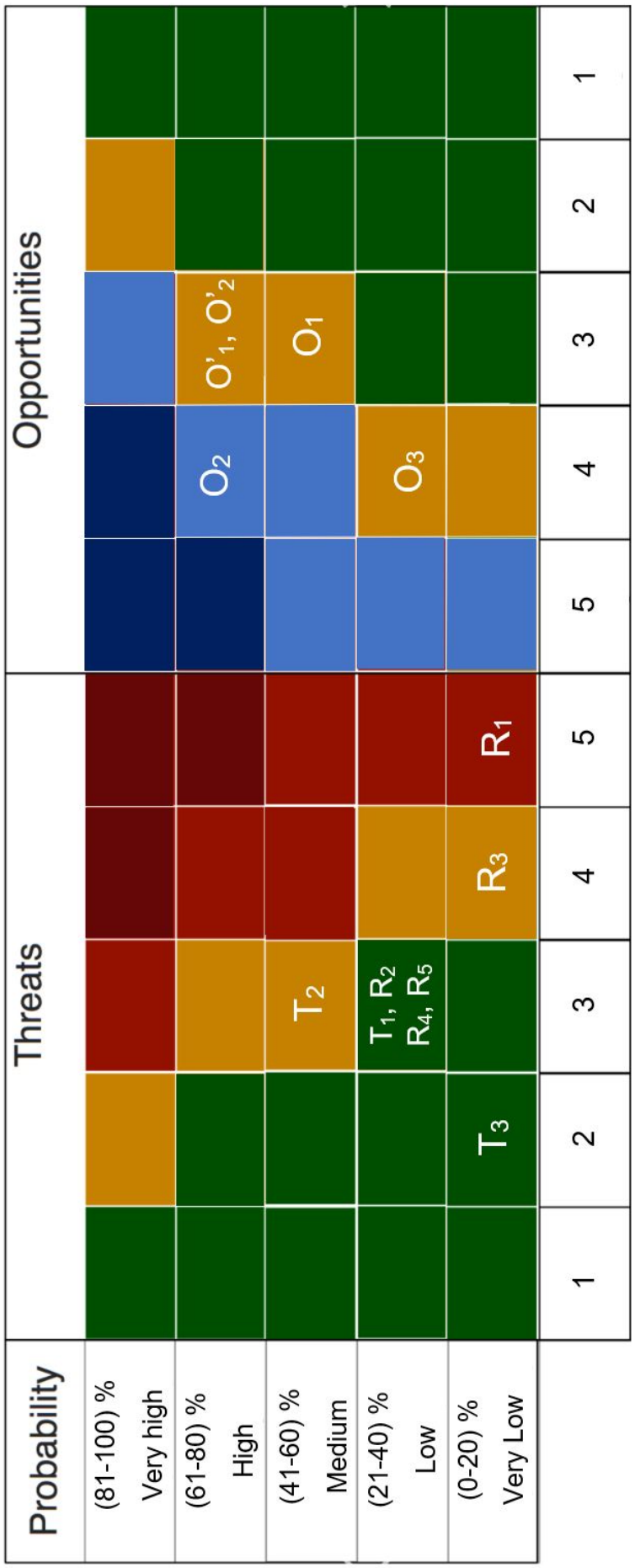

Figure 7.2: Risk matrix before response actions

The contingency actions proposed for each risk and the proposed management of the different opportunities are the following:

- T_1: Patent the new technologies developed to prevent their theft and establish strict security controls and protocols.
- T_2: Kuiper may seek to position itself as a leader in satellite broadband Internet service for businesses and governments, as there is less competition in this area (the Lightspeed constellation is not expected to be as powerful as the Kuiper project).
- O_1: Kuiper can encourage the growth of the demand for global broadband internet through large and powerful marketing campaigns which will also help the company to gain relevance in front of its direct competitors.
- O_2: Amazon should invest in AWS as it is already a fundamental part of the company and is the segment that has the greatest potential in the future. In addition, campaigns should be carried out to promote the platform throughout the business world as the best cloud platform.
- R_1: Kuiper satellites must be equipped with automatic on-board collision avoidance systems similar to those used by starlink satellites. In addition, exhaustive care must be taken from the ground to try to monitor all threats and to always try to guarantee the separation between satellites and between objects and satellites. In addition, satellites should be reinforced in their most sensitive areas to avoid major damage if very small pieces of space debris, the most common, impact with them.
- R_2: Reinforce the protocols for placing satellites in orbit to reduce their probability. In case of orbit entry failure, ensure that they cannot explode and guarantee a correct and natural de-orbiting.
- R_3: Use non-explosive, non-pressurized propellant storage. Protect the tank from space debris impacts. Take care in the design of the satellites to ensure that there are no design flaws that could create accidental events leading to an explosion.
- R_5: Increase the number of satellites in the future to avoid over saturation of the systems due to the large number of users connected simultaneously.
- O_1': Amazon has an extensive logistics system that sets it apart from its competitors. It could further lower the prices of its services by shipping its customer terminal without applying extra shipping costs.
- O_2': Amazon will need to establish strong relationships with mobile network operators and promote itself as the best option to try to expand 4G and 5G coverage areas. In the future, satellites will be able to integrate with networks to manage the connectivity of all IoT devices in remote and rural areas.

Once the risk contingency or opportunity management measures have been proposed, a re-analysis can be made and the revised score for each item can be obtained. The following table shows the revised total score for each risk and opportunity. It is important to note that these scores and the proposed actions are hypothetical and only a first estimation.

Table 7.2: Reassessment of risks and opportunities

ID	Probability	I_q	I_s	I_c	I_T(rounded)	Result
T_1	Very Low	1	2	2	2	Low risk
T_2	Medium	1	2	3	2	Low risk
T_3	Very low	1	5	1	2	Low risk
O_1	High	1	1	5	3	Medium risk
O_2	Very high	4	2	5	4	Extreme opportunity
O_3	Low	4	3	5	4	Medium opportunity
R_1	Very Low	3	4	5	4	Medium risk
R_2	Low	2	2	3	2	Low risk
R_3	Very Low	3	5	5	4	Medium risk
R_4	Very Low	2	5	4	3	Low risk
R_5	Low	1	2	3	2	Low risk
O'_1	Very High	2	1	5	3	High opportunity
O'_2	Very High	3	2	5	3	High opportunity

Once the reassessment has been made and taking into account its results, the risk matrix can be redrawn, since the positions of the risks and opportunities have changed. As can be seen in the figure 7.3, the risks have been moved to greener areas, reducing either their probability or their impact. It is important to comment the case of risks R_1 and R_3, since the probabilities of their occurrence were already very low at the beginning. The proposed measures would further lower their probability. The change in the probability does not result in a change of final position in the matrix since the probability blocks are very wide and do not allow appreciating sensible differences in this probability.

As for the opportunities, their positions have also changed, increasing the probability or increasing the positive impact that they would have if they occurred during the project.

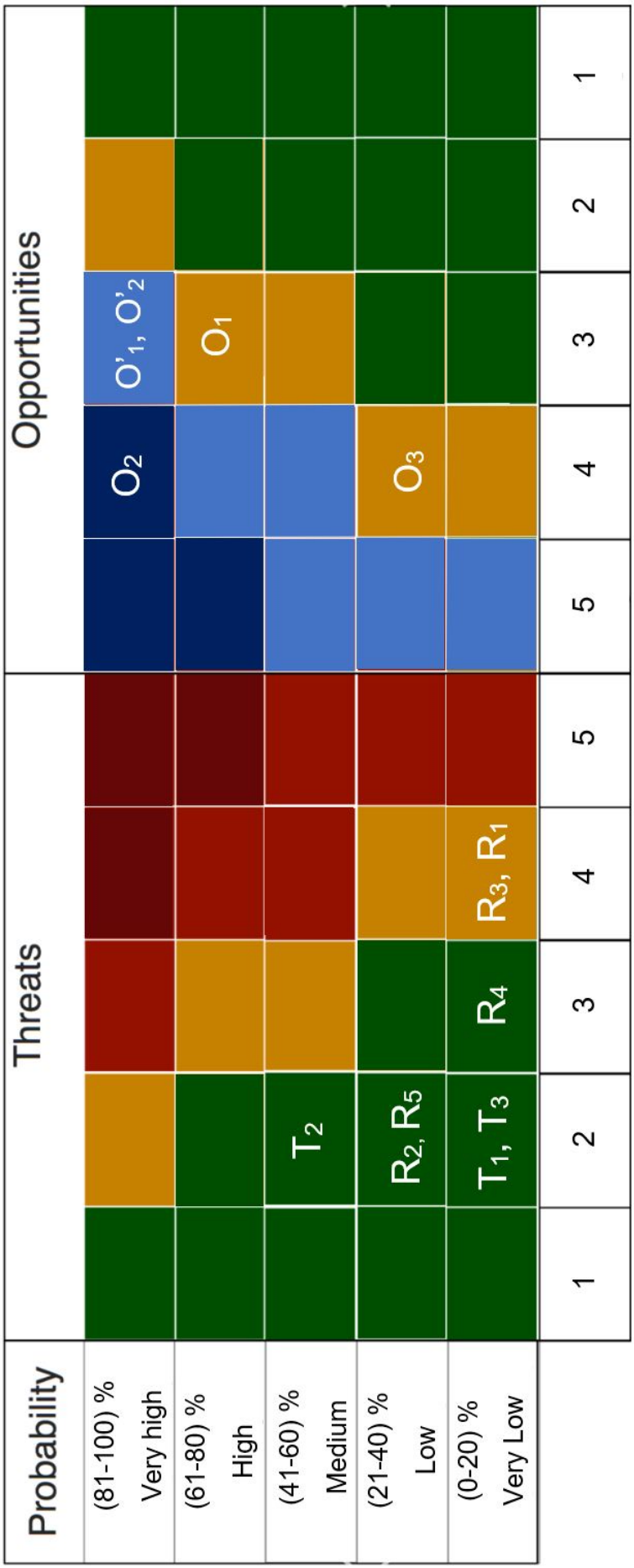

Figure 7.3: Risk matrix after response actions

Chapter 8

Environmental impact study

This chapter will first detail the negative environmental impacts that are expected to result from the development of the Project Kuiper, as well as from the other new LEO satellite constellations. In addition, the impact that the project may have on society, on the development of the economy and on scientific research will also be studied taking as a frame of reference the United Nations (UN) Sustainable Development Goals, which are part of the UN Agenda 2030 and describe the actions to be taken to promote the development of humanity while protecting the planet.

Carrying out this study is fundamental and extremely important since the Project Kuiper is a project of global dimensions that can have a significant impact on the environment but can also bring about changes to advance towards sustainable global development in other fields.

8.1 Negative Impacts of Project Kuiper on the environment

This section will analyze the main negative impacts that Project Kuiper, in particular, and all the LEO satellite constellations, in general, will have on the environment.

The new satellite constellations are expected to have a negative impact on the environment in three main aspects: pollution of the night sky, massifying the Earth's orbits and generating space debris and, finally, polluting the planet with the harmful gases emitted by the rocket engines during liftoff.

8.1.1 Pollution of the night sky

Artificial satellites and space debris orbiting the Earth, especially those in LEO, increase the brightness of the night sky. This light pollution could interfere with astronomers' capability to make observations of outer space.

The recent launches of Starlink satellites, with its spectacular glowing appearance after the launch, and the increasing publicity of other companies' plans to deploy large constellations of thousands of satellites in low orbits such as Amazon with its Project Kuiper, have caused alarm in the astronomical community.

The International Astronomical Union (IAU) is seriously concerned about this. This institution takes the principle of a dark, radio-transparent sky not only as essential for advancing on the understanding of the universe, but also as a resource that must be protected for the citizens of Earth. Currently, astronomers are conducting experiments trying to simulate the constellations of satellites to see what real effects they will have. However, it will take time to understand the real effect that the thousands of additional new satellites will have on astronomy at optical and radio wavelengths and alternatives will have to be found so that space observation will continue to be possible because the risk of repeating the mistakes of colonization on a cosmic scale is already real [49].

Figure 8.1: 300 short 13-second exposures taken within 70 minutes from Waldenburg, Germany, that shows the traces created by satellites reflecting sunlight below the horizon. Source: [49]

Regarding Project Kuiper, Amazon has assured that the team of scientists and engineers developing the project will work to keep space a safe and sustainable environment for all [29]. This can be achieved by darkening its satellites so that they reflect as little light as possible and thus have less impact on astronomical observatories. SpaceX is already starting to take measures to try to reduce these impacts and has made its satellites invisible to the naked eye one week after launch [50]. Considering that the Project Kuiper satellites will be in higher altitude orbits than Starlink and taking into account Amazon's involvement with the environment, it can be expected that its satellites will also comply, at least, with the same measure.

8.1.2 Risks of satellite overcrowding in terrestrial orbits

Currently, there are more than 30000 recognized objects orbiting the Earth, of which only about 3000 are active satellites. In essence, the other objects are space debris that has been generated over the last several years. Their number has been increasing for decades in all the different orbits. The 8.2 graph shows this evolution in LEO.

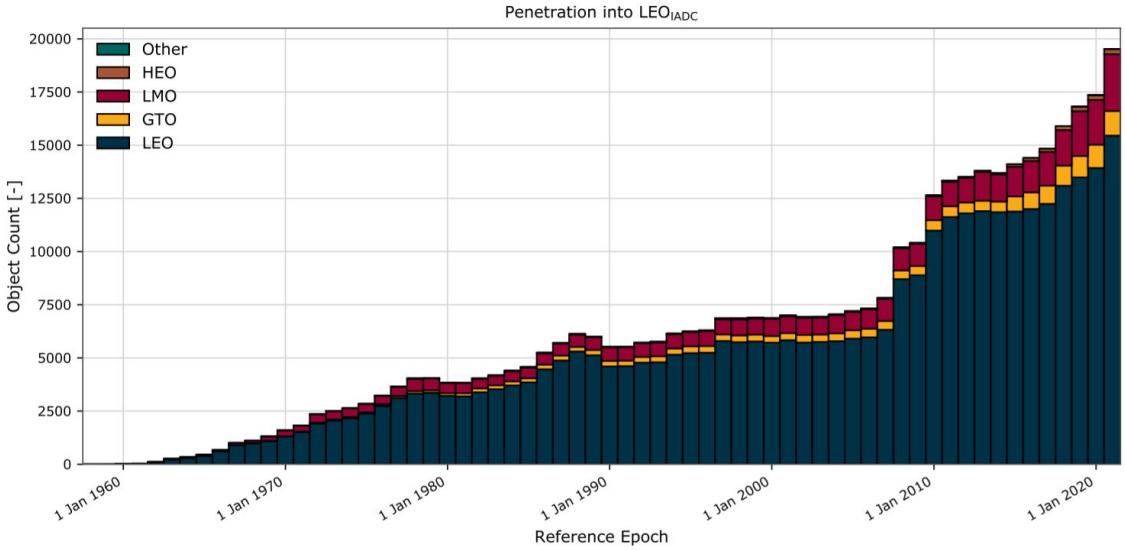

Figure 8.2: Evolution of absolute number of objects in LEO. Source: [51]

The new constellations to be placed in LEO have the risk of massifying this type of orbits and can provoke a devastating phenomenon. The risk is that they may become targets for space debris and other inoperative satellites orbiting the Earth at high speeds.

It is true that satellites carry automatic collision detectors and that space objects are accurately tracked, but the possibility of collision, while extremely low, does exist, as demonstrated in the February 2009 incident of the collision of a Kosmos military satellite and an Iridium telecommunications satellite [52]. These impacts in turn generate more space debris, as debris begets debris, which in turn became potential projectiles for other satellites. This could lead to a collisional cascade that would destroy all the objects in orbit and make it impossible to deploy new satellites as they would be automatically destroyed by the enormous amount of space debris. This scenario is the consequence of the Kessler syndrome [53]. Donald J. Kessler is an American astrophysicist who predicted the space debris problem and stated that in the early 1990s the impacts would begin to occur. Today, they are a daily occurrence. Since the last two decades there have been about 11 unintentional collisions per year [51] and ESA has found that the probability of collision with one of these objects has doubled since the early 2000s, from a probability of 0,15% per year to 0,3% in the 2020 [54].

These scenarios described above are entirely feasible scenarios in the not too distant future and severe measures will have to be taken by companies and governments to prevent these situations from occurring.

8.1.3 Rocket pollution

The global space industry is making great strides and space is becoming more accessible. The current trend is to launch more and more rockets. In fact, twice as many rockets are being launched in this decade as in the last. [55]. Despite the global pandemic, the 114 launch attempts in 2020 tied 2018 as the years with the highest numbers of orbital launches worldwide since 1990, when multibillion-dollar Cold War-era military budgets helped boost on-orbit missions [56].

The huge new constellations of LEO satellites will further increase the demand of launches in the coming years as they will consist of thousands of satellites that will need to be first deployed and then replaced as their useful life comes to an end. In addition, there are other activities such as space tourism, global surveillance, Internet of Things tracking and other emerging technologies that are also expected to grow in the coming years and will undoubtedly contribute to further increase the demand for launches.

As the number of launches increases, so do the total emissions of harmful gases from rocket engines. Rocket engines emit harmful gases and particles that undoubtedly affect the climate and the ozone layer and contribute to the greenhouse effect. Different rocket engines emit different types of emissions. However, the main emissions broadly speaking are: CO_2, water vapor, carbon soot, carbon monoxide, NOx, chlorine, alumina and sulfuric compounds [57]. Because some of the particles emitted by the rocket engines are small, they can reside for near 4 years in the stratosphere, where they accumulate, and can contribute to have an important impact on climate and on the ozone layer.

Figure 8.3: Launch of an Atlas V. Source: [30]

Until recently, these effects were not considered relevant as the total contribution of the space industry was considered to be very small and industries such as aviation, for example, were considered to have a much more significant impact. This assumption was valid but in today's world of increasingly frequent launches this issue should not be overlooked.

8.2 Contribution of the Project Kuiper on the Sustainable Development Goals

The 2030 Agenda for Sustainable Development was conceived in 2015 and adopted by all member states of the United Nations. It offers a plan to seek peace and prosperity everywhere on the planet. At its core there are the 17 Sustainable Development Goals (SDGs), which constitute an urgent call for action by all countries to move towards human development in all its facets, while being sustainable and not harming the planet [58].

Figure 8.4: Sustainable Development Goals. Source: [58]

The 17 different goals have been analyzed to determine those on which Project Kuiper will have the greatest positive impact. These have been: the SDG 4, the SDG 8, the SDG 9 and the SDG 10.

SDG 4: Quality education

This sustainable development goal is defined as: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [58].

Kuiper's satellite internet services will help the proliferation of quality education in all parts of the world. Schools located in rural or remote regions that currently do not have quality internet services could benefit from Kuiper's new services which will provide them with the same quality resources that exist in urban areas.

In addition, with these new Internet services everywhere, it is possible to move towards a less face-to-face model of education. The Covid-19 pandemic has demonstrated that many activities that were previously mandatory physical presence, such as teaching classes,

can be performed in a less face-to-face manner as long as efficient and reliable internet connections are available.

Communities living in isolated regions of less developed countries where children have to travel long distances to access education services could benefit greatly from Kuiper's services as quality education services could be available in all corners of the world with minimal installation.

Figure 8.5: SDG 4: Quality education. Source: [58]

SDG 8: Decent work and economic growth

This sustainable development goal is defined as: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" [58].

Project Kuiper is a large project that will create hundreds of new direct and indirect jobs. In fact, as described in previous sections, more than 500 people are currently working on the development of the project. In addition, new jobs will be created to perform the control tasks in the several AWS ground stations that will be created all over the world. It is also worth mentioning the jobs that will be created to send the customer terminals to customers all over the planet.

On the other hand, Project Kuiper could contribute to the economic development of different regions of the world. The Internet is changing the way people interact and socialize, but it is also profoundly changing the way people work. For this reason, some rural and remote areas of developed countries or large parts of less developed countries, which have less quality internet connections, are at risk of falling further behind in economic development compared to richer areas. Project Kuiper would provide these much needed broadband internet services for businesses so that they will be able to locate in these regions and in turn will be able to create new jobs.

One aspect that is relevant is that the Project Kuiper will offer its services in these rural and isolated sites without the need to deploy large terrestrial infrastructures such as the whole set of antennas and cabling that terrestrial connections require, thus contributing to keep these sites "clean".

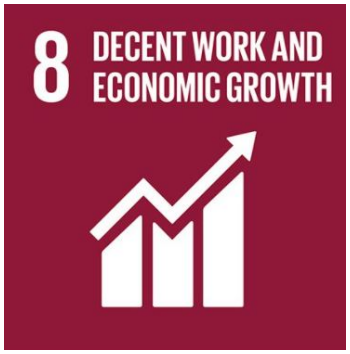

Figure 8.6: SDG 8: Decent work and economic growth. Source: [58]

SDG 9: Industry innovation and infrastructure

This sustainable development goal is defined as: "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" [58].

Project Kuiper is a project of incredible technological innovation which will undoubtedly have a positive direct impact on the population. The technologies implemented in the new internet constellations in LEO are cutting edge technologies in the telecommunications sector. In addition, the fierce competition that has already been generated between the different companies to see who can position itself as the leader in the sector and take full advantage of the huge potential market will generate more technological advances.

In addition, new ground stations will have to be created from AWS to serve all Project Kuiper services. However, Amazon wants to make these stations available to more users, thus lowering the barriers to access to space and bringing the opportunity for companies with limited resources to deploy their satellites and manage them from Amazon-owned ground stations.

Figure 8.7: SDG 9: Industry innovation and infrastructure. Source: [58]

SDG 10: Reduced Inequalities

This sustainable development goal is defined as: "Reduce inequality within and among countries" [58].

The impact of Kuiper Systems on this sustainable development objective is intrinsic to the project objective itself: Amazon wants to offer quality internet services to all the places that currently do not have them, thus resolving a clear and evident inequality that exists.

These inequalities are evident between developed and developing countries. It is estimated that only 35% of the population in developing countries has access to the Internet compared to the 80% in advanced economies [59]. In developed countries, although at first glance it is more difficult to see, the problem exists in the same way. Rural areas in many occidental countries have been neglected by administrations while all the technological development in the field of telecommunications has only been implemented in urban areas. In Spain, for example, about a quarter of the population cannot enjoy high-speed Internet services as high-speed broadband coverage, 5G or fiber optics are still scarce [60].

Project Kuiper could undoubtedly help to reverse these complicated situations of inequality between regions and help everyone to have access to quality internet as it is the defining technology of the information age that has come to change the dynamics and procedures of societies from top to bottom.

Figure 8.8: SDG 10: Reduced Inequalities. Source: [58]

Chapter 9

Conclusions

The aim of this work has been to study the main characteristics of the Project Kuiper, study its new business model and develop its Business Model CANVAS.

To achieve this, first of all, a study of the current situation of both the satellite telecommunications sector and satellite Internet constellations has been carried out. In this way, the main competitors of Project Kuiper have been detected and briefly studied. A PESTEL analysis has also been carried out to know the external situation that will surround and affect the Project Kuiper. Once these studies have been completed, a detailed study of the characteristics of the constellation has been done. With all this, it has been possible to design the Business Model CANVAS. In addition, a SWOT analysis of the project and an analysis of the risks it may entail have also been completed. Finally, a study of the impact on the environment that a project of the characteristics of Project Kuiper can cause has been performed.

With the development of this study, the main objectives of Project Kuiper have been detailed. This new constellation will have a direct impact on satisfying the global needs of citizens, businesses and governments for quality internet. Project Kuiper will offer high-speed broadband Internet services throughout the region of the Earth where the 95% of the population lives along with exceptionally low latency, a very important feature in multiple applications such as financial management. This is truly innovative and revolutionary. Just 25 years ago, Internet connectivity was rudimentary and completely non-existent in many rural and isolated locations. In a few years, thanks to this project, high-speed Internet will reach every corner of the planet, profoundly transforming the way people communicate, access to healthcare, education and entertainment.

In addition, the business opportunities open to Amazon with its new project are huge. The broadband satellite internet sector has already incredibly opportunities, but Project Kuiper also intends to establish relationships with mobile network companies to expand 4G and 5G coverage areas and thus become a key player in the new IoT revolution. However, competition is tough and fierce as we are undoubtedly facing the new space race of the 21st century. For Amazon, SpaceX, Oneweb, Telesat and other companies, are opening up

new business opportunities that are literally out of this world.

As has been recalled throughout this study, the Project Kuiper is a project that is still in the development phase. With the development of new end-of-study projects in the future, an even more reliable CANVAS could be developed, as it is expected that more valuable information will be made public in the coming months.

Finally, I would like to make a brief reflection from a more personal point of view about the sensations and thoughts that have been arising throughout the development of the project. I started this study with the statement "If there is one trait that differentiates human beings from other species, it is that in addition to being able to observe reality and analyze it, we are also capable of imagining it" as part of this final reflection.

I truly believe that projects as ambitious as Project Kuiper are the key to human progress. These great disruptive ideas and the great scientific thoughts, which a priori may seem impossible to achieve but eventually become feasible, introduce paradigm shifts in society and make us move forward being able each time to find answers to several questions. In the last century many of the great technological advances came about thanks to the investment of large amounts of money in the military industry. In this century and in the centuries to come, we must be able as a species to continue to advance technologically without war being the driving force behind the scientific development and we will have also to ensure that all citizens of the world can benefit from these advances.

We are an ambitious species by nature, driven by the intrinsic desire to know everything and the desire to explore what we don not know. Space has always been seen as the last frontier, but with the new technical developments we are managing to break this ancestral limit. As the Russian physicist Konstantin Tsiolkovsky said, "The Earth is the cradle of humanity, but humanity cannot stay in the cradle forever" [61]. It is hoped that in the next decade we will be able to perform interplanetary travels visiting our neighboring planet Mars. Who knows if the destiny of mankind is not to die on Earth.

For the moment, be that as it may, we still do not have another alternative than our planet, so we have to preserve it and be able to reverse the damage we have already done in the last centuries. We have to do it not only for our own convenience, but also out of respect for all the other living beings that inhabit the planet Earth. This is why we are facing an exciting new era that will require unprecedented transformative development in order to move forward as we have always done, but now in a sustainable way that respects our planet. A prosperous future is possible if all communities move simultaneously, collaborating at a global level, from the local to the global scale, in search of new great projects and new options for the sustainable transformation of the society.

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