UNIVERSITAT POLITÈCNICA DE CATALUNYA
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Study of the benefits and applications of VLEO (Very Low Earth Orbit) for Communications and definition of space new business models: Starlink case

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Author:
Albert Garcia Bescós

Director /Co-director:
Daniel García-Almiñana / Sílvia Rodríguez-Donaire

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STUDY OF THE BENEFITS AND APPLICATIONS OF VLEO (VERY LOW EARTH ORBIT) FOR COMMUNICATIONS AND DEFINITION OF SPACE NEW BUSINESS MODELS - STARLINK CASE

BACHELOR'S DEGREE THESIS

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Albert Garcia Bescós

Director: Daniel Garcia-Almiñana

Co-Director: Sílvia Rodríguez-Donaire

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"The Very Low Earth Orbits don't have many applications. Nobody is going to invest in them in the future."

My physics high school professor in 2016

"Everyone working on Starlink has Starlink. They know when the system has trouble spots, and they are dedicated to fixing it. The network has to get better every day. We are still stumbling and tripping and finding out new things about this system. But I'm confident that the system will be extraordinary."

Gwynne Shotwell, Starlink COO, in May 2021

ABSTRACT

Over the last years, the New Space phenomenon has generated a true revolution in the space sector, which has grown exponentially. One of the most promising discoveries are the Very Low Earth Orbits (VLEO) applied to the telecommunications sector, reason why they are a very interesting line of study with forecasts to expand the space economy even further. In relation to the above, the European Union, through the DISCOVERER project, seeks to promote existing technologies in this type of trajectories, as well as new business models, in order to take advantage of its benefits and applications.

As part of the DISCOVERER project, this thesis aims to add value in the definition of new business models in the VLEO telecommunications sector. To achieve it, a market study of the satellite sector in general terms is presented, showing its exponential growth (especially focused on the VLEO satellites), and analyzing the only private company regularly operating at these low altitudes: Starlink. After studying its competitors, the internal structure of the company is evaluated in order to understand how it works, with the objective of applying the CANVAS business model to the Starlink case. The methodology implemented allows to understand how the company creates and distributes value using VLEO satellites in the telecommunications field (particularly, as an Internet provider), remarking the key success factors that could be applied in the future by companies considering to engage in similar activities. The model highlights, among others, the need for a large number of resources and partners, as well as the need to focus the value proposition on the service quality, the long customer relationships and the diversification of the customer segments. In addition, external factors in the Starlink activity are also analysed through a complete risk analysis, which identifies the most relevant risks and opportunities, as well as possible responses to them using both qualitative and quantitative methods. The study reflects the enormous importance of being proactive in the external factors management, in a sector where the elements that do not depend on the company can determine its success or failure. Finally, the environmental implications of Starlink are investigated using a qualitative method based in the United Nations (UN) sustainable development goals for the next years; a fact that, on the one hand, shows the need for a commitment to sustainability because that is essential for the planet conservation and, on the other hand, contributes to adding value to the organisation.

Keywords: Very Low Earth Orbits (VLEO), CANVAS, business models (BM), satellites, Internet, telecommunications, value, Starlink, DISCOVERER, New Space.

En aquests últims anys, el fenomen conegut com *New Space* ha generat una veritable revolució en el sector espacial, que ha crescut exponencialment. Un d'aquests descobriments més prometedors són les Òrbites Terrestres Molt Baixes (VLEO) aplicades al sector de les telecomunicacions, per la qual cosa són una línia d'estudi molt interessant amb previsions d'expandir encara més l'economia espacial. En relació amb l'anterior, la Unió Europea, a través del projecte DISCOVERER, busca impulsar les tecnologies existents en aquest tipus de trajectòries, així com nous models de negoci per aprofitar els seus beneficis i aplicacions.

Com a part del projecte DISCOVERER, aquesta tesi pretén aportar valor en la definició de nous models de negoci en el sector de les comunicacions VLEO. Per aconseguir-ho, es presenta un estudi de mercat de el sector dels satèl·lits en termes generals, mostrant el seu creixement exponencial (especialment centrant-se en els satèl·lits VLEO), i analitzant l'única empresa privada que opera regularment a aquestes baixes altituds: Starlink. Després d'estudiar als seus competidors, s'analitza l'estructura interna de l'empresa per entendre el seu funcionament i amb l'objectiu d'aplicar-hi la metodologia de model de negoci CANVAS. El mètode aplicat permet comprendre com l'empresa crea i distribueix valor utilitzant els satèl·lits VLEO en l'àmbit de les telecomunicacions (en particular, com a proveïdor d'Internet), destacant els factors clau d'èxit que podrien aplicar en el futur les empreses que pensin dedicar-se a activitats similars. El model destaca, entre altres coses, la necessitat de comptar amb un gran nombre de recursos i socis, així com la necessitat de centrar la proposta de valor en la qualitat del servei, les llargues relacions amb els clients i la diversificació dels segments de consumidors. A més, els factors externs de l'activitat de Starlink també s'analitzen a través d'un complet anàlisi de riscos, que identifica les debilitats i oportunitats més rellevants, així com les possibles respostes als mateixos utilitzant un mètode tant qualitatiu com quantitatiu. L'estudi reflecteix l'enorme importància de ser proactiu en la gestió dels factors externs, en un sector on els elements que no depenen de l'empresa poden determinar el seu èxit o fracàs. Finalment, s'estudien les implicacions mediambientals de Starlink a través d'un mètode qualitatiu basat en els objectius de desenvolupament sostenible de l'Organització de les Nacions Unides (ONU) pels pròxims anys; un fet que, per una banda, posa de manifest la necessitat d'apostar per la sostenibilitat, ja que és fonamental per a la conservació del planeta i, per l'altra banda, contribueix a aportar valor a l'organització.

Paraules clau: Very Low Earth Orbits (VLEO), CANVAS, business models (BM), satellites, Internet, telecommunications, value, Starlink, DISCOVERER, New Space.

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To all my family, for being my emotional support and for encouraging me to chase my dreams. Especially to my parents, Eduard and Angels, for educating me and transmitting such wonderful values that I wish to keep all my life, as well as to my brother Sergi, for being my life partner and showing me the positive side of everything.

To all my friends from Piera and hockey, and my American family too, who have always given me sincere smiles and have been one of the best motivations to finish, not only the thesis, but also the whole degree. Thank you for turning this ephemeral time into something close to eternal. I will only tell one thing: Al fallo!

To my university friends, for accompanying me on this trip and supporting each other; for converting a simple coffee or a dinner together into a huge injection of happiness. It has been hard, but in the end it seems that we have succeeded and, in addition to the degree, we are taking friendships for life. It's time to enjoy!

To all the anonymous people who have crossed in my life, even for a few seconds, and have allowed me to learn from them.

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1 Introduction

1.1 Aim of the project

The aim of this project is the study and simulation of the Starlink company business model in order to show the potential added value and benefits that Very Low Earth Orbits (VLEO) telecommunications technologies can generate, as well as to study the Starlink company with the aim of implementing a business model methodology on it.

1.2 Scope of the project

1.2.1 List of tasks and activities

The project contents shall include:

- Benefits and applications of VLEO telecom constellations.
- State of the art development: VLEO telecommunications market segment and Starlink competitors.
- Study of Starlink company: history, business statement, philosophy, work environment, financial status and partnerships.
- Analysis and simulation of Starlink business model with CANVAS methodology.
- Risks analysis of the external factors in the Starlink activity.
- Identification of the keys to success factors of VLEO telecom sector using the Starlink business model.
- Study of the environmental implications of this project.
- Project budget elaboration.

1.2.2 Out of the scope

The project contents shall not include:

- Detailed technical description of the ground stations, satellites launchers and orbital mechanics.
- Technical description and blueprints of the satellites subsystems used by Starlink and other VLEO companies.
- Study of the production system of Starlink (due to company confidentiality).

1.2.3 Deliverable documents

- Project charter: initial report where the project and objectives are defined.
- Final project report: document where all the relevant information about the study is included.
- Budget: economical summary of the project cost, taking into account the different tasks developed and the level of effort needed to carry them.
- Quality self-report: own assessment of some formal and content aspects of the thesis.

1.3 Requirements of the project

Considering the scope of the project, some common requirements can be extracted:

- This project is part of the UPC-DISCOVERER research group.
- Secondary research sources have to be used in order to elaborate the Starlink business model study.
- Companies analyzed must operate in the VLEO telecom sector.

- Companies analyzed must meet the USA and EU satellite and telecommunications regulation.
- The CANVAS business model methodology must be applied.
- This project must comply with the UPC normative for bachelor's degree final thesis.

2 Project background

This section provides a general overview of the two of the most important concepts of the thesis, the Very Low Earth Orbits and the business models methodologies, in order to establish a framework that will be used in the justification section to explain the need to develop this project. It's important to remark that the following paragraphs don't provide an exhaustive description about the VLEO history or market, since it shall be developed in the state of the art section.

2.1 Very Low Earth Orbits: definition and market overview

In the recent years, the space sector is growing up towards the private sector, giving way to multiple innovative business trends with multitude of applications and benefits. This reinvention and democratization in the use of space -the sector is no longer just for large governmental agencies-, caused by the large number of companies investing on it, is known as New Space [1].

Among the opportunities offered by NewSpace, the Very Low Earth Orbit (VLEO) satellites are one of the most attractive. They operate in a range from, approximately, 100 km altitude (where the Karman line is located, which is used to indicate the beginning of space) to 450 km [2], with a maximum value of 550 km for the apogees [3]. Nowadays, the satellites operating at these altitudes are increasing due to the benefits that the VLEO trajectories provide: lower cost of putting the satellites into orbit, less mission risks, lower cost of replacement (which allows to adapt quickly to the market changes and trends), lower radiation and latency times for communications and, of course, orbital debris avoidance [2]. The main applications of these orbits are, basically, two: the Earth Observation (EO) [3], which is the most popular and the reason why these trajectories started to become popular, and the telecommunications (telecom) [2], which is increasing in the recent years and attracting a lot of investors (SpaceX, with the Starlink project, is one of the clearest examples) [4].

The market of satellites orbiting in Very Low Earth altitudes is growing up exponentially, as it explains the following data, extracted from the Union of Concerned Scientists Excel database (UCS) [5]:

Table 1: Number of VLEO and total satellites in 2021 and 2015. Data source:[5]

2021			**2015**		
VLEO	Total	**% (VLEO/Total)**	VLEO	Total	**% (VLEO/total)**
944	3,372	**28**	77	1,056	**7,2**

Thus, nowadays, the number of them according to the Union of Concerned Scientists (UCS) database is 944 (data until January 2021, filtering satellites with an apogee below the 550 km -because there is no perigee data, and 550 km can be considered a good approximation for VLEO- and filtering by years, too), which represents about the 28 % of the 3,372 total registered satellites. The number is significantly higher than 6 years ago, when these type of orbits didn't represent more than 7 % of the total number.

Furthermore, there are high-tech companies investing in these trajectories: for example, Starlink, part of SpaceX, requested the Federation Communications Commission (FCC) in 2016 to change the altitude of the licenses obtained for 4,425 satellites from 1,100-1,300 km to 540-570 km [6]. In 2018, the same company obtained the FCC approval for 7,518 satellites operating between 335 and 346 km [7], which became the first big deal for Very Low Earth Orbits and which will represent a total constellation of 11,943 VLEO-LEO satellites.

Only one thing is more positive than the Very Low Earth Orbits present: their future. According to [4], in this decade the number of satellites operating at these altitudes will be around 15,000, which will represent an extraordinary increase of 1,500 %. In addition to this, further investment from high tech companies is expected: Starlink is thinking in a constellation of 30,000 VLEO satellites approximately [6], and other companies, such as Amazon (with its Porject Kuiper) or Boeing are investing and planning the development of LEO and VLEO constellations [4].

2.2 Business model methodologies: definitions

The term business model is relatively recent. In fact, although it had already been used indirectly in the past, it was not born until the 1990s [8], and it was not until 1997 when the first journal with this term in its title appeared [9].

As a recent term, it has not a concrete definition. For Alexander Osterwalder, a reference in the field and the creator of the business model CANVAS -which will be explained in depth in the next sections-, it is:

> *"The rationale of how an organization creates, delivers and captures value"*
> Osterwalder and Pigneur, 2010 [10]

For other reference authors, the definitions of business model are quite similar to Osterwalder:

> *"Stories that explain how enterprises work"*
> Magreta, J., 2002 [11]

> *"A business model refers to the logic of the firm, the way it operates and how it creates value for its stakeholders"*
> Casadesús-Ricart, 2010 [12]

To sum up, the previous definitions can be summarized in these three key aspects -common to all BM- suggested by Otserwalder and Chesbrough [13]:

- The business models explain how the different components and/or functions deliver value to the customers.
- They describe how the different components and/or functions are interconnected within the organization.
- They specify how the organisation generates value using these interconnections.

As it can be seen in the previous paragraph, business models are essential for any organisation, as well as for those entrepreneurs thinking of starting a new business: for the existing companies, to improve and transform their institution, creating value and ensuring the activity in the medium and long term; for the new startups, to build a new company, which provides added value to the market and which can continue operating in the next years. Taking into account the above arguments, applying some of these methodologies to the Very Low Earth Orbits sector could be interesting, as the previous sections have shown that it is a relatively new sector, but with a high growth projection

and dominated by a few companies. In this way, the use of BM methodologies could allow existing companies to improve their value proposition and, at the same time, allow new companies to enter and develop their activity in the sector, creating new business models that provide new added value to the current market [10].

2.3 BM applied to VLEO: the DISCOVERER project

The study of the VLEO sector and the application of business models methodologies with the objective of defining space new business models is a relatively modern research line, which mainly starts with the DISCOVERER project, funding from European Union with approximately 5.7 millions of euros and focused on investigating in the VLEO technologies and their applications to Earth Observation, telecommunications and other applications [14].

More specifically, it's possible to find some projects related to the application of BM methodologies in this type of satellites developed inside the DISCOVERER by members and students of the Polytechnic University of Catalonia (UPC), one of the four European universities that are part of this project [15]. These thesis include roadmaps of the different VLEO technologies and business models methodologies applied to VLEO companies focused on Earth Observation, amongst others, but they have not studied in depth the VLEO telecommunications sector yet. In the following diagram it can be observed the number of bachelor's final thesis developed inside the DISCOVERER-UPC (according the data provided by the researchers), as well as other characteristics, such as if they include BM methodologies, which of them are developing the CANVAS method...

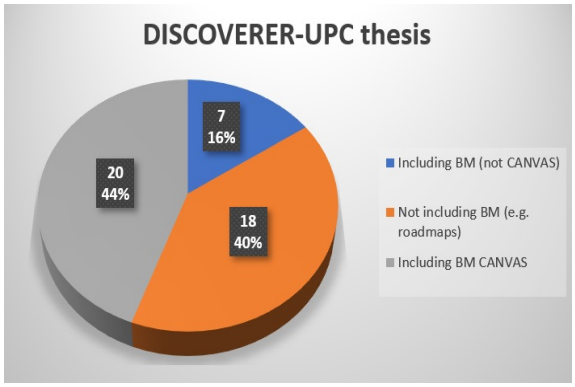

Figure 1: DISCOVERER-UPC thesis. Data source: DISCOVERER-UPC researchers

Therefore, there are 45 finished DISCOVERER-UPC thesis (and 7 in progress) according to the data provided by the project researchers. Almost the half of them (a 46 % in the diagram) develop the BM CANVAS, which represents an important background that must be taken into account in order to develop this report. The supervisors of this thesis (researchers of the DISCOVERER-UPC, too) have transferred the knowledge accumulated in these previous projects, with the aim of providing a starting point and a useful reference in order to develop this thesis.

3 Justification of the project

Based on the requirements of this project, as well as the information provided in the background section described above, some arguments can be provided to justify the need for its development.

Firstly, it is part of the DISCOVERER project, reason why it must necessarily focus on satellites operating at Very Low Earth Orbits, since the overall purpose of DISCOVERER is the study of this type of trajectories. Moreover, as this thesis is developed within the research group of the Polytechnic University of Catalonia (UPC), it has to focus on defining and investigating new business models for these VLEO orbits (either by elaborating roadmaps or implementing business model methodologies in existing or new VLEO companies), because it is the research line assigned to UPC within the DISCOVERER.

Furthermore, the report is also focused on the Very Low Earth Orbits altitudes sector due to the multitude of benefits provided by this type of trajectories (briefly described in the previous section), as well as their great potential and growth forecasts for the coming years (also illustrated in a general way in the background chapter).

Within the VLEO sector, the telecommunications applications will be studied for two main reasons: on the one hand, with the objective of opening up new lines of research inside the DISCOVERER-UPC project, since it has traditionally been oriented more towards Earth Observation; on the other hand, because communications applications for VLEO satellites are the future and they are emerging quickly (some high tech companies are investing and investigating in it). In addition to this, the diagram illustrates how this type of application is expected to represent the half of small constellations applications in less than three years:

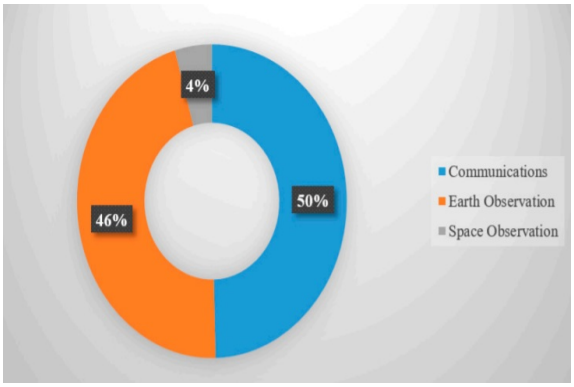

Figure 2: Estimation of the small constellations applications for 2024. Extracted from: [16]

The main focus of the work will be set around Starlink, because it is the company that has launched more Very Low Earth Orbit satellites so far. As seen in the previous paragraph, this company is, nowadays, the only operating in the VLEO altitudes, with licences for launching almost 12,000 satellites and thinking in a 42,000 satellites -approximately- constellation (data explained and referenced in the previous background chapter). The previsions of the company growth are positive too, because the broadband Internet service market will increase a lot in the next years, since there are still a lot of areas (54 % in 2017 according to OneWeb data [17]) with lack of Internet access.

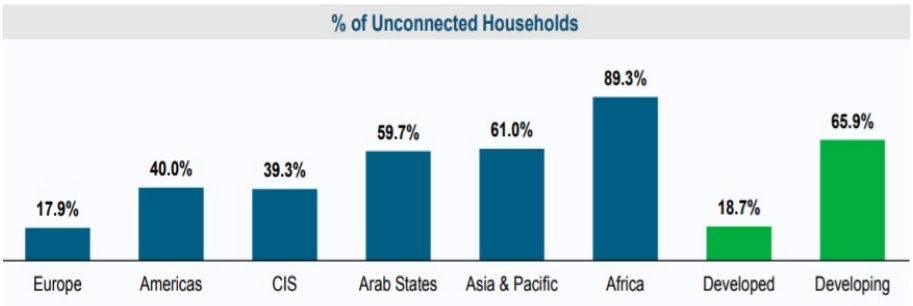

Figure 3: % of world zones without Internet in 2017. Extracted from: OneWeb [17]

Finally, a business model methodology will be applied to the Starlink company using its previously developed case study as a reference and trying to simulate its business structure and researching its key success factors, which can become a pioneering and very valuable references for other companies considering to enter in a market with spectacular potential and very positive growth projections.

The business model methodology selected is the CANVAS method, because it is one of the most complete, visual, efficient and popular BM methodology in the world. The book by Osterwalder and Pigneur published in 2010, in which the CANVAS model is explained and developed in depth, has become a reference in the field of business models, and it is essential in any existing or new created company, in order to redefine or create new value propositions, as well as to define the different elements of the value side, costs side and their interconnection between them. In fact, a detailed study of Osterwalder and Pigneur's book has been carried out in this project with the aim of successfully applying this methodology to the VLEO satellites telecom sector and, more specifically, to the particular case of the Starlink company.

4 State of the art

The project background has preliminary defined some general aspects of Very Low Earth Orbits and business models methodologies in order to provide a justification for this thesis development. In this section, some aspects (such as the VLEO technology or the current market) mentioned in the previous chapter shall be explained in more detail, with the aim of providing an appropriate framework that allow to develop the case study and apply the business model CANVAS to Starlink company.

4.1 The geostationary and non-geostationary satellites: history summary

To start with the state of the art, a historical framework is presented on the evolution of the different types of satellites throughout history, both qualitatively (important events, stages of change, most important applications...) and quantitatively (number of satellites over the different years).

4.1.1 From Sputnik I to Very Low Earth Orbits

The successful launch of the Sputnik-I satellite on October 4th, 1957 [18] by the Soviet Union was a historical milestone. Not only because it was the first object to orbit the Earth and it started an unprecedented rivalry in the space sector between the USA and the USSR; it also led to the birth of a business sector that is growing exponentially and constantly due to the numerous applications and benefits that it provides to society.

The application of satellites in the communications field begins at the end of 1958, when the USA Air Force launches the SCORE satellite [18] , but the first private design doesn't appears until July 1962, when NASA launches Telstar-I, a communications satellite developed by Bell Telephone Laboratories [18]. Despite it was a telecommunications satellite, the dimensions and the altitude (apogee at about 6,000 km) were still very different from the VLEO studied in this project.

In the 60's, the space race increases the satellites launching, reason why the United Nations elaborate the Outer Space Treaty (OST) in 1967 [19], which becomes the

international legal framework for space uses when USA and USSR accept it. In summary, this document forbids the appropriation of outer space resources and limits the private use of them.

The following two decades, the geostationary satellites for communications dominate the market, while the number of other satellites, non-geostationary and operating in a lower altitudes, are residual. But in the 90's the trend starts to change, and some companies, such as Globalstar or Iridium, start to invest in non-geostationary constellations [4] without good initial results because of the lack of potential costumers and the elevated operational costs.

Finally, in the 2,000's, the exponential rise of Internet and telecommunications increases the potential costumers. In addition to this, the small satellites operating in lower orbits than geostationary become more popular because of their lower cost. A lot of companies start investing in the sector of Medium Earth Orbits (MEO), Low Earth Orbits (LEO) and VLEO (in the next section, the operation altitudes and technological characteristics will be explained), initially mainly focused on Earth observation applications [4].

But in the 2010's decade the telecommunications applications grow significantly due to the emerging of new technologies (5G connection, Internet of Things), which causes that some of the most important high-tech companies of the world (e.g. Space X -Starlink foundation-, Amazon -Kuiper project- or Google -Loon project-) [4] start to invest in VLEO and LEO telecom sector. Moreover, the OST mentioned in the previous paragraph become outdated; the democratization of the space is accelerating and some countries, such as USA or Luxembourg, develop their own regulatory niches in order to guarantee the ownership of their space resources [19].

4.1.2 The different types of orbits evolution until nowadays

This history overview of the different satellite orbits, as well as the growth of each one over the years can be seen in the diagram.

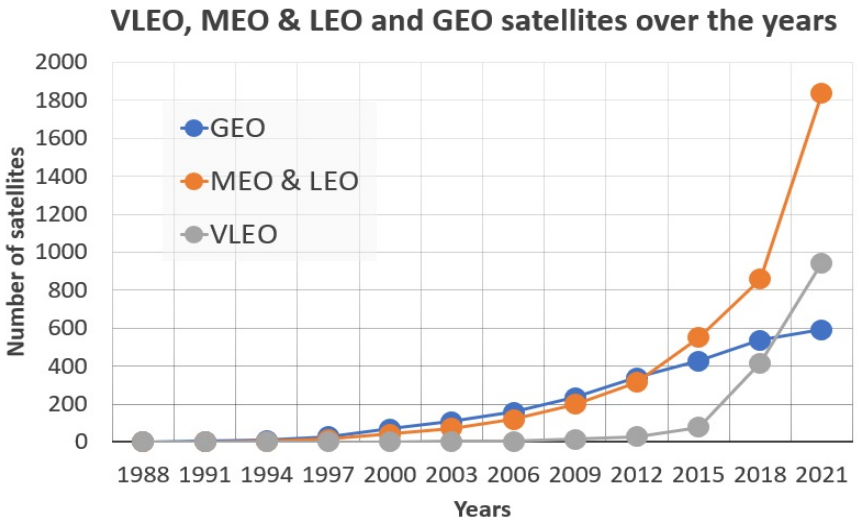

Figure 4: VLEO , MEO & LEO and GEO satellites growth over the years. Data source: [5]

The data has been extracted from the Union of concerned Scientists (UCS) database after an exhaustive search -in a similar way to Table [1], using multiple Excel filters, so the diagram is self-elaborated.

The chart sums up the history of the global satellites market explained in the beginning of the state of the art. While geostationary satellites show a linear growth over the years (which is slowing down a little in recent years due to their popularity decreasing in front off other types of trajectories), Medium and Low orbit satellites, as well as VLEOs, have experienced a clear exponential growth from the 2010s until today, as already mentioned the previous paragraphs of this section. This growth is caused by the benefits provided by this type of orbits (lower prices, less mission risks, more versatility...), together with the change in market trends which, as will be seen in the next sections, are focused on new applications, such as Earth Observation or satellite Internet with lower latency times, abandoning the old geostationary communications applications.

4.2 Technological requirements

Once the history of the different types of satellite trajectories has been introduced and their evolution and growth has been visually shown in order to illustrate the changes taking place in the market, it is important to briefly explain some technical data of these

orbits in order to clearly define them. Although the detailed description of the technology used by the different satellites is out of the scope of this thesis, as well as the structure of their subsystems or their orbital mechanics, it is important to explain some concepts without them the report would be difficult to understand.

4.2.1 Earth satellites: altitudes definitions

An orbit is a regular and repeating trajectory that one object in space takes around another one [20] caused by the action of gravity -or by the curvature of space-time, since both concepts are the same according to the Einstein's general relativity theory [21]-. An object located in an orbit is called a satellite, reason why if one object (natural, like the Moon, or human-made) is orbiting the Earth, it is called Earth satellite. There are thousands of satellites around our planet in this moment (3,372 registered in the UCS database [5]), classified according to the height of the orbit that they describe. In the following image are provided the different Earth orbits and their altitudes and periods, respectively. It's important to remark that it does not contain the VLEO altitudes, which were defined in the background (between 100 to 450 km):

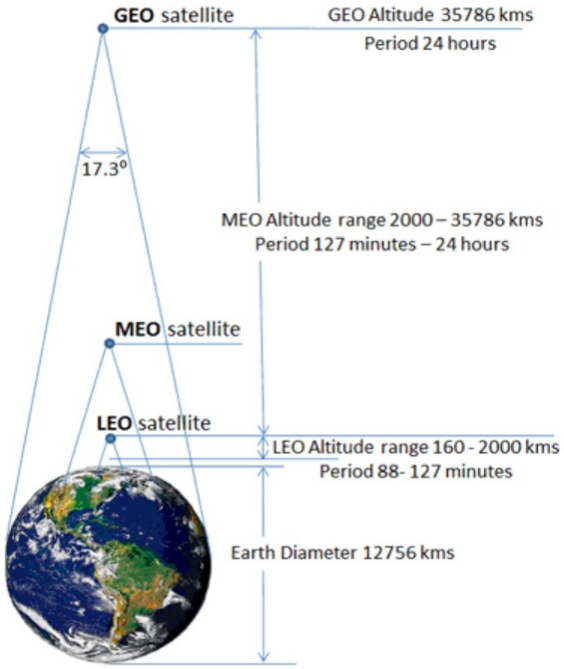

Figure 5: VLEO , MEO & LEO and GEO altitudes and periods. Extracted from: [22]

4.2.2 Summary of the orbits main characteristics

The most important technical characteristics of each type of orbit, as well as their most important benefits and disadvantages, are presented following a qualitative method.

Table 2: Orbits description: main characteristics.

Features	VLEO	LEO	MEO	GEO
Altitude [23]	100 to 450 km	450 to 2,000 km	2,000 to 35,586 km	35,596 km (+/- 200 km)
Period [23], [22]	88 to 127 min	88 to 127 min	127 to 1,346 min	1,346 min (24 h approx.)
Debris collision risk [23]	Very Low	Very High	High	Low
Solar wind effects[24]	Low	Low	High	Low
Atomic oxygen erosion[3]	Very high	Low	No risk	No risk
Latency time (Communications quality)[4]	Very low	Low	High	High
Launch cost [3], [4]	Very low	Low	High	Very high
Replacement cost [3]	Very low	Low	High	Very high

4.2.3 VLEO benefits and disadvantages

From the previous table, the benefits and disadvantages of the Very Low Earth Orbits shall be briefly presented, because it is the typology of orbits studied in this thesis, reason why it is essential to identify and remark them.

- The solar wind effects are low, which is positive for the satellite trajectory and expected lifetime. According to the reference used in the above table, the solar wind only has important effects at MEO altitudes.
- The low altitude of VLEO satellites allow them to present lower latency times than

other orbits (e.g. GEO), which become important for the satellite telecommunications market.

- The launch cost, and also the replacement of the satellite, is cheaper than with LEO, MEO or GEO, because the altitude is lower and the VLEO mass uses to be lower too. To sum up, the satellites can be launched and replaced relatively easily, reason why they are not as expensive as other type of satellites and the mission risk is much lower.

- Finally, they have a big disadvantage: the atomic oxygen erosion, which produces a short lifetime in the VLEO satellites. In addition to this, the drag resistance is also negative for the materials and it increases the oxygen effect. For this reason, one group of researchers of the DISCOVERER project (already mentioned and explained) [14] is investigating to solve this problem using Atmosphere Breathing Electric Propulsion (ABEP), which uses atmosphere residual gas as propellant for drag compensation.

4.3 Very Low Earth Orbits global market

Once the history and technological requirements of the different type of Earth satellites have been described, the report provides a study of the orbits studied by this project: the VLEO. Different and rigorous information sources have been studied in order to provide the results presented in the following sections. These results are an overview of the current situation of the VLEO market, as well as its growth projections and the new market trends in the telecommunications sector.

4.3.1 Current situation

Nowadays, the number of Very Low Earth Orbit satellites is increasing exponentially (which has been already mentioned in previous sections) with a total number of 944 according to the [5] database. This growth is a clear example of the New Space concept presented in the background: the space is opening to private investors which are more likely to use this type of orbits because they are not as expensive as higher ones and they offer benefits and applications more suited to the new satellite market trends. In fact, the image shows clearly the new satellites market trend: how the commercial applications

have growth a 30 % in the last 2 years (until 70 %) in comparison with the period between 2009 and 2016:

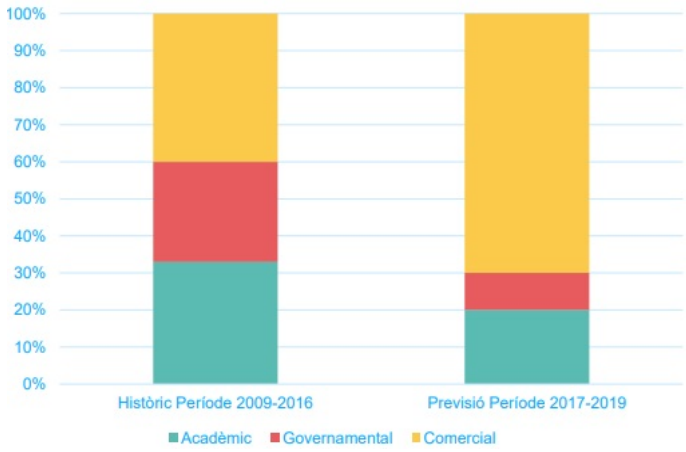

Figure 6: Satellites applications (2009-2016 and 2017-2019). Extracted from: [25]

The commercial applications (yellow colour in the diagram) are increasing significantly, but what type of orbits are leading this growth? The chart below illustrates perfectly the satellites market composition until January, 2021. The data has been obtained from UCS satellite database using different Excel filters in the same way as in section 4.1.2:

Table 3: Number of satellites according to orbit altitudes in January, 2021. Data source: [5]

Number of satellites (Jan, 2021)		
VLEO	**MEO & LEO**	**GEO**
944	1,837	591

The above data generates the following diagram, where the market segmentation of Earth satellites can be observed more clearly:

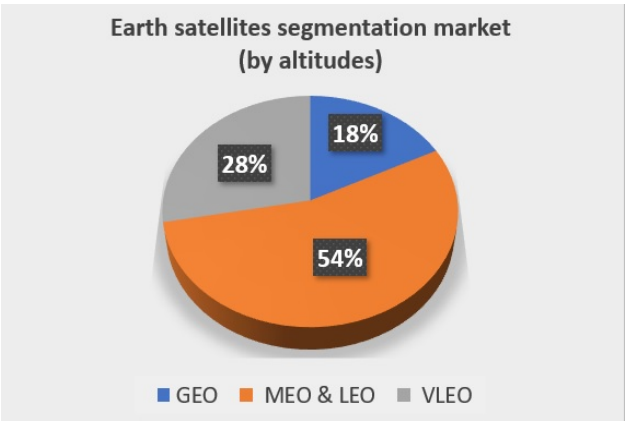

Figure 7: Earth satellites segmentation market (2021). Data source: [5]

These values are much higher than the numbers of satellite market five years ago, at the January, 2016:

Table 4: Number of satellites in January, 2016 and % growth 2016-2021

Orbit	**VLEO**	**MEO & LEO**	**GEO**
Number of satellites	77	551	428
% growth in the next 5 years (comparison with Jan, 2021 data)	**1,125 %**	**233 %**	**38 %**

The above data generates the following diagram, where the market segmentation of Earth satellites in 2016 can be observed more clearly:

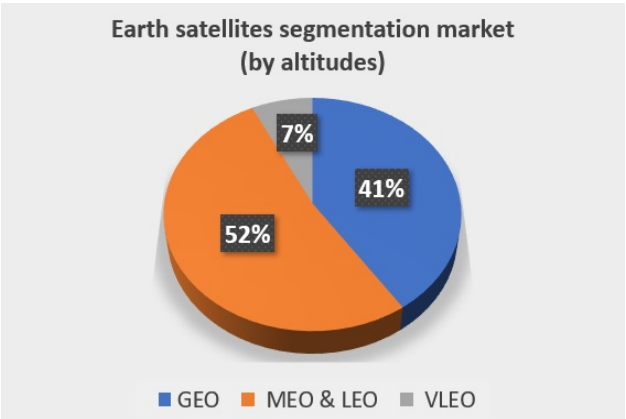

Figure 8: Earth satellites segmentation market (2016)

As it can be seen, the VLEO satellites are the group with the most significant growth (more than 1,000 % compared to 5 years ago). In contrast, MEO, LEO and GEO satellites do not show such large increases (in fact, the number of GEO satellites is stagnating, as seen in the previous section), which shows that the Earth satellite sector is shifting from geostationary satellites -mostly managed by governmental agencies- to small satellites operating at low altitudes -managed by private companies and with new applications, most of which are commercial-. This change in market trends leads to very positive growth forecasts for the VLEO sector, which are explained in more detail in the next paragraph.

4.3.2 Growth forecasts

Within the current space economy, the growth of the VLEO sector is certainly one of the brightest. On the one hand, because of the democratisation in the use of space resources (the New Space defined previously), but also because of the multitude of benefits that these orbits bring when they are used in the applications that currently dominate the new trends in the satellites market: Earth Observation and, especially, telecommunications.

Therefore, although it is impossible to quantify the exact growth, because it depends on many factors, it can be categorically stated that the market for satellites orbiting at Very Low Earth Altitudes is going to grow a lot in the coming years. In fact, it is currently growing in an exponential way. Thus, while five years ago the number of objects orbiting in VLEO was a residual 7 % of the total number of satellites, today this number has multiplied by 4, reaching the 28 % (a fact already mentioned in the previous sections). The diagram below shows how the VLEO satellites have been gaining importance within the total number of satellites over the years:

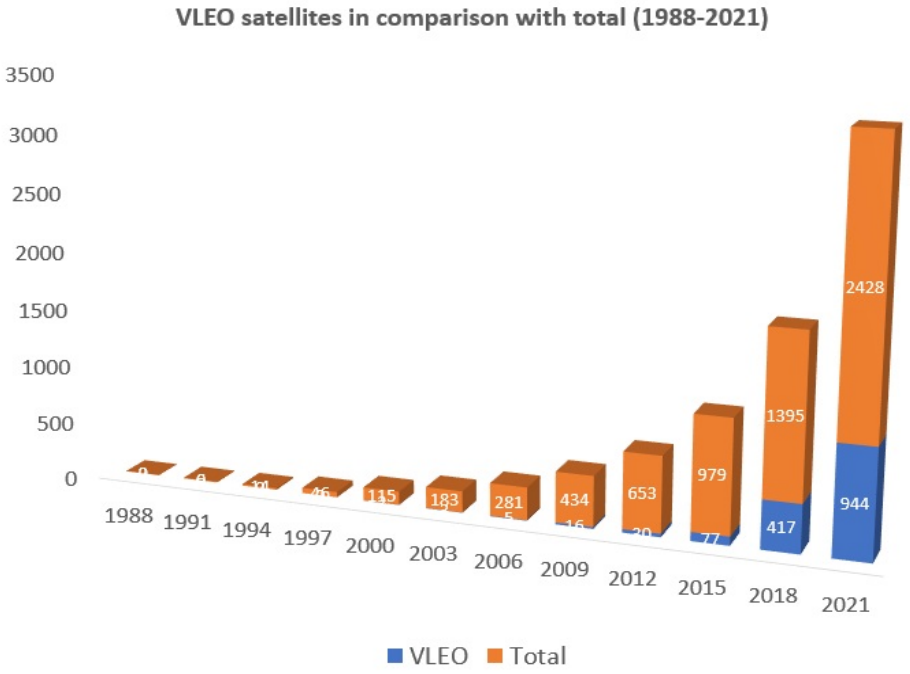

Figure 9: VLEO satellites and total number (1988-2021). Data source: [5]

It shows perfectly how the VLEO satellites have growth in the last years, a trend that will continue in the next years. In order to show better this continued growth prevision, the last launches of two of the most important VLEO and LEO telecommunications companies, Starlink and OneWeb, respectively.

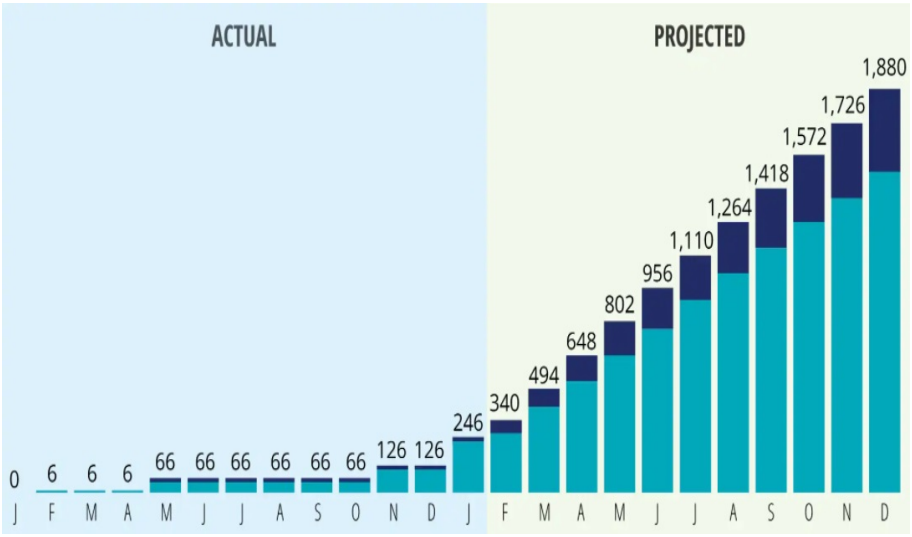

Figure 10: Starlink (turquoise) and OneWeb (dark blue) launches (2018-2020). From: [26]

So, looking at this latest graph, it is clear that VLEO orbits will continue its growing over the next few years: the chart above shows that Starlink, the main company operating in VLEO until today, far outstrips in terms of launches its main Internet provider competitor (OneWeb), which operates at higher altitudes. This growth will continue to increase, thanks to a number of key factors summarised below:

- Starlink has FCC licences for launching 11,943 VLEO satellites and it expects to establish 30,000 more over the course of this decade, bringing its total to 42,000 [27], which would convert the VLEO satellites in the most used around the world.
- Other important high tech companies are starting to invest in the VLEO and LEO sector, which is a proof of the market potential. For example, Amazon, with its Project Kuiper, is planning to launch about 3,236 satellites in a altitude of 630 km approximately (according to [27]) in order to provide Internet worldwide and compete against Starlink.
- The New Space is changing all the satellites market trends, and the VLEO are the trajectories are which meet better the new sector requirements. In this way, the telecommunications applications have to be remarked, because they are the most important part of VLEO applications for the future because of their growth forecasts, as it will be seen in the next section.

4.3.3 VLEO telecommunications market

The previous sections have discussed the current satellite market situation in general terms, in which it has been seen that the fastest growing group by far in recent years is the satellites operating at Very Low Earth Orbits (recalling section 4.3.1, in 5 years they have grown an extraordinary 1.125 %). This growth is due to the benefits offered by these orbits and their applications, which are better adapted to the explained new phenomenon known as New Space. After explaining the current market, the future forecasts for the sector have been presented, and it has seen that VLEO satellites have a lot of growth potential thanks, for the most part, to companies that want to use this type of orbits for applications related to the telecommunications sector, such as Starlink, which already has large constellations planned for this decade. This section will comment on the situation of the VLEO market applied to telecommunications: what factors justify

its current situation and its more than foreseeable future growth, as well as the forecasts for the next years. The information about the companies that operate (or will operate) in these orbits focused on telecommunications will not be provided in depth, because this will be done in the next section, where the thesis will give information about Starlink and its main competitors.

The growth of the satellite Internet sector responds to a clear need: Internet connectivity is an essential element in today's society, but there are still many areas of the world (rural, poor countries...) with lack of Internet access.

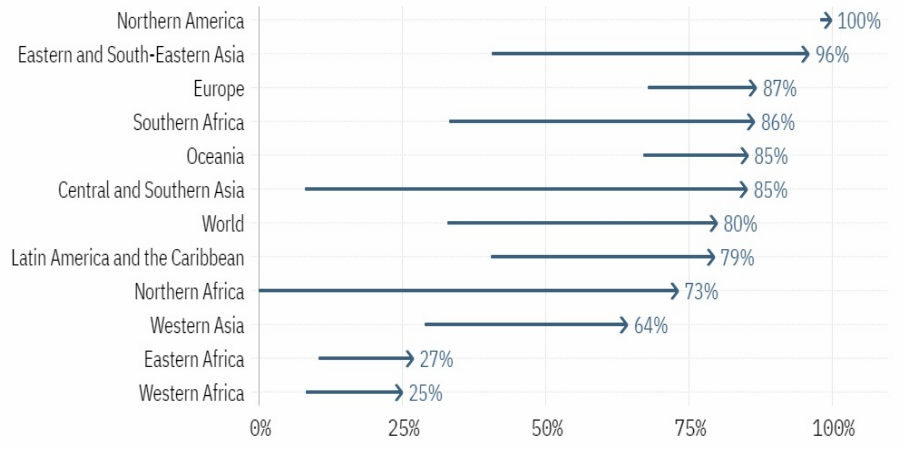

Figure 11: Population covered by 4G network (2014-2018). Extracted from: [28]

So, according to United Nations data published by [28], around the 20 % of the world's populations can not access to 4G Internet network. The situation is even worse in some parts of Africa, where there are more than 70 % of people without connection. It is important to remark that the previous diagram shows only the percentage of people without Internet, but it does not provides data about rural areas from rich countries (e.g. in Europe or Northen America), which have very bad Internet signal and it is not possible to use most of the network applications. Only in the USA, the rural areas without high speed connection access is around the 35 % according to the New York Times study [29], and, in Europe, the percentage is not better.

As a result of the need to provide good Internet coverage worldwide, the number of companies dedicated to achieve this using satellites are beginning to grow. Although the thesis shall go into more detail about these companies later, most of them do

not operate in Very Low Earth Orbits at the beginning, as these trajectories were not very well known. However, when their great performance was demonstrated for various applications, especially in Earth Observation, and as the New Space has attracted a lot of private investors to the VLEO sector in the recent years, some companies are now considering the VLEO telecommunications sector (in particular, the provision of broadband Internet) as a good opportunity. The pioneer is Starlink which, after seeing the many benefits offered by these orbits (lower prices, shorter latency times..., as described in the background section) decided to change its strategy in 2016 and 2018, replacing 11,943 licenses to develop a MEO constellation (between 1,000 and 1,200 km) for VLEO and LEO altitudes [6].

In January 2021, almost the half of the VLEO satellites applications were the telecommunications, according to UCS database:

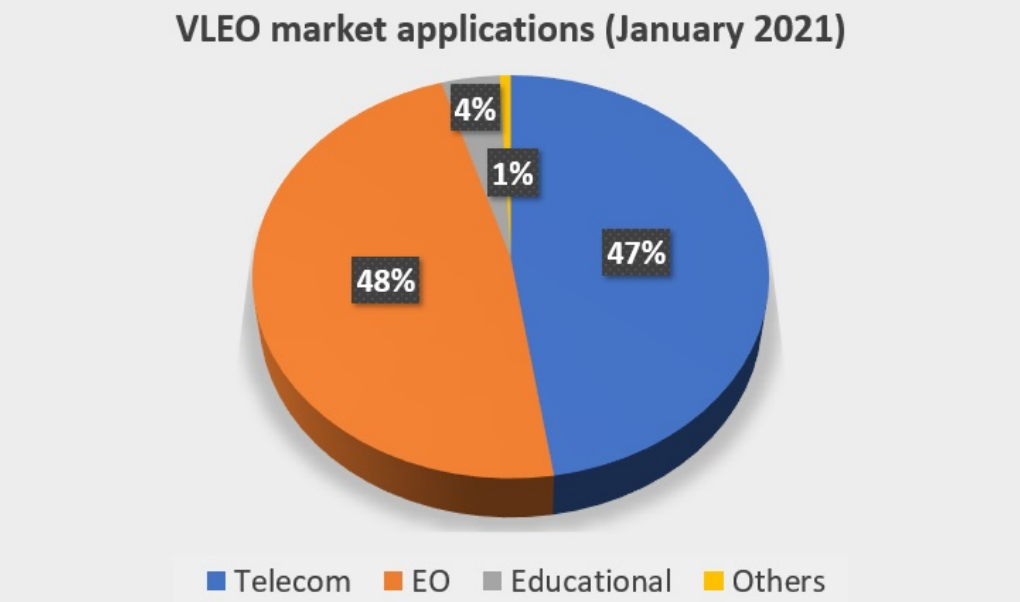

Figure 12: VLEO applications (January, 2021). Data source [5]

The data has been obtained using a similar method implemented in the other sections, filtering by satellite purpose in this case, in the same UCS Excel database [5]. As it can be seen, telecommunications are close to Earth Observation (EO) in 2021, which it was impossible a few years ago, when the EO applications dominated the market. And it is important to remark that this percentage is going to grow in the next years due to the

commitment of high tech companies to deploy large constellations of satellites operating in Very Low Earth Orbits.

If the focus is put on turnover rather than the total number of satellites, similar results are obtained. While in 2016 the satellite Internet and broadband applications did not reach 1 billion of dollars generated, as satellites operating in VLEO were practically non-existent and the market was dominated by TV, ground equipment and government applications, the US financial company Morgan Stanley estimates that in about 20 years, (around 2040), broadband consumer applications will reach 95 billion of USD, while Internet applications will be by far the jewel in the global space economy, with a volume of approximately 400 billion of USD, outstripping any other application by more than 50% [28]. This revolution and growth in satellite Internet consumption will be led, as already highlighted throughout this chapter, by VLEO satellites due to the numerous benefits that they offer, which has caused that the high tech companies presented in the following section to start investing in them and plan to deploy large constellations at these altitudes over the next two decades. This data can be observed in the chart below:

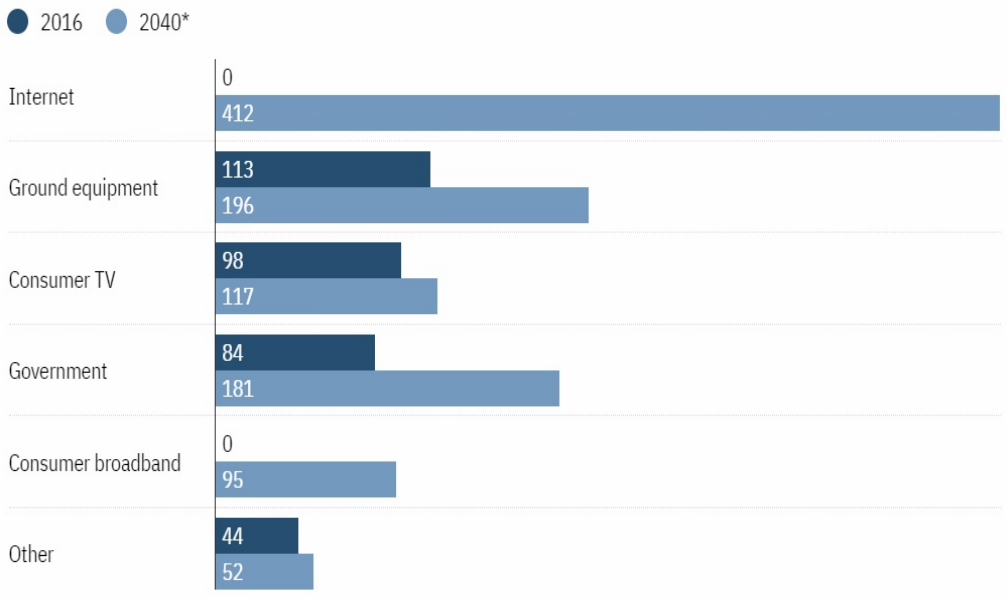

Figure 13: Global space economy forecast (in $ bn) by Morgan Stanley. Extracted from: [28]

4.4 Starlink

To conclude with the state of the art, a study of the company on which the case study and the BM CANVAS shall be carried out is provided: Starlink. This company, part of SpaceX, dominates the VLEO telecom market, which is why it has been chosen as a reference for this thesis, as it can provide very interesting data with the aim of extracting its key to success (which could be applied to other companies of the sector). Although the following sections do not present a detailed study of the company (as this is done in the next section, the case study), they summarise its current situation and elaborate a comparison with some of its most direct competitors.

4.4.1 Current situation

Starlink is the most important company in the VLEO market and one of the most in the global. Not only because it is the only that, to date, operates effectively at these Very Low Earth Altitudes, but also because it is clearly committed to this technology for the future, as it has 11,943 licences approved by the FCC (the regulatory agency for launching communication satellites in the United States), and plans to process another 30,000 licences to reach the incredible figure of 42,000 satellites with which the CEO of the company, Elon Musk, wants to achieve the global Internet coverage. This section does not intend to provide an exhaustive description of Starlink, as this will be done in the next case study chapter; simply presents some very specific data about the company, which helps to understand why it is considered the main reference in the sector and why it has been chosen as a reference to implement the case study and to apply the CANVAS methodology.

Table 5: Starlink key data (data sources in table rows)

STARLINK: KEY DATA	
Satellites launched (Jan, 2021) [5]	**902 (recent data from April reports about 1,300 [30])**
Currently launch frequency [31]	**120 sats/month**
Number of licenses from FCC [6]	**11,943**
Broadband Internet customers (Apr, 2021) [32]	**10,000 (Beta version)**
Broadband Internet pre-orders (May, 2021) [32]	**500,000**
Total constellation planned [27]	**42,000 (approx.)**

As it can be seen in the table above, Starlink is not only the current market leader with more than 1,300 satellites and 10,000 users, but also wants to be the VLEO telecom sector reference in the future. Proof of this is its current 12,000 licences to deploy a large Internet constellation, as well as its half a million broadband service pre-orders. While today it looks set to achieve this dominance for the next decade, the companies presented in the next section shall try to stop Starlink growth.

4.4.2 Main competitors

The main competitors of Starlink are presented in the following table:

Table 6: Starlink and main competitors information. Data sources: [27], [4]

Company	**Current satellites**	**Planned total constellations**	**Type of orbits**	**Altitudes (km)**
Starlink	1,300	42,000	VLEO & LEO	570-540 335-346
Amazon	0	3,236	LEO	590-630
Hughes Net	6	7	GEO	36,200
OneWeb	146	648	MEO	1,200
Telesat	15	15 298	GEO LEO	35,700 550-1,200
ViaSat	5	5 288	GEO LEO	35,400 550-1,200

The previous figure shows five high tech companies planning to compete with Starlink in the broadband Internet service sector. It's important to remark that they are not the only companies investing in this sector, but they are the most important ones.

- **Amazon:** with its Project Kuiper, it is maybe the most important of the five because of their resources, cost structure and innovation commitment, since it is one of the most important companies in the world, with extraordinary revenues and with the capacity to invest in this expensive sector. Nevertheless, no satellites have been launched until May, 2021 [27], because the company is still studying how to enter and have a significant market impact. For the time being, they have planned the number of satellites that they have to launch (3,236, half of them before 2,026 according to [27]), in order to request FCC for licenses, and they have decided the operation altitude of the constellation, which shall be closer to VLEO: between 590 and 630 km [4].

- **Hughes Net, Telesat and ViaSat:** these companies are offering broadband Internet and operating at GEO altitudes (around 35,000 km). The constellations deployed have a few satellites, because the launch costs and mission risks to put a satellite in a geostationary orbit is much higher than VLEO. In addition to this, the number of satellites required to have a large coverage in GEO is lower than in the low orbits. In spite of the above commented, the irruption of the satellites operating at VLEO and LEO which, as already explained, present a long list of benefits for the telecommunications, has changed the strategy of some of theses companies. For example, Telesat and ViaSat have announced the development of constellations made up of satellites operating at Low Earth Altitudes (between 550 and 1,200 km) for this decade, aiming to compete against Starlink dominance. This is another example of how the VLEO and LEO markets are going to grow in the next years, becoming the main reference in the satellite global market because of their applications and benefits.

- **OneWeb:** the company from UK is, nowadays, the only real competitor of Starlink, because it has deployed a significant constellation in MEO altitudes (around 1,200 km). Although it has not an elevated number of satellites orbiting, he covers an important area of the northern hemisphere (countries such as Russia or Canada), reason why it has a lot of current and potential customers, too. Besides that, one

of its key partners is the United Kingdom government, who rescued the company from bankruptcy a few years ago and invested twice as much money than SpaceX in Starlink in 2019 (see the image below this paragraph), reason why OneWeb could become a dangerous competitor of Starlink in the next coming years.

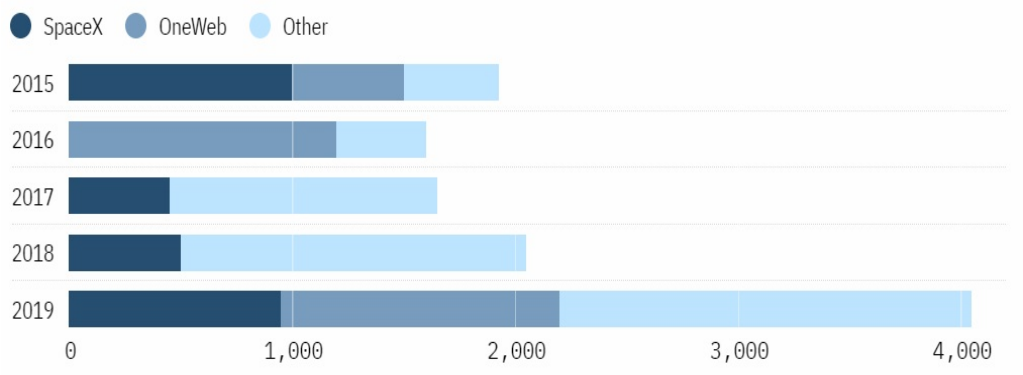

Figure 14: Starlink and OneWeb investments in $ billion (2015-2019). Extracted from: [28]

Finally, a diagram showing the planned constellations of Starlink main competitors is provided, in order to show more visually the satellites launched by each company in this decade. Starlink has not included in the chart, because of with its 42,000 satellites constellation it will represent the 90% of the satellites distribution, which will not be useful and visual for the diagram objective.

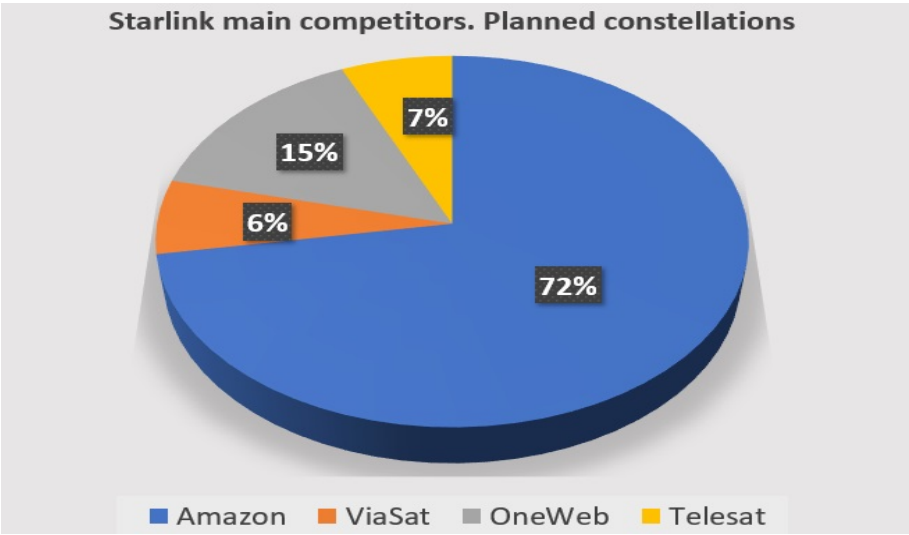

Figure 15: Planned constellations of Starlink competitors. Self elaboration from data: [27]

To sum up, the state of the art has provided a detailed study of the current satellite market, after summarising its history and some of its characteristics from a more technological point of view. Within the market study, the current and general situation of the market has been described, remarking the importance that satellites operating in Very Low Earth Orbits have increased in recent years. This was followed by a discussion of the growth forecasts for the satellites market, which are very positive and are led by these VLEO satellites thanks to the set of benefits they provide, which are perfectly adaptable to the new market trends, applications and some phenomena that accompany them, such as the mentioned New Space. In the following section, the market for LEO and VLEO satellites with telecommunications applications was discussed in general terms: it was seen that there is an urgent need to provide satellite Internet in some world areas, and that the type of satellites that can best respond to this need are VLEO satellites, thanks to the benefits they offer. This demand has led many technology companies to believe in the sector opportunities, as well as private investors. Among these investors, Starlink has emerged as the dominant agent in the short and long term, operating with more than 1,300 satellites, 10,000 current users and with the goal of reaching constellations of around 42,000. Other important organisations are OneWeb, which is already operating with the valuable support of the UK government, and Amazon, which plans to launch more than 1,000 satellites over the next five years. It is clear that the sector has a bright present and future and shall be very popular in the coming years, although it is difficult to predict which company will take over the domain. Furthermore, as investment is generated, new companies with new applications and business models shall be created, too

For the time being, this thesis continues, studying the particular case of this important company in the VLEO telecommunications sector (Starlink) with the aim of implementing on it the CANVAS business model methodology and extracting the key success factors.

5 Case study: Starlink company

A comprehensive study of Starlink, the most important company in the Very Low Earth Orbit satellite market applied to telecommunications (specifically to broadband Internet service) is essential for this thesis. On the one hand, because it helps to understand how the company works, giving a global vision of its structure and operability, a fact that is very interesting for a relatively new company such as Starlink, since there is still not a great data and research on it. On the other hand, it allows to identify the elements used by the company to generate added value, as well as its connections, which will provide the most relevant information to implement the CANVAS business model methodology, extracting the keys to success of the company (with the aim of characterising the VLEO telecom sector), and being able to apply these keys to success to other existing and/or future companies operating at these type of orbits.

It is important to remark that the information available on Starlink is very limited, as it is a recently created company (it did not exist six years ago, as will be seen below). Furthermore, it works with a very innovative technology, which means that it publishes very little information about certain aspects of its activity in order to prevent other companies from plagiarising its way of operating: for example, the data about its supply chain or constellation characteristics is very restricted. Despite this lack of information, the project has been tried to extract as much information as possible, always from rigorous sources, in order to provide a detailed case study as shown in the next sections.

The different sections of the case study are: the company overview, the work environment, the partners, the operations, and the economic summary. They have been selected because of all of them are essential for a great company performance in the satellites sector (not only for telecommunications applications, but also for Earth Observations or similar). For each of these previous elements, the case study introduces the main characteristics of them, explaining how they are implemented by Starlink. The structure used with the aim of describing the different elements is divided in two parts: firstly, a visual diagram, in order to present an overview of the case study's section and, after that, a further detailed study, explaining the different aspects of the previous diagram.

5.1 Company overview

The first step of this study briefly summarises the history of Starlink in order to understand the origins of the company, why it was created, what changes it has undergone over the years..., with the objective of creating an adequate background that will help to understand the situation in which it finds. An overview of its philosophy and business statement will also be presented in this section, with the aim of understanding the company's objectives and its operating structure, which, as will be seen later on, should be focused on meeting these objectives.

5.1.1 History

Starlink is a division of SpaceX, reason why it has a different business statement and works independently, under its own trademark, but it shares a lot of important resources with SpaceX, such as the human capital (they share the employees -which work for both companies projects at the same time-, and part of the board team -for example, the CEO, Elon Musk- is the same), financial sources or part of the facilities [33].

Starlink appeared in 2015 in public for the first time, when SpaceX published the beginning of a project aimed to develop a large constellation of satellites in order to provide high-speed Internet worldwide [34]. After that, a series of important factors followed in a very short period of time, which have made Starlink the reference company in the field of Very Low Earth Orbit in communications, leading the company to deploy more than 1,300 satellites until April 2021 [27].

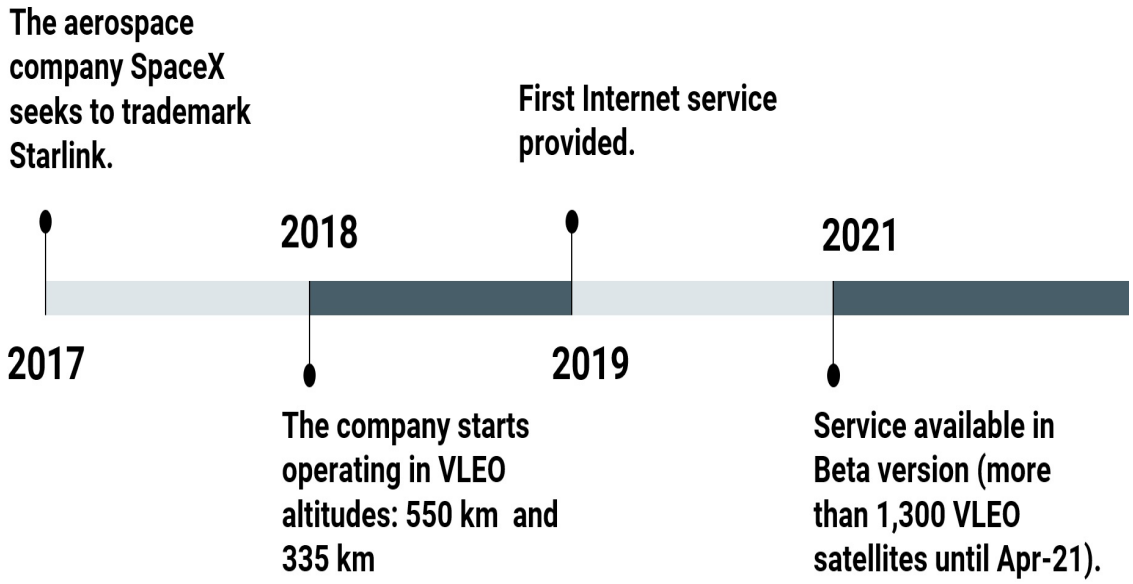

Figure 16: History of Starlink: key data.

Although the project was announced in 2015 as mentioned above, it was not until 2017 when the creation of Starlink was formalised through SpaceX's seek to trademark [35]. In this way, the satellite company, despite continuing to be a division dependent on Elon Musk, began to work autonomously, with completely different objectives and with some of its own resources (e.g. financial), although most of them are still shared with SpaceX. In 2017, the Federation Communications Commission (FCC), a US government agency in charge of regulating satellite launches, granted the company 11,943 licences to deploy satellites at an initial altitude of between 550 and 1,200 km (LEO altitudes) [36], a fact that gave a big boost to the project and attracted some investors.

Only one year later, Starlink decides to change strategy and starts operating in VLEO orbits. For this reason, it asks the FCC to change its initial licences to lower altitudes, approximately at 335 and 550 km [37]. After receiving confirmation from the agency, it became one of the first private companies in history to make a firm commitment to this type of orbit, and began working on the development of the satellites in order to start testing the service in the following year.

The 2019 was the most important year in the company's recent history. In May, SpaceX launched the first 60 Starlink satellites using the Falcon 9 rocket [34], putting them at

550 km. Other satellites were launched along the year by SpaceX rockets and, finally, a fem months later, Starlink provided its first Internet service, when the company's Chief Executive Officer (Elon Musk), used this Internet signal to share a *tweet* in the Twitter social media [38].

Over the past year, Starlink satellites have been launched regularly, reaching 120 per month at the beginning of 2021 [31]. Its Internet service is currently in Beta version, with more than 1,300 satellites in orbit, 10,000 active users and approximately half a million pre-orders [32], a remarkable achievement considering its recent creation. The company plans to continue this extraordinary growth in the future, increasing its number of satellites to a constellation of 42,000 covering the entire planet, and consolidating its position as a reference in the satellite communications sector.

5.1.2 Business statement and philosophy

According to its official website [33], Starlink is a company offering high-speed and low latency broadband Internet service through the management of a large satellites constellation. This is the principal statement of the company, but there are others published in its website, which are very important and contribute to adding value to the whole organisation:

- **Innovation commitment:** the company is focused on the research and development of new technologies, which could decrease the latency times or increase the data speed.
- **Worldwide coverage**: although the service is only available in some areas of the world, one of the most important objectives of Starlink is the Internet worldwide coverage.
- **Easy to set up ans install:** the customers receive a kit with all the material required to receive the Internet signal and they can use the Starlink app in order to be assisted by the company during the installation.
- **Preserving the night sky:** the company is really committed to reduce the light pollution produced by its satellites, reason why it is implementing some mitigation

measures against this phenomenon (see section 9, about Environmental impact study).

- **Quality and reliable:** as part of SpaceX, one of the high-tech most important organisations in the world, the customers are aware of the company's ability to offer extremely quality services, as well as its reliability in terms of the key resources needed in the sector, such as rockets.

5.2 Work environment

Once the company's history and business statement have been defined, the thesis begins a more internally study to determine how Starlink develops its labour relations. In this aspect, the project shall provide information about the two agents that play the most decisive role in the company's work environment: the owners of the company and its employees. Firstly, a visual explanation of the internal structure is presented, followed by a description of the owners, the management team and the different levels within this structure, as well as a summary of the most important activities that each segment engages in.

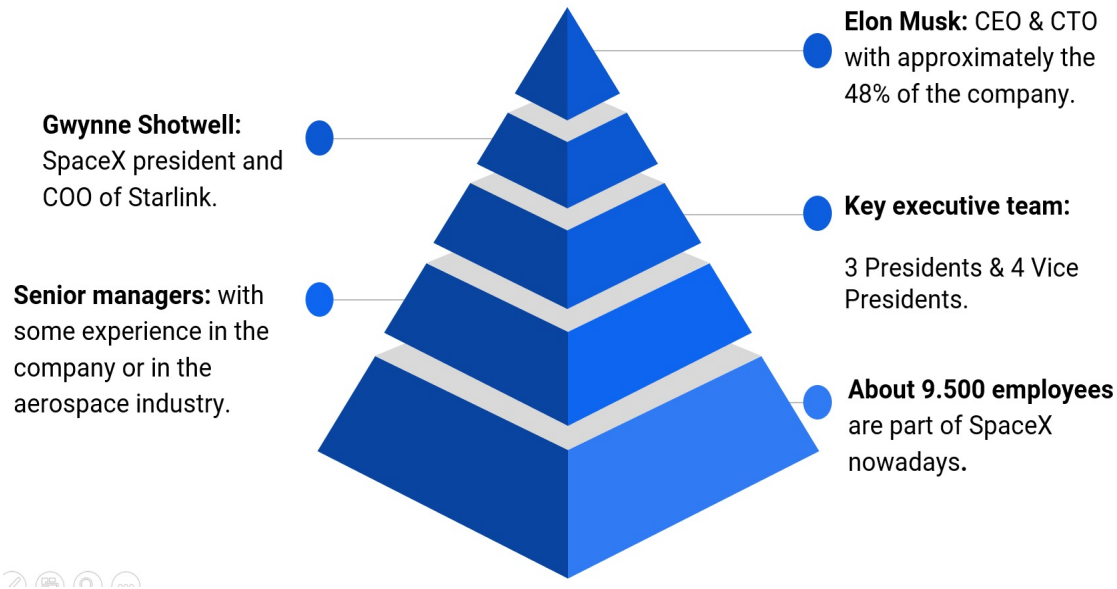

Figure 17: Work environment of Starlink: key data.

5.2.1 Owners

It's difficult to determinate the main owners of Starlink, because, as a private company, the information is restricted. Instead of this, the thesis shall present the two most important persons in the Starlink work environment.

- **Elon Musk:** he is the Chieff Executive Officer (CEO) and Chief Technological Officer (CTO) of Starlink, as well as being its founder and owning, according to [39], about the 48 % of the company. He is considered one of the most innovative and successful businessman on the planet, achieving success in many technological projects that, at the beginning, seemed impossible to carry out (as is currently the case with Starlink); for example, Tesla or SpaceX are also owned by the American entrepreneur. He is responsible for most of the important decisions related to the strategy of Starlink, as has a lot of experience and his intellectual capacities to lead technologically innovative projects are, at the moment, the best of the world.

Figure 18: Elon Musk. Extracted from: [40]

- **Gwynne Shotwell:** she is one of the most important presidents of SpaceX, in addition to being the Chieff Operations Officer (COO), which is why she is also COO of Starlink. In fact, Elon Musk is more focused on the space company and it is Shotwell who is being the responsible for managing all Starlink-related operations. She was the 11th employee of SpaceX, joined in 2002, which is why she is one of

the directors on who Elon Musk places the most trust and decision-making power [40].

Figure 19: Gwynne Shotwell. Extracted from: [41]

5.2.2 Employees

Starlink bases its value proposition on the quality of the service offered, as well as its fast and effective customer service, whether for installing the hardware, resolving doubts about the use of the service or attending to them quickly in the event of an incident. In addition to this, the technological demands of the associated processes (monitoring the constellations, handling the signals in the ground stations...) to produce the service offered are very high. For this reason, human capital is essential in its activity, as without it, the company would not be able to offer a high-tech service with the quality and reliability with which it carries out its activity. Thus, Starlink requires employees with extensive knowledge in sciences, especially in the aerospace and telecommunications fields and, preferably, with experience in the sector in order to be able to face the technological challenges of the company.

With regard to the internal structure, exact details are not known, as this is confidential information. However, it is known that there is a en executive team, consisting of approximately three presidents and four vice presidents [42], most of whom are common to both SpaceX and Starlink. At the next level there are senior managers, who coordinate the different departments, and finally the general workers, who are also a shared resource

with SpaceX (SpaceX has around 9,500 workers [41], although it is impossible, for confidentiality reasons, to know exactly which of them are only dedicated to Starlink).

5.3 Partners

While internally, the owners and employees described in the previous section are one of the key factors that enable Starlink to offer and deliver its value proposition, externally, one of the most essential elements for the company are its partners. These agents tend to be companies that provide the resources that Starlink cannot produce (either because it is not cost-effective or for other reasons), and without which would be impossible to provide the satellite Internet service and the value propositions associated with this service. Apart from private companies, partners may also include governments or government agencies which, while not collaborating with Starlink for the main purpose of financial gain, may offer investments or enter into co-operation agreements with the company in order to provide benefits for the society, as will be discussed below.

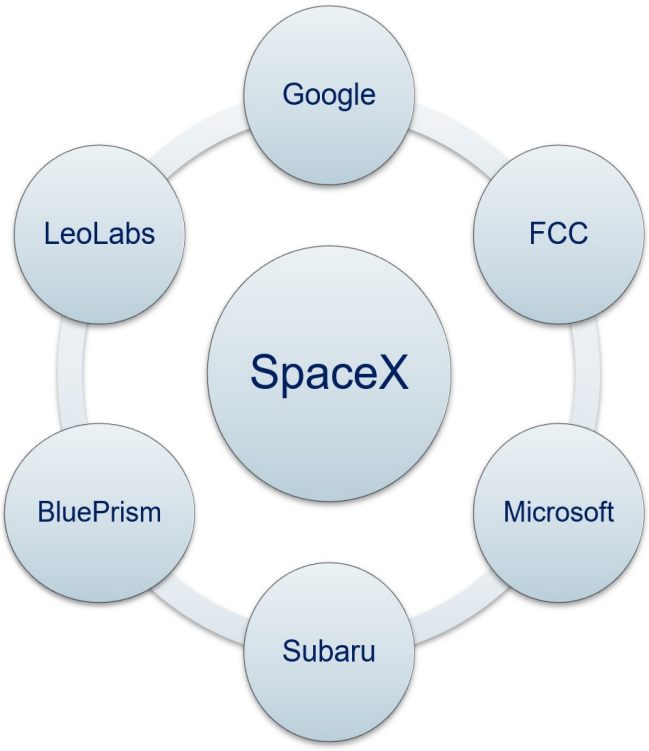

Figure 20: Main partners of Starlink

These partners are classified in three categories:

- **Internal:** as a division of SpaceX, Starlink has many competitive advantages because of the space company is its major partner, handling much of the supply chain processes: the full process of designing and manufacturing the satellites that are launched, as well as their launch operations [43], which is why Starlink activities can focus more on the Internet service, maintaining the constellation, managing signal delivery and signal status, and administering the costumer relationships.

- **Legal:** as it has been seen in previously sections, the FCC sets the normative framework for satellites launches, reason why it is important to establish a regular relationship with the agency, in order to obtain the number of licenses needed to deploy the constellation planned. In this way, the FCC can be a financial partner too, because it is developing actions in the USA with the objective of bringing Internet to rural areas. A clear example of this is the almost 900 million $ received from the agency last year as part of the *Rural Digital Opportunities Fund* program [44].

- **Value-added services:** in this group, all companies and organisations that collaborate with Starlink in some associated services and, therefore, contribute to add value to the service offered, have been included. Obviously, there are many organisations that indirectly collaborate with Starlink, but only those that have a direct relationship with the company and have publicly announced their status as partners are mentioned. This includes Google, as a financial partner (it invested almost $1 billion in 2015 [45]) and by offering cloud services [46], which are very important as channels to reach market segments and increase customer loyalty. Microsoft, with its Azure service [47], has also been providing cloud services to Starlink users since last year, generating value in a similar way to Google. Another cloud provider recently incorporated into Starlink activity is BluePrism, focused only in a particular region, the Middle East [48]. In other tasks, LeoLabs collaborates in constellation tracking [49], which allows Starlink to reduce its operational costs, and Subaru, the automotive company, has signed an agreement with the company in order to include the compatibility of its cars with the Starlink service [50].

5.4 Operations

The case of operations is very similar to the previous one: since, despite being a key element in the success of Starlink, there is very little information available about its functioning due to confidentiality issues and the fact that the company has recently been created (which is why there is scarce published information about it). Nevertheless, extensive work has been done to find data related to Starlink operational processes, which cover both the tracking of the satellite constellations, their operational characteristics and also the processes of supplying the service to customers (both the Internet service and the physical instrumentation necessary to receive the signal), as well as the coordination of customer relations, which the company develops through different channels that shall be analysed.

Figure 21: Main operations of Starlink

- **Constellation tracking:** these operations are key to providing Internet service, as they check satellite trajectories, thus avoiding service interruptions. Starlink also checks the status of the signals (and their frequencies) emitted by the satellites, in order to take action or replace the satellite if it is not functioning optimally. To do this constellation monitoring, the company collaborates with various external

partners, the most important of which is LeoLab, which helps to do the tracking in the initial phase after the launch, because of this is the most critical part of the operations [49].

- **Ground stations management:** another of the essential activities of Starlink is the management of the ground stations, which allows to process the data received from satellites and sending to customer centers. To perform this activity, the company uses different ground stations located in different regions of the world (until April, 2021, in USA, Canada, United Kingdom, Germany, New Zealand and Australia) [51]. Nowadays, the number of ground stations is low and it not allows to achieve a global coverage, but Starlink is working hard in order to build new ground stations around the world. In addition to this, in May, 2021, the company agreed with Alphabet, Inc. to use some of Google data centres as ground stations [52], which is an important step towards one of its key value propositions: the worldwide service.

- **Service set up and installation (at customer locations):** for the service set up, Starlink delivers to customer's location the Starlink kit, which includes everything needed connect to Starlink network: Wi-Fi router, power supply, cables and mounting tripod [33].

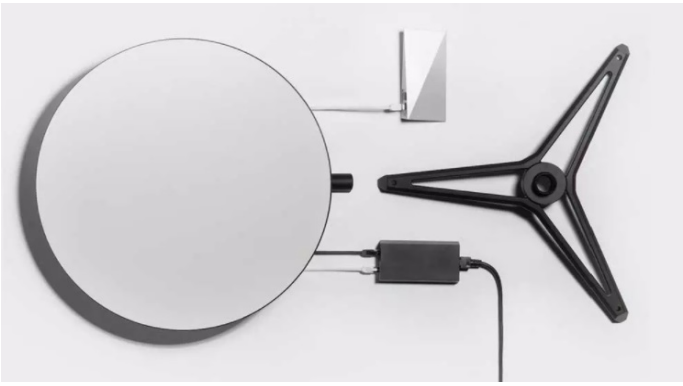

Figure 22: Starlink kit. Extracted from [33]

The installation is managed by Starlink app, which studies the costumer's location and geography, and suggests the better place for receivers (parabolic antenna) included in the kit. The interface of the mobile application, which is available for

iOS and Android, is interactive and easy to use, and it allows to report technical incidents or contact with the company through the *Customer support option* [33].

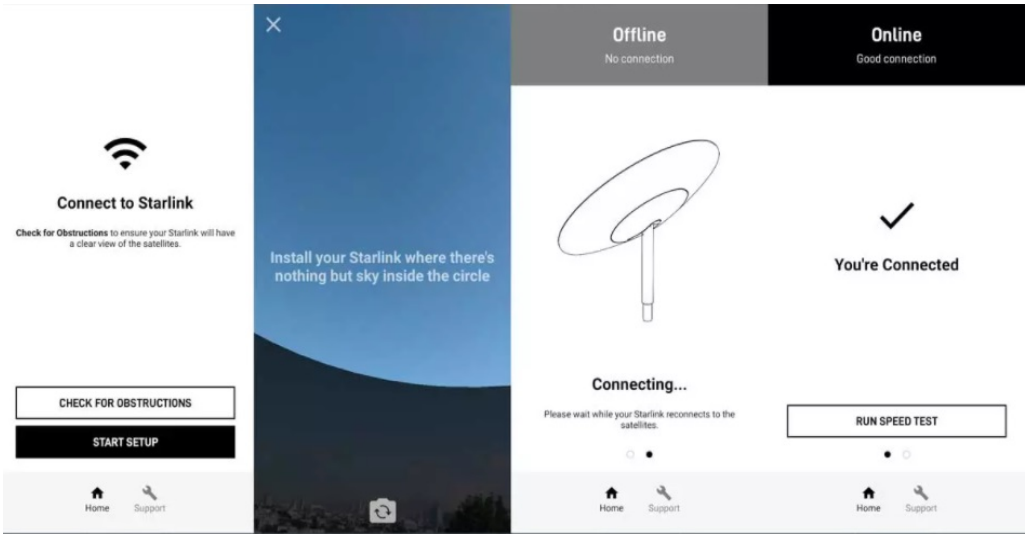

Figure 23: Starlink app interfaces. Extracted from [33]

5.5 Economic summary

To conclude with the Starlink case study, some financial data is presented. Although a feasibility study or an in-depth economic analysis is beyond the scope of the project, it is necessary to give an overview of it, as financial resources and revenue streams are especially important in the satellite sector.

5.5.1 Main funders

The telecommunications satellite sector requires a huge initial investment in order to start the activity (designing and building the different satellites, setting up the ground stations, tracking systems...) and also high and continuous investments, since in the first years of activity there are economic losses (i.e. the customers subscribed to the service do not cover the costs of the whole service and maintenance). In fact, it is estimated that, in order to deploy 12,000 satellites (which is the first round of licences approved by the FCC), Starlink will require $10 billion [53] approximately, which makes the need for financing an obligation in order to maintain its activity. To clearly visualise

the situation of these investors, the thesis has summarised the most prominent and public ones (as with some investors it is decided to maintain the confidentiality), as well as the motivations of each one to invest, the total amount and the year of the contribution.

Table 7: Main funders of Starlink: past, present and future. Data source: [44]

Organisation	Reason	Amount	Year
SpaceX	Main funder of Starlink. Both companies share a large number of financial resources since Starlink is a division of SpaceX.	**Unknown ($ billions)**	Continuously
Google	To accelerate the satellites design and the whole constellation development.	**$ 900 million**	2015
FCC	Rural Digital Opportunities Fund (Phase I - auction) to develop US rural areas.	**$ 885.5 million**	2020
Private investors	The company is evaluating the option to do an IPO (Initial Public Offering) in the future, in order to attract new private investors.	**Unknown ($ billions)**	Future

As it can be seen, the investments presented are large (because of the activities carried out in the satellites sector requires large amounts of money), reason why the number of companies that can contribute significantly to Starlink is small. These companies, according to [44], are: SpaceX, which has invested billions of dollars since it decided to start developing Starlink project in 2015; Google, which contributed almost a billion dollars in 2015 to help in the constellation deployment (which would have influenced Starlink to use Google Cloud services or some of Alphabet centres as ground stations). Also some government agencies, such as the FCC, contribute financially to the company. For example, the FCC donated almost $900 million of the $9.2 billion it awarded to other companies as part of the first phase of the auction dedicated to encouraging digital development in US rural areas. Finally, the company is also considering an IPO [54],

taking advantage of its good business situation (with 10,000 Beta users and around half a million pre-orders), with the aim of attracting private investors by the stocks exchange. This action, which involves some risks, could be the definitive economic help that Elon Musk's satellite company needs, at least to reach the almost 12,000 satellites for which it already has a licence in the short term.

5.5.2 Financial status and growth forecasts

In addition to the investors described above, the company has different revenue streams from the various services it offers to different customer segments.

- **Subscription fee:** at a price of USD 99 per month [55], customers and businesses receive low latency (20 to 40 ms) and high speed (50 to 150 Mb/s) [33] Internet signal. This is a very interesting revenue stream for the company, as it generates income on a regular and long-term basis.

- **Starlink kit:** the Starlink kit, priced at USD 500 [55], is a one-off payment that customers make to obtain all the necessary hardware (mentioned in the previous section) to receive the Internet signal. Although it does not generate regular revenues, it does help to maintain customer loyalty, as it is a long-term investment for customers due to its high cost.

- **Long term contracts:** this source of income is composed of those customer segments formed by governments, organisations that depend on it and large companies. All these organisations share a common factor: because of their large size, they require fast and repeated signal in order to avoid network congestion and reach all their employees. For this reason, they do not purchase the service in the same way as an individual consumer, as the needs of a family or small businesses are obviously very different from those of a government organisation (e.g. a military) or large enterprises (e.g. international airlines with more than 500 aircraft). Thus, to address this market segment, the company uses a professional sales and installation team, made up of members from different Starlink departments, who negotiate with the customer the price, the contract, the payment method... A clear example of this process would be what the company studied is doing with

some airlines (which can be considered as big companies part of B2B sector) to offer satellite broadband Internet service on planes: according to [56], Starlink sales staff is negotiating with the airlines, fixing the price, testing the signal quality...

Taking into account the Starlink revenue streams and the total subscribers expected at the end of this year by Trefis Consultancy and Forbes [57] (200,000 approximately), and the Average Revenue Per User (ARPU) in the broadband Internet sector for a single month (which is established in 60 USD [57], according the Leichtman Research Group and Trefis Consultancy calculations), the revenues expected for this 2021 are approximately $240 millions. This result adds the price of the Starlink kit, as it can be seen:

$$Revenues = 200,000(users) \cdot [60(ARPU) \cdot 12(months) + 500(kit)] = \mathbf{240}\$\ millions \quad (1)$$

With the company's future subscriber estimations elaborated by the Trefis consultancy for the next 5 years (taking into account the global Internet market and also the satellite Internet market), it can be projected the subscribers until 2025.

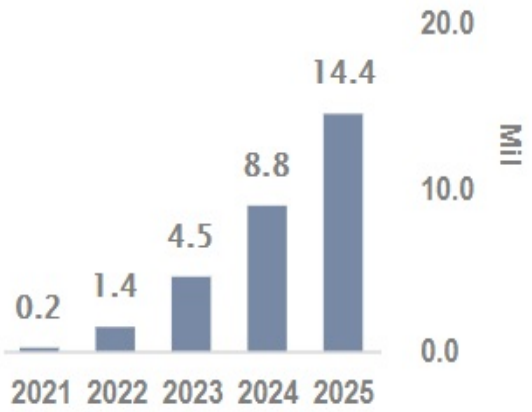

Figure 24: Starlink subscribers until 2025 (millions). Extracted from [57]

The subscribers are expected to arrive until 14.4 millions in less than five years [57], which is an optimistic scenario but could very perfectly happen, as there is a lot of

expectation for the service and there are already half a million pre-orders. Compared to 2021, it would represent an extraordinary 7,100 % growth, which indicates the huge potential of the Starlink service according to the current and future market demand.

Finally, with the future subscribers data, it is possible to estimate the Starlink revenues in 2025, as well as its valuation (considering a price-to-sales (P/S) ratio equal to 3 [55], due to the market expectations about the company and the P/S values of other broadband Internet organisations).

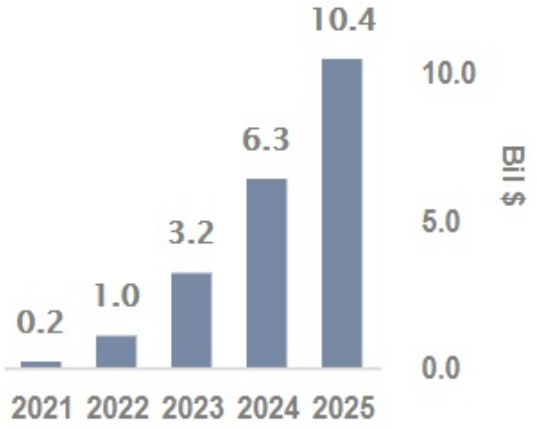

Figure 25: Starlink revenues until 2025 ($ billions). Extracted from [57]

The expected revenue in 2025 is $10.4 millions, which represents a 5,100 % increase compared to 2021. The valuation can be calculated multiplying the P/S ratio and the revenues, obtaining a Starlink valuation of $31.2 billions for 2025, which represents an incredible growth equal to the revenue growth (5,100 %, because of the P/S does not change).

To sum up, this economic study remarks the need for funding in the satellite Internet market, which is why financial partners become a key success factor in the sector, a fact that shall be discussed later. In addition, the enormous potential of the sector can also be seen, with very high growth expectations due to the demand that, if maintained, can greatly increase the subscribers of Starlink (always considering that the company remains the market leader). In addition, its diversified revenue streams and high price-to-sales ratio (due to the expectation that the company generates in the market and investors)

mean that its future valuation shall be very high. This fact, which would only occur if the expectations of customers and revenues are met, would be essential for the longer term future of the company, as it would allow it to go to the IPO with guarantees and to obtain, after the IPO, a set of very valuable financial resources.

6 Business model CANVAS implementation

In this section, a business model methodology shall be applied to the company studied. After evaluating different alternatives and in consensus with the thesis directors, the CANVAS model has been chosen, as it is one of the most important references in the field of business models, as well as being efficient and visual. In addition to this, the method has been used for different applications than telecommunications (e. g. Earth Observation) in other final thesis inside the DISCOVERER-UPC research group, and the results have been interesting and positive in most of the projects.

The main reference used in order to implement the business model methodology is [10] because it is the book where the CANVAS is presented and explained in depth by its two authors (Osterwalder and Pigneur), becoming one of the most relevant references in the businesses model generation field. According to the reference previously mentioned, the definition of the BM CANVAS is the detailed description of the process by which a company creates, delivers and captures value, and it is a common language for defining business models, often subject to subjective perceptions and difficult to explain using the same terminology. Hence, the CANVAS method solves this problem by developing nine modules, which cover the four main areas of any business: the value offer, the customers, the organisational infrastructure and the economic viability.

6.1 Starlink business model CANVAS

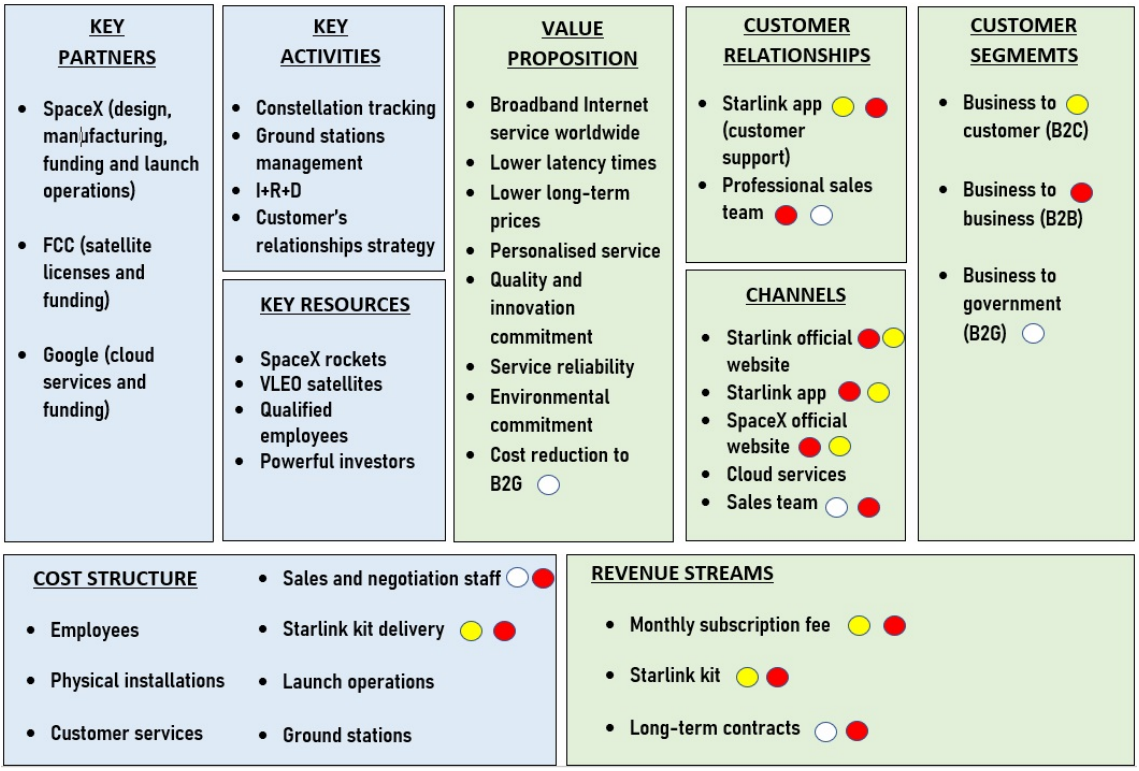

Figure 26: Starlink Business Model CANVAS.

In the following sections, each module of the business model will be developed by applying it to the Starlink company, based on the information obtained about the market (in the state of the art) and the data about the company's structure (presented in the case study). The theoretical knowledge on concepts related to the CANVAS blocks are all extracted from the above-mentioned reference book. It is important to note that this is the practical part of the thesis, and all the conclusions and statements are original and self-elaborated. For this reason, concepts and information extracted from the state of the art, case study or Osterwalder's book are not referenced again, and only specific data, which had not been provided in any previous section of this thesis, is referenced.

In order to make a complete implementation of the CANVAS methodology, the thesis first provide the scheme of the complete model with the aim of giving a global vision of how Starlink creates and provides value and, subsequently, the different elements that

make up the business model are developed and exhaustively described, explaining in detail how they are applied in the case of the company studied.

6.2 Value side

The value side section describes the five modules from CANVAS BM that Starlink uses to offer and distribute its value proposition among society: the customer segments, made up of the groups of people and entities that the company focuses on; the value proposition, which is the set of products and services that the company offers to the previous market segments; the channels, composed by the different communication strategies that the company uses to reach the different market segments and offer them its value proposition; the customer relationships, which define the type of relationships that Starlink establishes with the different market segments that it focuses on; and, finally, the revenue streams, which define the different processes used by the company in order to earn money from the services and products offered to the market segments.

6.2.1 Customer segments

In the case of Starlink, its target market is segmented into three main groups. Although the problems and needs of these groups are similar, the company must develop three slightly different sales strategies to meet the needs of each one:

- **Business to Customer (B2C):** applies to any individual person (or group of persons) who want to purchase Starlink's Internet service for personal (non-profit) use. Nowadays, these people can only be from Northern America (as the service only works in very specific areas of the USA); despite that, it is expected that the next decade the service will be available worldwide. Their age range and level of education can also be very varied but, as it requires a complex installation and is a very innovative technology, it is expected that this market segment will be made up of people under 50-55 years of age (as older generations have a significantly lower percentage of technology use, according to [58]), people with an average level of education (as the installation is complex but it is guided by the company through the Starlink app). These consumers would live in areas without

internet access or with poor connectivity, which is why they would seek to improve their connectivity through Starlink broadband. This group may also include people who prefer satellite internet to other forms of internet for various reasons (more convenience, less environmental impact on landscapes...).

- **Business to Business (B2B):** the strategy will be developed in those companies that wish to acquire the Starlink Internet service, either to develop their business activity (using the service as a corporate network, in order to connect to the multitude of services offered on the Internet and allowing their workers to connect to it) or to use it as a support for the main network, in case it is very saturated. Similarly with consumers, these companies will have a high tendency to be located in rural, poorly connected (or unconnected) environments, and most will be relatively small in size, as large businesses with many employees are more likely to be located in well-connected areas. It is also important to note the particular case of airlines and cruises or large ships who already have Internet service on board, even though could contract the service to offer connection at a lower prices, high velocity (less time-delay due to the latency) and without the risk of poor connectivity in remote areas.

- **Business to Government (B2G)**: this segment is made up by all those agencies and organisations that are part of governments. Although the service could be accessible to all governments around the world, the most likely to use it will be the United States, as Starlink is an American company and would have fewer problems with sensitive issues, such as confidentiality. In this market segment, the service would support government agencies operating in remote areas with lack of Internet access. For example, they could easily provide internet to the US army or US Navy when they are developing missions in areas with poor coverage (or no coverage at all). Another good example could be the space agencies (e.g. NASA or ESA) which could contract the Starlink service when they are experimenting in the upper atmospheric zones (below the 100 km of the Karman line) and need to connect to the network easily.

6.2.2 Value proposition

Starlink creates value for the different market segments described in the previous paragraphs in a different ways, which make the company a benchmark not only in the VLEO satellite sector, but also in the high-tech market in general terms. The company builds its value proposition around the following elements:

- **Broadband Internet service worldwide:** Starlink wants to be the first company to cover the entire surface of the earth with a high-speed Internet connection. This is a very attractive innovation in the market, as there is currently no company offering quality Internet anywhere in the world (there are satellite Internet companies, especially in GEO orbits, as seen in the state of the art with Telesat, Hughes Net..., but they operate in certain areas, without achieving perfect broadband global coverage as Starlink intends to do. To achieve this, Elon Musk's company plans to put into orbit a large constellation of Very Low Earth Orbit satellites, around 42,000, as mentioned in previous sections.

- **Lower latency times:** one of the great benefits of VLEO orbits is their proximity to Earth, which allows the data exchange time with satellites to be shorter than in higher altitudes, such as MEO or GEO orbits. This attribute constitutes a clear performance improvement, as it enhances the usual way in which the satellite Internet sector creates value: it does not just provide Internet as geostationary orbits do, but also does so at high speed, reducing signal time delay. This lower latency greatly increases the company's market, as it allows users to use the service offered for applications that were previously difficult to do due to the slow speed of satellite Internet, such as playing online video games or making video calls.

- **Lower prices:** in relation to the previous point (and it as has been repeatedly mentioned throughout this thesis), another of the most outstanding benefits of these low altitude orbits is that the price of putting satellites into orbit is lower than with higher trajectories. Moreover, in the specific case of Starlink, being part of SpaceX allows it to have many competitive advantages in the price of designing, building and launching the satellites. Therefore, although Starlink's price may not be lower than other competitors in the short term, it is expected to be lower in

the future, once the initial investments start to be covered. The company's CEO and founder, Elon Musk, has remarked on this on numerous occasions, the last in 2020 [59].

- **Personalised service:** another aspect that adds value to the company studied is its customer service. Starlink, despite being an international company, bases a large part of its strategy on personalisation, which it mainly develops using the Starlink app, a mobile application that is already available on the market and has many functionalities. These include locating the best place to receive the Internet signal according to the customer's geography, as well as an interactive guide for installing them and a study of possible factors that could interfere with the connection based on the customer's location. In addition to this, it also allows the monitoring of the connection status and it offers direct contact with the company to resolve any doubts or incidents as quickly as possible through the contact support option, as well as the possibility of offering possible new ideas for improving the service (as it is in Beta version). In this way, the customers perceive the value of being in direct contact with the company, and also the important fact that it adapts to their geographical particularities in order to give the best possible service.

- **Quality and innovation commitment:** as part of SpaceX, one of the most innovative companies on the planet and a leader in the space industry, customers feel the Starlink commitment to innovation and quality: they are part of the company, knowing that they are betting on a prestigious brand in the world of technology. Proof of this quality is the collaboration of SpaceX with prestigious government agencies, such as NASA in space transport, as well as the commitment of its CEO and founder, Elon Musk (one of the most successful entrepreneurs on the planet), to continue researching to improve the service and its performance, as he has done with other companies he owns (e.g. Tesla), which have become the reference leaders in their respective sectors.

- **Service reliability:** similar to the point above, being part of SpaceX also gives customers a sense of security and reliability that is not available in other companies offering broadband satellite Internet. Thus, although the service is still in Beta version, current and future customers are aware that the quality of the connection and the service in general will improve in the future. Moreover, the fact that

the FCC has processed almost 12,000 licenses to the company also reinforces this confidence, as it provides future prospects for the business (which is reinforced with the fact that Starlink has its own rockets to launch satellites as part of SpaceX). A clear evidence of this enormous confidence and customer trust in Starlink and its long-term service are the 10,000 current customers and around 500,000 pre-orders the company has received over the last year, as mentioned in the previous sections.

- **Environmental commitment**: in a similar way to the price, this value-adding proposition is not yet perceived, but it is expected to be very decisive in the future. As explained in depth in the case study, one of the factors that most concerns consumers and governments nowadays is the environmental impact that may be generated by the deployment of satellites planned for this decade. In response to this, the company has stated that it is working on two main lines of action: the development of a system to make satellites invisible for a period after their launch (approximately one week) and the satellites darkening by means of a deployable visor. In this way, although the systems are not yet implemented, customers perceive the Starlink commitment to the environmental impact in light pollution, and are certain that they will become a reality imminently. Furthermore, they are aware of the CEO's (Elon Musk) environmental commitment to pollution in all aspects; proof of which is the electric cars brand developed a few years ago: Tesla.

- **Cost reduction to B2G:** finally, it is also important to remark a value proposition that mainly affects the business to government segment. This last element part of this CANVAS block is basically the cost reduction that the deployment of a global Internet coverage would imply for governments, since it would not be necessary to develop large infrastructures that require a lot of investment. For this reason, many countries see Starlink as an opportunity to reach rural areas without the need to invest in theses expensive infrastructures, which may help them to commit to the company with long-term contracts. A clear example of this is the case of the United States, a country with many rural areas that are still unconnected and where it is extremely expensive to deploy terrestrial infrastructure to provide high-speed Internet. For this reason, it is common for the government, through its agencies, to fund companies that contribute to this mission: the clearest example is the almost 900 million dollars that Starlink receive from Federal Communications

Commission (FCC) last year, as a part of the *Rural Digital Opportunities Fund* program mentioned in the case study.

6.2.3 Channels

To communicate with its different market segments and provide its value proposition, Starlink has different channels. All these channels are company-owned and can be classified as direct channels, as they are based on a sales team (B2G sector and part of B2B) and Internet sales (B2C segment and part of B2B). Indirect channels, such as third party shops or wholesalers, are not used in any case.

- **Starlink official website:** this is the company's most important channel, as it provides information on the value proposition offered, as well as managing the entire purchasing process and part of the service delivery. The URL address of this website is: *https://www.starlink.com/*. Its functions include information about the high-speed broadband Internet service provided by the company, as well as helping potential customers to evaluate the value proposition, providing data about some of the most important characteristics of the service: Internet speed, ease of installation, applications that it can be accessed... Finally, it also manages the entire process of acquiring the service, as it allows customers to pre-order and manage the shipping address, as well as making the first payments to be made once the service is purchased: first monthly fee and Starlink kit.

- **SpaceX official website:** although not as important as Starlink website, the website of SpaceX also plays an important role in the processes of informing about the value proposition and helping customers to evaluate this proposition. The URL address is: *https://www.spacex.com/*. It is important to note that Starlink, despite being an independent company, was born as a SpaceX project and the last remains as its most important key partner, as they share resources and employees. Therefore, it is common for the SpaceX website, despite not being able to order the service, to provide information on the advantages and qualities of Starlink, as well as updates on the new satellites that are being put into orbit (for example, the following [43]).

- **Starlink app:** this is the company's most important element for maximising the customer's after-sales experience. It is already available for smartphones and can be accessed by all customers who have purchased the Starlink service. Its most important applications include providing assistance during the delivery of the value proposition, such as installation instructions for the Starlink kit or monitoring the status of connections. It also allows direct contact between customers and the company, as consumers can propose improvements to the installation system and the service (it is important to remember that the service is still in the Beta phase), and allows technical incidents to be resolved quickly through the *Customer support* option.

- **Cloud services:** another type of channel that also plays an important role in the after-sales experience is cloud services. In Starlink case, these will be Microsoft Azure and Google Cloud, which will operate from the second half of 2021 [46]. These services, in addition to proposing a better experience (faster and more secure) in customer connectivity, allow the company to anticipate the needs of consumers: for example, if they need more storage space, if their connection is slower than normal, etc.; Thus, it is an important channel, which should also be taken into account, as it helps to convey the Starlink value proposition.

- **Sales team to B2G:** the channels previously described applied to whole B2C and a large part of the B2B market segment. Nevertheless, Starlink can also offer services to the B2G sector, which does not typically use the channels presented above, as these are large organisations with very specific needs. For this reason, the channels with Business to Government market segment (and also with some companies in the B2B sector) would be integrated by a Starlink sales team, which would negotiate directly with the client and would be in charge of managing the entire communication process; this team would develop the functions of informing the product (making it known to the company or government agency in question in a formal way), evaluating its value proposition (through tests of its good performance, for example), managing the purchase process (negotiating the price, possible discounts...), and the delivery of the product (installation, delivery process). Finally, the sales team would be the responsible of the after-sales experience of this market segment, through regular meetings and responding to possible accidents and notifying the company's technical services.

6.2.4 Customer relationships

An important key factor behind Starlink success is the type of relationships it maintains with its different market segments. Despite being a multinational company and offering its service worldwide, the company tries to offer a relationship that is as personalised as possible, with the intention of building loyalty among existing customers and, in addition, attracting new customers to this type of attention. In this case, these customer relationships are developed in two main ways:

- **Starlink app for B2C and part of B2B:** consumers receive personalised and exclusive attention through this application; in other words, they interact directly with company employees, who advise them on the installation of the signal receivers, resolve doubts about the service use, deal with possible technical incidents in real time... This fact, which had already been described in a similar way when explaining the channels for the after-sales experience, would be applicable to the B2C segments and part of B2B (those companies that do not have a lot of employees and do not require a large number of connections and signal receivers). This method is clearly aimed at customer loyalty, as they feel part of the company, although it also adds value to the service and can be used to attract new customers by this personalised attention. Starlink app not only offers this personal assistance as part of the customer relationships strategy, but also allows customers to collaborate in improving the service, as it is in Beta version. For this reason, customers can participate in the collective creation of value by writing comments on the functioning of the service, aspects to be improved for the future, possible innovations..... In this way, existing customers, who are aware that the company is genuinely committed to innovation in order to improve the service in the future, are retained, and new customers can also be attracted by this strategy, which allows them to participate in the creation of value.

- **Professional sales team for B2G and part of B2B:** the customer relationship strategy for the business to government segment and for some companies in the business to business sector (those that need a far-reaching service because they have many employees) is different from the previous one. In this case, Starlink uses exclusive personal assistance by means of a professional sales team, made

up of members from different departments of the company, who comprehensively manage everything related to the specific customer: from the negotiation process to the purchase, installation, possible technical incidents or service extensions (this highly personalised relationship of the company with the B2G sector and part of the B2C sector has already been mentioned above). This strategy allows for a high degree of loyalty on the part of the members of this consumer segment (a fact that explains, to a large extent, why the contracts are of such a long duration) and, furthermore, responds to their needs, as governments, agencies or large companies normally require highly personalised and exclusive attention (i.e. for reasons of security, confidentiality, etc.).

6.2.5 Revenue streams

Depending on the market segment it targets, Starlink has three main revenue streams, which can be identified below:

- **Monthly subscription fees for B2C and B2B:** these revenues are monthly incomes and their payment allows customers uninterrupted access to the high-speed broadband Internet service offered by the company's satellites. It is currently priced at 99 $, but it is expected to decrease in the future. This revenue stream would apply to both individual consumers and businesses, although with a slight difference: while regular consumers would pay a single subscription fee, businesses, which tend to need higher speeds to avoid network saturation (especially if they have many employees), could pay more than one fee to ensure that the quality of the service does not decrease. Therefore, in the case of the B2B sector, negotiation according to the size of the company would also be involved in determining the number of subscriptions (thus, the price could be dynamic), whereas in B2C the monthly revenue would be individual and equal for all consumers (fixed price regardless of the customer).

- **The Starlink kit for B2C and B2B:** this revenue is the income Starlink earns from the sale of an asset: the kit with all the material and hardware necessary to be able to receive the satellite Internet signal. It is currently priced at 500 $, although, as with the monthly fee, it is expected to decrease in the coming years.

The income is, therefore, a single payment, reason why it does not constitute a monthly fee. Despite that, the differences between the B2C and B2B sector would be very similar to the previous case: while individual consumers would pay for a single product, businesses would possibly have to purchase more than one kit, especially if they have a large number of employees, as they would need several signal receivers and Internet repeaters throughout their premises to avoid network congestion that would disrupt their normal activity. For this reason, in the B2C sector this source of revenue would always be the same with its price fixed, but in the B2B sector there could exist negotiation of the price (which would not be fixed) depending on the size of the company purchasing the service.

- **Long-term contracts for the B2G:** these would be revenues derived from the provision of satellite Internet services to governments and government agencies. These organisations work differently from individual customers and businesses, which is why they tend to enter into long-term contracts, ensuring stability and confidentiality (especially if the military is involved). For this market segment it is not possible to establish a reference price, as it will vary greatly depending on the government or organisation to which the service is provided. Therefore, for the B2G sector there is one key element that will set the revenue stream: the negotiation. Prices will be totally dynamic and, depending on many variables (duration of the contract, amount of service required, type of organisation, confidentiality requirements...), an income will be established, which may be punctual or divided into different payments, also depending on the needs of the agency or army contracting the service.

6.3 Costs side

The costs side section describes the four modules from CANVAS BM that Starlink needs to create and distribute value: the key resources, which are the most important elements that enable the company operation; the key activities, made up by the essential company actions in accordance with its business model; key partners, composed by the organisations and suppliers without which the company couldn't exist; and, finally, the costs structure, which are a summary of all the costs of Starlink.

6.3.1 Key resources

The exclusive value proposition offered by Starlink requires a very unique set of resources to create this proposition, as well as to deliver it to the customers. In addition to this, it is important to note that Starlink operates in a very complex high-tech market, which is why these resources are vital and very difficult to find and replace. The most important assets that enable the operation of Starlink business model are presented below.

- **SpaceX rockets for launch operations:** within the shared resource policy of Starlink and SpaceX, one of the most important elements is the availability of rockets to support Starlink satellites launch operations. These operations, which are normally the most expensive part in a space mission (due to the enormous costs of infrastructure, fuel, materials, etc.), are much cheaper for Starlink than for an external company that wants to put a payload into orbit using SpaceX services. It is, therefore, an extremely important physical resource that allows Starlink to offer one of the most important points of its value proposition: global Internet coverage through a very large constellation of satellites. That is, by owning SpaceX rockets, the company can afford a lot of launches (it plans a total of 42,000 by the end of the decade, and currently puts about 120 objects into orbit each month, a rate that is increasing), thus obtaining a constellation that leaves no corner of the Earth surface without service. This gives it a competitive advantage over other satellite Internet companies, which cannot afford to deploy such large constellations because of the cost of outsourcing the launch infrastructure and rockets would be too high.

- **Very Low Earth Orbit satellites:** another of the Starlink key resources are the satellites it uses to provide the broadband Internet service. These, which are mainly designed and manufactured by SpaceX, allow the company to offer one of its most relevant value propositions: lower latency times (and, consequently, more applications and navigation capacity), a benefit obtained thanks to the fact that these satellites operate in Very Low Earth Orbits. This is, therefore, another physical resource composed of the satellites and the technology they incorporate, which allows them to orbit in VLEO, taking advantage of the benefits provided by these type of altitudes. In addition to reducing this time-delay, it also reduces the cost or risk of mission failure and the associated costs of replacing the satellites when

they reach the end of their useful life; for this reason, it is clear that these satellites are indispensable for the company to operate and offer its service, differentiating itself from the competitors by using different trajectories to the majority, which adds enormous value to its already attractive value proposition.

- **Qualified employees:** in Starlink business model, human resources are vital to be able to offer the final service to consumers, as it is a service that requires high technology and workers with a lot of technical knowledge in many fields of applied sciences: telecommunications, physics, mathematics, mechanics... For this reason, people are very important within the company studied, as they are a human factor without which it would be impossible to be one of the world's leading high-tech companies. As mentioned above, workers are a shared resource with SpaceX, which is why there is no official data quantifying the exact number of workers involved only in Starlink (because of there are employees who can work on Starlink and also on other SpaceX projects, such as Starship). In total there are more than 9,500 employees at SpaceX (many of whom are fully or partially dedicated to Starlink), the majority of whom are qualified professionals with many years of experience in the all the engineering fields (aerospace, mechanical, telecommunications...). Furthermore, proof of their value and qualities is the fact that the interviews and the process to join SpaceX are very difficult (one of the most difficult in the world, according to [60]), and are conducted by the CEO of the company himself, Elon Musk, considered an eminence in the field of technology and one of the most innovative people in the world.

- **Powerful investors:** Just as the human factor is very important considering the market in which Starlink operates, financial resources are equally or even more fundamental than the above, as the investments required to deploy a constellation of telecommunications satellites are very high (and even more so if the target of 42,000 is to be reached). For this reason, it is extremely important for Starlink to be able to finance itself through various channels and thus ensure that it can continue to develop its value proposition. The company has a number of different funding streams, the vast majority of which are made up of private companies and organisations. For example, SpaceX is one of Starlink's major investors (a logical fact, as they share the vast majority of resources), but also other high-tech companies, which see the enormous potential of the company (such as Google, which

invested almost a billion in 2015 to help develop the first satellites) are a significant financial resource base. Also noteworthy are some of the public investments that Starlink receives as part of development strategies and digitisation of rural areas (the most important of which was almost 900 million from the FCC). In reference to the above, it is worth noting that the company, should it require financing in the future to complete the deployment of its constellation, is planning an IPO (Initial Public Offering) [61], which would allow Starlink to go public and attract more private investors.

6.3.2 Key partners

Starlink has many partners, as the type of service it offers is very complex and it needs the collaboration of many companies to be able to offer its final value proposition. It is important to note that, while in the case study all the company's main partners have been described, in the following section only the most important ones are mentioned, without which it would be impossible for the company to offer its value proposition. For example, the cloud services offered by Microsoft are not indispensable, as Starlink could contract them from many other companies (Amazon or Google, for example), but the satellite design or launch services offered by SpaceX are essential, as there are no other companies that offer them at the price and quality offered by SpaceX. Taking into account the above, the key partners of Starlink are the following:

- **SpaceX:** undoubtedly, it is the Starlink most important partner. In fact, the company studied was born as a SpaceX project until it was decided to split it into a different company - since the value proposition changed a lot -, although maintaining some common elements, such as the cost structure (employees, facilities, some member of the executive committee...). The most important activities and resources provided by SpaceX are the design of the satellites that provide the service, as well as a large part of their construction and their launch using the company's rockets. Thus, it is a very important partner, as it helps to optimise resources and maintain the scale economy (which is also one of the major barriers to entry in the satellites industry for new companies); i.e. SpaceX enables Starlink to reduce the enormous costs of having to design all the satellites, build them and launch them. For this reason, the rocket company is classified as a key partner,

since without them it would be impossible to offer the Internet service.

- **FCC:** although it is not a private company (it is a government agency that depends on USA government), it can be considered a partner because it is essential to Starlink operation. In fact, without the collaboration of the FCC, the company would be unable to deliver its value proposition, as it is this commission that is responsible for processing the licences that allow the deployment of satellite constellations at different altitudes. In this sense, the Federal Communications Commission is essential to ensure continuity of service and is a risk-reducing partner, since when it grants new licences to Starlink, it confirms that the service will continue in the future. Therefore, it reduces the uncertainty associated with whether it will actually be able to deploy the desired constellation, a recurring concern for potential customers, which is greatly reduced with the FCC (in fact, as it has already been mentioned numerous times, almost 12,000 licences have already been processed and 30,000 more are expected for this decade). In addition to this, it is important to note that this partner also provides funds to the company on some occasions, as it usually rewards financially those companies committed with the digitisation of rural areas in the USA. The clearest example of this is the almost 900 million euros that Starlink received last year as part of phase 1 of this FCC digitisation process. In the coming years, it is expected that agencies and governments in other countries will also invest in digital development strategies and become key partners of Starlink.

- **Google:** Google's case is different from the two previous ones, as the company offers a very specific service to Starlink customers: cloud services. In other words, it is a very specific activity that, although it is not as significant and does not contribute as significantly to the optimisation of resources as SpaceX, it adds value to the service - especially, more functionalities - and it reduces the costs that Starlink would incur if it had to develop its own cloud service. Despite that, Google has not been included in this group of key partners just because of the service described above (as other companies, such as Microsoft with its Azure platform, also provide these services to Starlink); it has been taken into account because Google is also one of the company's major investors. This investment, which started with the amount of almost 1 billion dollars five years ago [45], helps Elon Musk's company to be able to deploy the constellation and to make the

multi-million dollar investments required for the service offered. Moreover, it is possible that this investment shall grow in the next year, since Google left recently the Loon project [62] (with the aim of providing Internet worldwide ,in a similar way to Starlink, but using balloons instead of VLEO satellites), reason why Google is an important partner nowadays but it could become more essential in the next years.

6.3.3 Key activities

In order to make its business model work, Starlink develops some very important activities that allow it to deliver its value proposition or build relationships with customers, among others. The most important activities are described in the next paragraph:

- **Constellation tracking:** this is probably the most important activity that enables the company to offer its value proposition. An efficient management of the satellites that make up the constellation is essential to ensure the proper operation of the service for all consumers around the world. This activity is complex and requires a large number of processes (many of which are developed entirely by SpaceX), ranging from monitoring that the trajectories are correct or verifying the signal emitted to forecasting the life cycle of the satellites in order to replace them in the shortest time. Therefore, being efficient and making good decisions in constellation management is vital for Starlink business model to work. In this way, constellation management can also help to improve the value proposition by uncovering potential service needs (e.g. areas with poor satellite coverage or high frequency noise) and allowing the company to find solutions to these needs.

- **Ground stations management:** while the previous section described the importance of good maintenance of satellites in orbit, this section highlights another vital activity for Starlink: the efficient management of ground stations. Just as broken satellites can cause service disruptions and penalise customers, problems at the ground stations can have exactly the same effect or even worse, as these facilities are the centres responsible for receiving the satellite signal and processing it in order to subsequently offer the broadband Internet service to consumers. Similarly, this station management includes many processes, although the most important ones

are to ensure that it is in good condition and to continuously monitor the status of the connections in case there are problems with any of the receivers available. In this way, if the monitoring is rigorous, imminent or already existing situations of danger can be detected, allowing rapid action to be taken and avoiding serious disruptions to the service.

- **Innovation, research and development investment:** as part of SpaceX, one of the world's most powerful and important technology companies, Starlink is highly committed to researching and pursuing new technologies and processes to improve the quality of its service and customer experience. For this reason, one of its key activities is its annual investment in researching and developing new ways to improve its current service. Although there is no official data on the specific value, it is clear that this is one of the hallmarks of both Starlink and SpaceX, as stated repeatedly by its CEO and founder, Elon Musk. This innovative commitment also contributes to adding value to the service (discussed in the section on the value proposition) and allows it to reach markets and customers, who perceive Starlink as a high-tech company capable of improving the service it offers them in the imminent future. Moreover, the activities related to this innovation play a key role in the company's future objectives: on the one hand, to optimise the service in order to reduce costs and, thus, being able to offer to the market a price lower than the present; on the other hand, to discover new technologies and orbital trajectories that will enable it to comply with Starlink environmental philosophy, which is mainly focused on reducing the light pollution caused by its numerous satellites.

- **Customer relationships administration:** the personalised service is one of Starlink most important value propositions as, despite being a large multinational and offering worldwide service, it tries to give to each customer a unique service taking into account their needs (for example, it adapts to the geographical area of residence where the consumer lives and proposes the optimal installation location for the signal receivers). Consequently it is clear that the management of these customer relationships is another of its essential activities, enabling it to deliver its value proposition. There are two basic activities focused on this management of customer relations: on the one hand, the management of the Starlink app, an activity aimed at the B2C market segment and part of the B2B (smaller companies

with few employees) and which focuses on keeping the application operational 24 hours a day, with the aim of always being available to the customer, solving possible incidents and advising on installation issues such as the one mentioned above. On the other hand, for the B2G sector and part of the B2B sector (large companies), the key processes aimed at maintaining customer relations would not be related to this application (since this segment, due to its particular needs, does not use it) and would be based on all the activities carried out by Starlink professional sales team, mentioned in previous sections, and which encompasses the processes of negotiation, product purchase, management of technical incidents, etc.

6.3.4 Costs structure

The following section defines the most important costs that Starlink incurs when operating its business model. The company follows a clearly value cost structure, as it offers a high-tech, and complex service aimed at providing a differentiated and personalised service to the customer. It does not, therefore, seek extreme price minimisation by basing its strategy on cost, as this would be incompatible with its value proposition; moreover, this cost structure is more common in markets with strong competition in order to use cost reduction to adopt an aggressive pricing policy (which would not make much sense, since, as seen in the state of the art, Starlink has only a few competitors currently).

The Starlink cost structure can be classified into two main groups: fixed and variable. Fixed costs are those which do not vary according to the volume of service produced, while variable costs are characterised by the fact that they are directly proportional to the quantity produced. Apart from the above, some elements of this cost structure also constitute economies of scale, as will be discussed in the following paragraphs.

Fixed costs

- **Employees:** in the majority of companies, this element is a fixed cost that is always present, and Starlink is not an exception. As it has been seen in previously sections, the human factor is one of the key resources of the company studied, reason why the employees are largely qualified and highly paid, becoming an important fixed cost. The exact number of the 9,500 workers of SpaceX dedicated to Starlink is

not known exactly, although it is a value that will not vary significantly depending on the amount of service produced, since their function is not to manufacture the satellites, but to add value to the product through the tasks they perform in the different departments of Starlink: researching new ways of innovation, developing the marketing and supply strategy, monitoring the status of the constellation... The only conditions in which employees could stop the constitution of a fixed cost would be short periods with extraordinary demand, which would mean having to expand the workforce and the obligation to hire on a variable basis.

- **Physical installations:** another common fixed costs are the facilities required to create the value proposition and maintain it over time. In the specific case of Starlink, these costs would be its headquarters in Seattle, from where the different departments coordinate together to monitor the constellations, develop the different strategies for innovation, communication, pricing, etc., as well as the different ground stations around the world, which enable the processing and sending of the Internet signal, and other specific facilities that the company might have (for example, specific customer service centres in some parts of the world). As with the human factor, the fixed costs are independent of the amount of service produced (ground stations, for example, will remain the same unless the number of satellites increases significantly in a very short time) and will only have to increase if there is extraordinary demand (which would require hiring more workers and, as a consequence, expanding headquarters or other employees facilities).

Variable costs

- **Customer services:** One of the most important variable costs of the company studied is related to its personalised customer service. In this sense, for the B2C market segment and those smaller companies part of B2B, the cost of customer service (which is mostly done through the Starlink app) is proportional to the amount of service offered. In other words, the more service produced means that there are more customers using the service, which is why Starlink will incur in more staff and application maintenance costs, as it shall need to be able to solve more technical incidents, advise a greater number of customers with the installation of the kit, have more powerful data processing tools to prevent the application from

collapsing... For this reason, it is foreseeable that in the future, if the pre-order forecasts are achieved (it is important to remember that they reached the 500,000 a few months ago), the costs related to this customer service will increase a lot in the coming years.

- **Professional sales and negotiation staff:** this cost would be similar to the previous one, as it is also directly related to the personalised customer service offered by Starlink as part of its value creation and communication strategy, but in this section applied to a different market segment (B2G and the part of B2B made up of large companies). These professional sales teams (formed by workers from the different departments of the company, as has already been mentioned in other blocks of this business model), are in charge of integrally managing the communication, negotiation, purchase, installation and after-sales experience of the value proposition offered. For this reason, it is clear that, if more and more governments, agencies or large companies decide to contract Starlink services, the company shall need to have more sales staff capable of negotiating with these customers, who have very specific needs but are very interesting to attract due to their enormous purchasing power and their tendency towards long-term contracts. Therefore, the cost associated with these negotiation staff will rise as the service offered to this market segment increases, phenomenon expected in the coming years.

- **Starlink kit delivery:** while some elements of the company (e.g. facilities or number of employees) do not change significantly when the amount of service produced changes, there is one cost that does depend on production: the cost related to the entire production infrastructure of the Starlink kit. If the number of consumers increases, the demand for this kit, which includes all the necessary equipment (router, cables, power supply...) to receive the broadband Internet connection, will also grow. Consequently, the company shall have to contract more manufacturers of the various elements of the kit (which will increase Starlink costs proportionally to the demand increase) and also more distributors and companies to deliver these signal receiving materials to each customer's address.

Economies of scale

- **Launch operations:** the average cost per unit of satellite launched decreases greatly as production increases. In other words, if Starlink is able to obtain more licences from the FCC in the future and develops all the necessary infrastructure to be able to design and build satellites at a higher rate (financial resources, new factories, etc.), it will gain a competitive advantage because the more satellites it launches, the lower the unit price of launching each satellite. The reason of this is that, in the case of SpaceX, the approximate unit price for 1 kg of payload is $1,500 (according to [63]), but the price decreases as mass is added (always within a limit set by the company). Thus, launch operations constitute an economy of scale in the case of Starlink, as long as the company is able and has the necessary resources (especially financial) to produce satellites at the current rate (approximately 120 per month) or even faster, which would allow it to further reduce the unit satellite cost of each rocket launch.

- **Ground stations:** The case of ground stations is similar to the above. The more satellites Starlink produces, the lower the unit cost of each satellite relative to the number of ground stations deployed. Therefore, these ground stations also constitute an economy of scale, since the average cost associated with each ground station decreases as satellite production increases. In other words, Starlink decides to deploy several ground stations around the world in order to be able to process the signals from its satellites and provide Internet service to consumers worldwide. Hence, the initial investment is huge and, if the price of each ground station is counted against the number of satellites currently deployed, a very negative ratio is obtained. But if the satellites are produced at a higher rate in the future, there shall be more satellites in operation, which does not generally require the construction of a new number of ground stations. Moreover, the cost of adding signal management for new satellites is very residual; for this reason, producing more satellites would lower the average cost of ground station management, which is why Starlink is interested to maintain high production (nevertheless, this does not depend so much on it, but on investors, FCC licences to deploy new constellations...).

7 SWOT analysis

First of all, the analysis of the different strengths, weaknesses, opportunities and threats of the Starlink company is presented. To obtain them, the thesis has used the different modules presented in the CANVAS business model section, as well as the information about Starlink provided by the case study and the market data provided by the state of the art.

Figure 27: SWOT analysis of Starlink

8 Risk analysis

Once the business model methodology has been implemented, it is interesting to evaluate the effect that external factors (threats and opportunities) may have on the company, as well as the necessary actions to mitigate their effect (in the case of threats that constitute risks) or amplify them (in the case of opportunities). For this reason, this risk analysis is carried out, in which these risks and opportunities are identified using a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of Starlink. Then, the different risks shall be studied quantitatively by assigning a probability and impact according to various factors and, finally, they will be presented visually within an overall risk matrix.

8.1 Risks matrix

The risk matrix shall allow the allocation of the different threats and opportunities extracted from the SWOT analysis. This element consists of the probability (in percentage) of the event happening (placed in different rows) and the quantified impact between 1 (minimum) and 5 (maximum). Depending on these two factors, the risk or opportunity will be allocated in a certain position in the matrix, which will dictate whether it is negligible, minor, moderate, significant or severe. The size of this matrix, as well as its internal distribution has been provided by the thesis director in a thesis seminar [64], who has elaborated it using rigorous information sources.

Table 8: Risks matrix definition

	IMPACT									
	1	2	3	4	5	5	4	3	2	1
PROBABILITY	**Threats**					**Opportunities**				
(80-100)%	Low Risk	Moderate Risk	High Risk	Extreme Risk	Extreme Risk	Extreme Risk	Extreme Risk	High Risk	Moderate Risk	Low Risk
(60-80)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	Extreme Risk	Extreme Risk	High Risk	Moderate Risk	Low Risk	Minimum Risk
(40-60)%	Minimum Risk	Low Risk	Moderate Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	Low Risk	Minimum Risk
(20-40)%	Minimum Risk	Low Risk	Low Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Low Risk	Low Risk	Minimum Risk
(1-20)%	Minimum Risk	Minimum Risk	Low Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Low Risk	Minimum Risk	Minimum Risk

8.2 Risks and opportunities identification

Once the risks matrix has been defined, the next step is to provide the description of each threat and opportunity previously identified in the section [7] SWOT analysis.

- Risks
  - **R.1**: the main competitors of Starlink (currently mainly operating at GEO altitudes) are offering lower prices for satellite Internet.
  - **R.2**: new high-tech companies, with a lot of financial and human resources are starting to invest in the satellite communications market, such as Amazon with its Project Kuiper, reason why the dangerous competitors could grow a lot in the next years.
  - **R.3**: Starlink is seen as the dominating company in the VLEO and LEO telecommunications market, so a lot of companies are trying to stop its growth. For example, ViaSat is requesting FCC to revise the licenses given to Starlink, because of they want to stop the company's launches [65].
  - **R.4**: some environmental organisations and researchers, such as William Ailor [66] are trying to stop Starlink activity, arguing the dangerous effects of the light pollution produced by the satellites.
  - **R.5**: satellite collision with other Starlink satellites operating at VLEO altitudes (it could be a full collision between two satellites or a hit with space debris from an old satellite).
  - **R.6**: satellite collision with the International Space Station (ISS), which is operating at VLEO altitudes, between 370 and 460 km (according to [67]).

- Opportunities
  - **O.1**: the presence of private investors is growing the last years due to the New Space phenomenon, so Starlink could fins new funds.
  - **O.2**: the market demand is very high, because of there are a lot of areas in the world with lack of Internet access.

- **O.3**: Starlink is a pioneering company offering high-speed broadband Internet (with lower latency times than GEO providers), reason why it can reach most of the market demand in these first years, without competitors operating at VLEO and LEO altitudes.
- **O.4**: some governments are committed to invest in the digital development of rural areas, which means that the B2G segment could have a lot of growth potential. A clear example is the almost 900 million $ received from FCC last year.
- **O.5**: the environmental and space ownership laws are not clear, so the FCC is processing a lot of satellite launch licenses in the last years.
- **O.6**: the Very Low Earth Orbits are being deeply studied (e.g. by the DISCOVERER project) by a lot of research centres and private companies, reason why new technologies could be discovered in the future, so the costs of deployment and environmental impacts of the constellation could decrease significantly.

8.3 Impact and probability assessment

The probability and impact of each of the risks and opportunities identified in the previous section shall then be assessed. To assign these two attributes, two criterion will be implemented: on the one hand, a qualitative criterion for probability, based on the market information provided in the state of the art and the company data presented in the case study; on the other hand, a quantitative criterion for impact, which will be focused on three areas of affectation, each of which will receive a percentage of the total impact:

- **Quality impact (QI)**: in the case of Starlink, this is a very important impact, because of, as seen throughout the thesis, the company is focused on the quality as the most important part of its value proposition. The percentage of the total impact for the quality shall be the **33%**.
- **Schedule impact (SI)**: the competence of Starlink is growing nowadays and the company's service is still under development, reason why the delays caused by the

different risks are very important too. The percentage of the total impact for schedule shall be the **33%**.

- **Economic impact (EI)**: the cost is a key factor in all the companies, which try to reduce it as much as possible. Despite that, Starlink has a lot of financial resources and is aware off the large investments needed to deploy the constellation planned, reason why this impact shall not be the most important (as it is the case in the majority of companies), and its percentage will be the same as the quality and the schedule, a **33%**.

Consequently, the expression which allows to obtain the total impact (TI) is:

$$TI = 0,33 \cdot QI + 0,33 \cdot SI + 0,33 \cdot EI \tag{2}$$

Where the values of quality, schedule and economic impact are assigned in a range from 1 (minimum) until 5 (maximum impact), rounding up to the nearest integer.

Table 9: Impact and probability assessment

Risk	Probability	Impact				Associated Risk
		QI	SI	EI	**Total**	
R.1	**80-100 %**	1	3	3	**2**	Moderate Risk
R.2	**20-40 %**	2	4	3	**3**	Low Risk
R.3	**40-60 %**	1	5	3	**3**	Moderate Risk
R.4	**1-20 %**	1	4	2	**2**	Minimum Risk
R.5	**1-20 %**	5	2	4	**4**	Moderate Risk
R.6	**1-20 %**	3	2	5	**3**	Low Risk
O.1	**40-60 %**	3	3	5	**4**	High Risk
O.2	**80-100 %**	2	3	4	**3**	High Risk
O.3	**60-80 %**	2	1	4	**2**	Low Risk
O.4	**60-80 %**	2	3	5	**3**	Moderate Risk
O.5	**20-40 %**	2	5	2	**3**	Low Risk
O.6	**60-80 %**	5	2	3	**3**	Moderate Risk

8.4 Risks and opportunities preliminary allocation

Once the risks have the impact assigned, they have to be allocated in the risks matrix presented in the subsection [7.1]:

Table 10: Risks and opportunities: preliminary allocation in risks matrix

IMPACT										
	1	2	3	4	5	5	4	3	2	1
PROBABILITY	Threats					Opportunities				
80-100 %		R.1						O.2		
60-80 %								O.4 O.6	O.3	
40-60 %			R.3				O.1			
20-40 %			R.2					O.5		
1-20 %		R.4	R.6	R.5						

8.5 Risk response

One of the main objectives of any company is to reduce the impact of its risks and increase the impact of its opportunities. For this reason, this risk analysis also includes a study of the possible responses that Starlink could give to the previously defined risks and opportunities, as well as a new allocation in the risk matrix according to the reduction (in the case of the risks) or increase (in the case of the opportunities). The different responses have been provided and summarised by the thesis director in the already mentioned reference [64]:

Type of response	Use for risk or opportunity	Description
Avoidance	Risk	Eliminate risk by accepting another alternative, changing the design, or changing a requirement. Can affect the probability and/or impact.
Mitigation (control)	Risk	Reduce probability and/or impact through active measures.
Transfer	Risk	Reduce probability and/or impact by transferring ownership of all or part of the risk to another party, or by redesign across hardware/software or other interfaces, etc.
Acceptance	Risk and opportunity	Adopt a wait-and-see attitude and take action when triggers are met. Budget, schedule, and other resources must be held in reserve in case the risk occurs or opportunity is selected.
Share	Opportunity	Share with another party that can increase the probability and/or impact of opportunities.
Enhance	Opportunity	Increase probability and/or impact of opportunity.
Exploit	Opportunity	Take advantage of opportunities.

Figure 28: Risks and opportunities response. Extracted from [64].

The previous risk responses have been applied in the risks and opportunities identified, taking into account all the information collected about Starlink along the project, in order to select the better measures, aligned with the company's objectives. The information has been summmed up in a similar way to the impact assessment table.

Table 11: Risk response: new impact and probability assessment

Risk	Initial Risk	Response	Measure adopted	New probability	New impact				New Risk
					QI	SI	EI	Total	
R.1	Moderate Risk	Mitigation	Increase the internal investment in I+R+D and funders research in order to find new technologies and investors to reduce costs and lower the prices.	**40-60 %**	1	2	3	**2**	Low Risk
R.2	Low Risk	Acceptance	N/A	**20-40 %**	2	4	3	**3**	Low Risk
R.3	Moderate Risk	Transfer	Engage legal services to take action against ViaSat for unfair competition and to ensure the validity of the licenses from Starlink.	**20-40 %**	1	3	3	**2**	Low Risk
R.4	Minimum Risk	Acceptance	N/A	**1-20 %**	1	4	2	**2**	Minimum Risk
R.5	Moderate Risk	Mitigation	Develop an effective replacement plan in order to act efficiently in the event of a collision, reducing the service damages.	**1-20 %**	3	2	3	**3**	Low Risk
R.6	Low Risk	Mitigation	Develop an agreed emergency plan with NASA to act in case of a possible collision.	**1-20 %**	2	1	3	**2**	Minimum Risk
O.1	High Risk	Enhance	Apply new measures in order to attract new private investors (an IPO, for example)	**60-80 %**	4	5	5	**4**	Extreme Risk
O.2	High Risk	Acceptance	N/A	**80-100 %**	2	3	4	**3**	High Risk
O.3	Low Risk	Enhance	Intensify the marketing strategy and increase the communication channels (e.g. digital advertising) to bring its value proposition to the market more quickly.	**80-100 %**	2	1	4	**2**	Moderate Risk
O.4	Moderate Risk	Share	Offer integrated long-term contracts for B2G segments, including services from its most important partner (SpaceX) (e.g. Internet service from Starlink and astronaut transportation from SpaceX for the U.S. Government).	**60-80 %**	3	4	5	**4**	High Risk
O.5	Low Risk	Exploit	Try to obtain the maximum number of licenses in this years, before the application of new regulations in VLEO altitudes.	**40-60 %**	2	5	2	**3**	Moderate Risk
O.6	Moderate Risk	Enhance	Invest in external research and innovation sources (e.g. universities) currently studying the benefits of these types of low trajectories.	**60-80 %**	5	3	4	**4**	High Risk

8.6 Risks and opportunities definitive allocation

Finally, the new risk associated to each element has been allocated in a new and definitive risk matrix. As it can be observed, almost all the risks and opportunities have been mitigated and increased, respectively, which is a key indicator that, if the company studied could apply this actions, it could achieve a better and more efficient control of the external effects, which is a key factor to success in all organisations, regardless off their activity sector.

Table 12: Definitive risk matrix

IMPACT										
	1	2	3	4	5	5	4	3	2	1
PROBABILITY	Threats					Opportunities				
80-100 %								O.2	O.3	
60-80 %							O.1 O.4 O.6			
40-60 %		R.1						O.5		
20-40 %		R.3	R.2							
1-20 %		R.4 R.6	R.5							

9 Environmental study

As the thesis itself does not have any environmental implications (beyond the electricity consumption used to elaborate it), this section shall analyse the possible environmental impacts produced by the company studied, Starlink, when offering its value proposition. These impacts can be extrapolated to other companies in the sector that operate with satellites at low altitudes (as light pollution or carbon dioxide emissions are a common factor in all of them). In addition to this, a description of the measures taken by the company to mitigate the negative impact of its activity on the environment will also be provided.

9.1 Starlink environmental impact

The company defines itself as an organisation really committed with the sustainability, specially against the light pollution, which can be observed in its official website [33]. Nevertheless, a lot of people and organisations disagrees with that (a clearly examples are the researcher, William Ailor, or the company, ViaSat, both mentioned in the risk analysis section), reason why it is difficult to measure the real environmental impact generated. In order to try to evaluate this impact, the thesis shall apply a qualitative approach, using the 17 *Sustainable Development Goals* established by the United Nations (UN) [68].

The thesis has selected which of these goals apply to the activities developed by Starlink (taking into account the amount of information collected) and, after that, the particular targets needed to achieve the goals (defined by UN) have been briefly described. With the aim of presenting the environmental impact in a visual way, the report provides a diagram, highlighting in red colour the negative elements for the environment goals, and in green colour the positive.

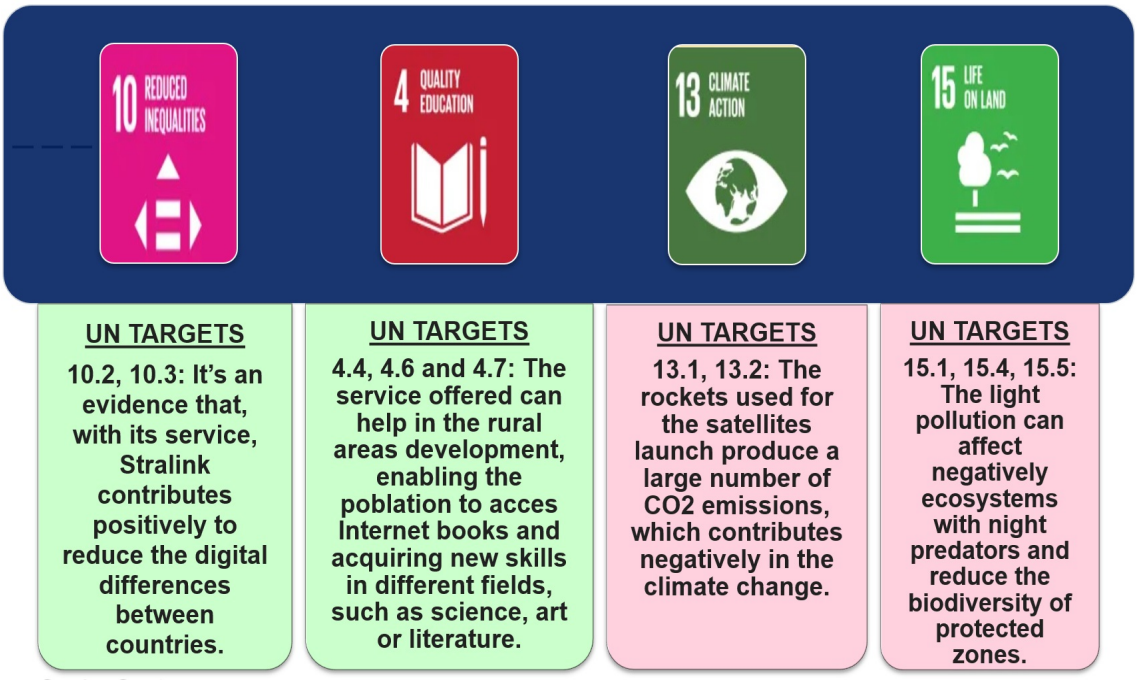

Figure 29: Starlink environmental impact.

9.2 Mitigation measures

Starlink activities have some positive aspects for global sustainable development, but they also have negative impacts. For the latter, the company plans to take some actions in order to try to mitigate these adverse effects, as its value proposition also includes a the environmental commitment. These measures are still under development, reason why the information about them is scarce and confidential.

- **Darkening constellations**: satellites trajectories shall be designed in order to become invisible to the naked eye within a week of launch [33]. Starlink has been testing the action recently, introducing modifications in the orbital mechanics with the objective of achieving a complete darkening in the next years. If this change is successfully implemented, the light pollution (one of Starlink environmental biggest problems) should be significantly reduced, which contribute to add value on the company as an environmental committed company.

- **Deployable visor:** the company includes the equipment of a deployable Sun visor in the satellites, with the aim of reducing the solar reflection and, consequently, decrease the light pollution. This mitigation measure, in a similar way to the above, is still being tested. In the last studies, the conclusions showed a growth of the 31% in the satellites darkening [69], which is positive for the company's objective of achieving higher percentages, closer to 80-90%. The reason to reach these high percentages is the negative effects that satellites can have in the astronomers data: while a darkening of 50% it's enough for reducing significantly the light pollution, it can still ruin the astronomers activity, reason why the darkening has to increase.

10 Conclusions

The initial objectives of the thesis were the study of the Very Low Earth Orbits satellite market, as well as to summarise the applications and benefits of these trajectories. Furthermore, it would exhaustively analyse the dominant company in the market, Starlink, and would apply the CANVAS business model methodology to it, which would provide a global vision of the keys to success of the VLEO and LEO satellite market in general terms.

In the state of the art, the satellite market has been first studied in general terms, and then applied to the particular case of VLEO trajectories. This study has made it possible to observe how the satellite market has grown exponentially in recent years, a fact that is motivated by the exponential growth of these satellites operating in VLEO and also in LEO in a particular application: telecommunications, focused, above all, on the Internet broadband service. This is justified for two main reasons: on the one hand, the benefits of these orbits compared to traditional GEO or MEO orbits; on the other hand, the enormous demand in today's world, where there are very high percentages of the population without access (or with very little access) to the Internet. This demand, together with the democratisation of space known as NewSpace, has led some companies and private investors to start taking an interest in the sector, such as SpaceX, which, by creating Starlink in 2015, has become the dominant satellite Internet provider. Even so, there are many other organisations starting to operate or with a plan of action for the sector in the coming years, a fact that augurs very positive growth.

In the case study, the structure and operation of the dominant company in the VLEO telecommunications market, Starlink, has been analysed in depth. Although the confidentiality that inevitably surrounds high-tech companies has made it difficult to extract information, it has finally been possible to document a large part of the company's organisational structure from reliable and rigorous sources, which has made it possible to obtain a global vision and understand its value proposition, focused on service quality, innovation, operations and customer relationships. Moreover, the economic summary has allowed to observe the extreme importance of financial resources in the sector, as well as it has reinforced the market study elaborated in the state of the art showing the positive Starlink revenues and valuation expected for the next years.

Based on all the information gathered in the case study, and also with some data from the state of the art, the most practical part of the thesis has been carried out, implementing the CANVAS business model methodology in Starlink structure. This analysis has made it possible to observe which are the key factors (the most important ones, without which it is practically impossible to operate in the sector) in the Very Low Earth Orbits sector for telecommunications applications. These factors are, on the cost side, the partners, who enable to diversify the production and certain operations (especially launch operations, which have high costs). Also in this way, having key quality resources (especially the ability to finance through private investors, partners or IPOs) is essential for a VLEO telecommunications company, as it guarantees the activity in the long term. On the value side, it is particularly important to diversify the offer, focusing on the three possible segments and, after, checking which is the most profitable (the B2C and B2B segments can be very interesting from the point of view of aggregate demand and regular incomes, but B2G is also important, as it generates long-term relationships and allows for one-off but very high revenues). In this sense, an other key factor for success are the customer relationships: it is very important to try to serve customers on a personal basis, as this is a very interesting added value, but it is also essential to do it efficiently, with different channels adapted to each customer segment, thus guaranteeing the optimisation of resources. Finally, it is clear that, as in any sector, the value proposition is the most decisive factor. It is important to offer a quality service, which is perceived as valuable by customers, and which differentiates itself from the competition. In the satellite telecommunications sector, the most relevant points to success are the quality of the service, global coverage, attention to customer needs, and a firm commitment to some aspects, such as the innovation, the reliability or the environment.

After the CANVAS implementation, a risk analysis of the company has been carried out, which showed the extreme importance of controlling external factors for companies that operate in VLEO (such as Starlink). It also has shown the importance of proactivity in risk response, as it allows the mitigation of threats and the enhancement of opportunities, facts that multiply the chances of success of a company operating in this sector.

Finally, in the environmental study, the impact of Starlink in relation to the sustainability objectives of the United Nations has been evaluated. The company studied has a positive impact on aspects related to reducing inequalities and promoting education, although it also has negative impacts, especially in relation to light pollution. In this sense, it is

important for other companies operating in the same sector as Starlink to learn from the company and be committed to reducing environmental impact through mitigation measures, as this contributes to sustainability and also adds value to the service offered.

As possible next steps, this thesis could be used to develop a business plan for a company operating in the telecommunications satellite sector. Taking into account the needs of the market, and with the Starlink structure data and the keys to success that can be extracted from the CANVAS and that have been summarised in this conclusion, this business plan could be successfully developed, which could serve, together with this work, to have a very good theoretical basis for creating a real project (for example, a start-up) that would operate in the VLEO sector applied to telecommunications.

Other lines of research could be the use of this thesis as a starting point to develop new business models applicable to other space companies. This would also be very interesting, as it would allow us to understand how the most important companies of a sector that last year was valued at more than 400 billion dollars create and distribute value. In this way, new business models would encourage innovation and the creation of new companies within the space sector which, developed in a sustainable way, can have a very positive impact on society as a whole.

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