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Study of the benefits and applications of LEO (low Earth orbit) for communications and definition of space new business models

CASE STUDY: Telesat

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PROJECT REPORT

Study of the benefits and applications of LEO (low Earth orbit) for communications and definition of space new business models CASE STUDY: Telesat

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Abstract

Having a quality connectivity service is key in the economic, educational and health development of today's society. However, current communication systems are not capable of providing full community connectivity, leaving the most remote areas underserved.

This project analyzes how the Telesat satellite operator, through its Telesat Lightspeed constellation, proposes a business model based on deploying 298 satellites in low Earth orbits (LEO) to face the most demanding telecommunications challenges, and close the digital divide between urban and rural communities by delivering a universal, fast and affordable internet service.

Therefore, studying the benefits and applications of low Earth orbits, analyzing the characteristics of Telesat and its constellation of satellites, as well as examining how it intends to carry out its value proposition and the risks it faces, are the main points on which this thesis is based.

Disponer de un servicio de conectividad de calidad es clave en el desarrollo económico, educativo y sanitario de la sociedad de hoy en día. Sin embargo, los sistemas de comunicación actuales no son capaces de proporcionar una conectividad comunitaria completa, dejando desabastecidas las zonas más remotas.

En este proyecto se analiza cómo la operadora de satélites Telesat, mediante su constelación Telesat Lightspeed, plantea un modelo de negocio basado en desplegar 298 satélites en órbitas terrestres bajas (en ingés, LEO) para afrontar los desafíos de telecomunicaciones más exigentes, y cerrar la brecha digital entre comunidades urbanas y rurales mediante la entrega de un servicio de internet universal, rápido y asequible.

Por tanto, estudiar los beneficios y las aplicaciones de las órbitas terrestres bajas, analizar las características de Telesat y de su constelación de satélites, así como examinar cómo pretende llevar a cabo su propuesta de valor y los riesgos a los que se enfrenta, son los pilares sobre los cuales se sustenta esta tesis.

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Chapter 1

Introduction

The aim and the scope of the thesis, besides the requirements and the justification of it, are presented in this introduction chapter, where the project framework is also established.

1.1 Aim of the project

The aim of the current project is to carry out the study and the simulation of the Telesat business model with the objective of analyzing the communication advantages and applications, as well as the viability, of its new low Earth orbit satellite constellation, Telesat Lightspeed.

1.2 Scope of the project

This project includes the following points:

- Research of the most important LEO network features, as well as its main advantages and disadvantages, and the different applications they have.
- State of the art study regarding the market competitors and a PESTEL analysis that allows having a general knowledge of the global situation, identifying as well the present telecommunication technologies.
- Exhaustive investigation of Telesat and the Telesat Lightspeed project, and CANVAS business model implementation.
- SWOT analysis in order to identify both the external and internal elements that could affect the company's behaviour.
- Risk study to determine the threats and opportunities the company may face.
- Environmental footprint of the Telesat Lightspeed satellite constellation.

This project does not include the following points:

- Telecommunications technical specifications.
- Detailed studies regarding the satellites orbital mechanics, launchers and subsystems.
- Description of the satellites technical data and performance.
- Blueprints of the satellites and its components.

1.3 Requirements

The overriding requirements of this project are as follows:

- The current project must meet some DISCOVERER [1] main goals, as it is part of this research group.
- This project must follow the *Universitat Politècnica de Catalunya* (UPC) normative framework for bachelor's final degree thesis.
- Both the European Union (EU) and the United States of America (USA) satellites and telecommunications regulation must be met by all the companies presented along the study.
- The CANVAS business model implementation must be part of the overall analysis.

1.4 Justification

Being able to access information immediately has become an essential factor in the personal and professional lives of most people nowadays. So much so, that the majority of society takes high-speed internet for granted. However, almost half of the world's population, especially in rural and remote areas, still do not have a good quality internet connection, which directly limits the economic growth of the region and hinders both access to education and to health services within that territory. Therefore, as high-speed internet does not only mean being able to access this service but also translates into health, prosperity and empowered communities, offering connection to everyone, everywhere, at any time should be considered a necessity.

In order to meet the goal of providing complete community connectivity, it is imperative to create a new global communication network as neither existing satellite systems nor fibre optic cabling are considered an option. On the one hand, traditional satellites that provide GPS and television services do not work as efficiently for internet connections since they are too far apart, increasing latency [2], which is the amount of time it takes for a packet of data to be transmitted and received within the network and that influences many processes, including the loading speed of a web page. On the other hand, fibre optics is only viable in cities or densely populated areas, where a large number of users can afford

the cost of installation. Logically, in rural and remote regions, where fewer people live and the terrain can be much more complex, fibre optic is not feasible.

Hence, the best solution to eradicate the digital divide and meet new global connectivity challenges, whether aeronautical, maritime or governmental, is to create a high-performance low Earth orbit satellite network, known as LEO. Recent technological advances make LEO satellite constellations ideal for global broadband connectivity. This is because LEO satellites are approximately 35 times closer to Earth than traditional ones, resulting in a shorter distance for the signal to travel, which lowers latency and makes it possible to have ultra-fast internet anywhere.

Telesat Lightspeed is the low-orbit satellite constellation of Telesat, one of the world's largest and most successful satellite operators. It aims to redefine global satellite connectivity with affordable, high-capacity links with similar speeds to fibre. It is intended to guarantee high-speed internet to all citizens, regardless of where they are and to respond effectively to the current and future telecommunication needs of society. To do this, Telesat Lightspeed has been designed to meet the connectivity requirements of leading internet service providers and mobile network operators.

Finally, it is worth highlighting that this thesis is part of the DISCOVERER project and, therefore, it shares the objective of analyzing if the business model applied to low-orbiting satellites is achivable, at the same time as economic and technically viable, for these specific purposes.

1.5 DISCOVERER project

In order to set up the framework of the study, an overview of the DISCOVERER project is undertaken. The vision and the main goals of the project, as well as its outline and structure, are analyzed in this subsection of the report.

The project officially started on the 1st of January of 2017 and has an expected duration of 63 months, which contains a 12-month extension due to the COVID-19 pandemic. In it, a total of 8 institutions from 5 different countries are currently collaborating; 2 consultancies, 2 space engineering companies and 4 universities, including UPC.

DISCOVERER, which stands for *DISruptive teChnOlogies for VERy low Earth oRbit platforms*, is a project that aspires to develop the key technological elements needed to revolutionize the Earth observation (EO) field through the use of satellites at a much lower altitude than the current ones. These new satellites would operate in very low Earth orbits (VLEO), which have a mean altitude below 450 km, and would prove their usefulness for a range of applications that could favor several sectors of society. Because of this, proposing new business models is an essential part of the research group, and what makes it relevant to this thesis.

In summary, the DISCOVERER project combines the technology research with the market research. Regarding the first, the three investigation lines are as follows:

- Materials ⟶ The satellites materials must present optimal properties to combat the atomic oxygen found in these very low Earth orbits and ensure the proper operation of all the systems.
- Electric propulsion ⟶ Propulsion technologies must be studied in order to take advantage of the residual atmosphere that these low orbits still have.
- Control methods ⟶ Aerodynamic control systems must be developed in order to generate attitude control.

Regarding the second, the market research, on which UPC is significantly more focused, the aim is to identify the best system designs and create a business model for the low Earth orbits in order to achieve a commercial exploitation that reveals all the advantages this technology offers.

Moreover, referring to the UPC involvement previously commented, more than 60 students from this university have already contributed in terms of value, knowledge and creative ideas to the DISCOVERER project with their final degree or master thesis. In this occasion, DISCOVERER is nourished again by the study of the benefits and applications of LEO for communications and the definition of a new space business model based on the Telesat Lightspeed satellite constellation, driven by Telesat.

Chapter 2

Project background

In this section of the document, the main theoretical framework of the project is established, that is, the key concepts of the lines of study that this thesis follows are presented. On the one hand, an analysis of the geocentric orbits is carried out, with special emphasis on LEO. From this, the general characteristics are determined, the main advantages and disadvantages are discussed, the market segment is described, and its commercial applications are identified. On the other hand, and to conclude this background, the methodology used to create a business model is defined. Therefore, the two essential elements of the project; low Earth orbits and the implementation of a business model are both theoretically established.

2.1 Earth orbits

The curve described by a body that moves around another due to gravitational action is called an orbit [4]. It is, therefore, the path that an object travels in space due to the gravity exerted by another.

The knowledge of orbits is largely due to Johannes Kepler (1571-1630), a German mathematician and astronomer who postulated the three laws of planetary motion. He reported that the orbits of the planets in the Solar System are elliptical, not circular; that the orbital speed of the planets is not constant but varies according to the distance between it and the Sun; and he determined a universal relationship between the orbits of all the planets around the Sun [4]. In the Solar System, the Moon moves around the Earth, and the Earth moves around the Sun following these Kepler Laws. However, in today's day and age, space is increasingly full of artificial satellites and multi-use spacecrafts, among which the telecommunication ones stand out. When rockets launch the satellites that provide these services, they place them in space orbits, where they are maintained thanks to gravity, in the same way that the Moon keeps orbiting the Earth, and the planets, the Sun.

Orbits can be classified in various ways; by inclination, by shape (determined by their eccentricity), or by the direction of the movement of the satellite, among other options [5].

However, the most common way to define the orbits in which space satellites are located is according to altitude, which is what applies to this project. These are geocentric orbits as the satellites move around the Earth, and they are:

Very low Earth orbit (VLEO)

VLEOs extend from an altitude of 160 km, slightly above the *Kármán Line*, to an altitude of 450 km [6]. The *Kármán Line*, established by the *Fédération Aéronautique Internationale*, a body that determines all international standards and records aeronautics and astronautics records, is the border between Earth and space, and is located at an altitude of 100 km [7].

VLEO is an orbit that can provide the satellites located in it with great benefits in terms of terrestrial observation and the telecommunications market. Still, being so close to Earth, satellites in this orbit must be able to cope with the challenging resistance from the residual atmosphere at that altitude. In fact, this is what the DISCOVERER group works on, as it has been explained in section 1.5. Finally, it is worth noting the fact that, at an altitude of 400 km [8], it orbits the International Space Station (ISS).

Low Earth orbit (LEO)

Despite being an orbit near the Earth's surface, with an altitude of around 1.000 km [9], the LEO range varies from the end of VLEO to the beginning of the MEO orbit, at an altitude of 2.000 km. It is an orbit with a wide range of applications, among which Earth observation and telecommunications stand out again. In addition, it includes the Sun-synchronous orbit (SSO).

The SSO is a type of polar orbit, which means that it passes approximately above the poles of the planet, which is between 600 km and 800 km in altitude [9]. Objects in that orbit are in sync with the Sun, so they pass over a region of the Earth at the same local time every day. This makes the satellites located in this orbit very useful to compare the changes that occur in a specific location as time passes, as well as allowing data and information to be collected from the monitored place in order to identify and investigate possible environmental phenomena, among other uses.

Medium Earth orbit (MEO)

The MEO is an orbit found in-between LEO and GEO, it ranges from an altitude of 2.000 km to 35.786 km [9]. The satellites located in these orbits are used mainly for geographic positioning and navigation. Its main benefits are that the cost of launching satellites into these orbits is moderate, small signal trip delays occur, and the image resolution produced is relatively good [6].

Geosynchronous orbit (GSO)

Located at an altitude of 35.786 km [9], GSO is an ideal orbit for telecommunications satellites, since its orbital period is the same as that of the Earth's rotation: 23 hours, 56 minutes, and 4 seconds, which makes it more difficult to lose the signal because the

antennas can point to the satellite constantly without moving. Another form of GSO is GEO, a circular orbit inclined 0^{o}, above the Earth's equator. The satellites located in GEO allow constant visibility of the globe but have large round-trip delays.

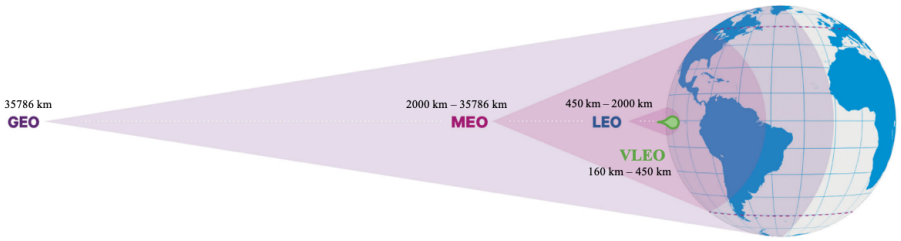

Figure 2.1: Orbital altitudes and coverage. Source: [10]

2.2 Low Earth orbits

Due to its great importance in this project, carrying out a detailed study of LEOs is a crucial requirement. For this reason, in this section the space environment in which they operate is studied, their commercial market is highlighted, and their most prominent advantages and disadvantages are specified.

2.2.1 Space environment

Because the Earth's atmosphere extends numerous kilometres above the planet's surface, some effects of the thermosphere, which is the region between 80 km and 500 km [11], are clearly manifested in the lower orbits. It is a layer of the atmosphere in which the temperature increases with height as it absorbs a lot of ultraviolet energy and X-rays from solar radiation. In addition, when the Sun is very active and emits a large amount of radiation energy, the thermosphere heats up and expands, reaching an altitude of 1.000 km [12], which includes a large part of the LEOs. When this happens and there is a slight change in the density of the little air that there is, a drag force is generated that directly affects the satellites that operate in these orbits, composed of atomic oxygen, as seen in Figure 2.2. This compound has a negative impact on satellite surfaces, as explained in subsection 2.2.3.

Despite what has just been explained, many LEOs are in the exosphere, which begins when the thermosphere ends. This region, considered the highest layer of the atmosphere by some scientists and part of outer space by other experts [13], continues to present the challenge of resistance caused by the very thin air that exists and the materials exposed to the presence of atomic oxygen, although with much less intensity.

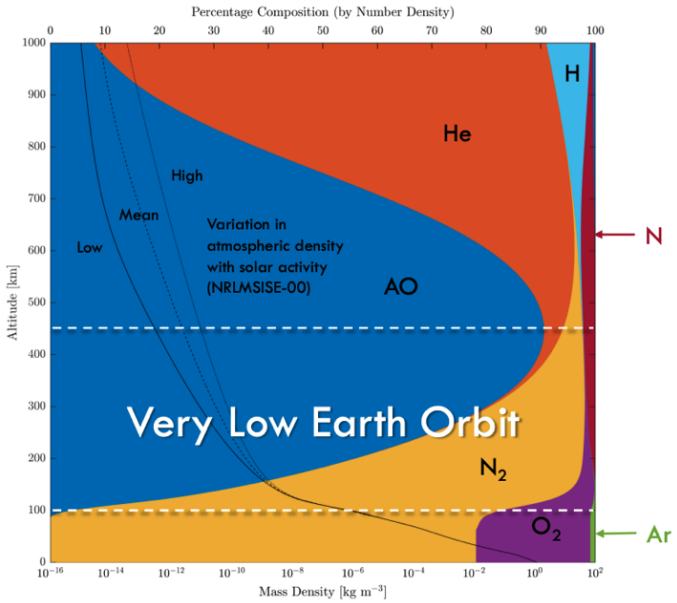

Figure 2.2: The environment in VLEO and part of LEO. Source: [14]

2.2.2 Market segment

Satellite operations related to Earth observation and telecommunications can benefit greatly from LEO. This makes them the main applications of this type of orbit, as can be seen in Table 2.1, which shows all the purposes of LEO satellites, how many of them perform these functions and the overall percentage they represent.

Table 2.1: Applications and number of LEO satellites. Data extracted from [15]

Purpose	**Number of LEO satellites**	**Percentage (%)**
Communications	2.039	59,74
Communications/Maritime Tracking	5	0,15
Communications/Technology Development	4	0,12
Earth Observation	914	26,78
Earth Observation/Communications	2	0,06
Earth Observation/Technology Development	7	0,21
Earth Observation/Earth Science	1	0,03
Earth Observation/Space Science	1	0,03
Earth Observation/Communications/Space Science	1	0,03
Earth Science	16	0,47
Space Observation	4	0,12
Space Science	70	2,05
Surveillance	9	0,26
Platform	1	0,03
Satellite Positioning	1	0,03
Signals Intelligence	1	0,03
Technology Demonstration	33	0,97
Technology Development	299	8,76
Unknown	5	0,15
TOTAL	**3.413**	**100**

As can be seen in the table above, the applications have been classified into four groups:

- Orange: communications
- Blue: Earth observation
- Red: technological applications
- Green: other applications

Then, Table 2.1 can be rewritten as follows:

Table 2.2: Grouped version of the applications and number of LEO satellites

Purpose	**Number of LEO satellites**	**Percentage (%)**
Communications	2.048	60,01
Earth observation	926	27,13
Technology applications	107	3,14
Other	332	9,73
TOTAL	**3.413**	**100**

From Table 2.2, the following graph is extracted:

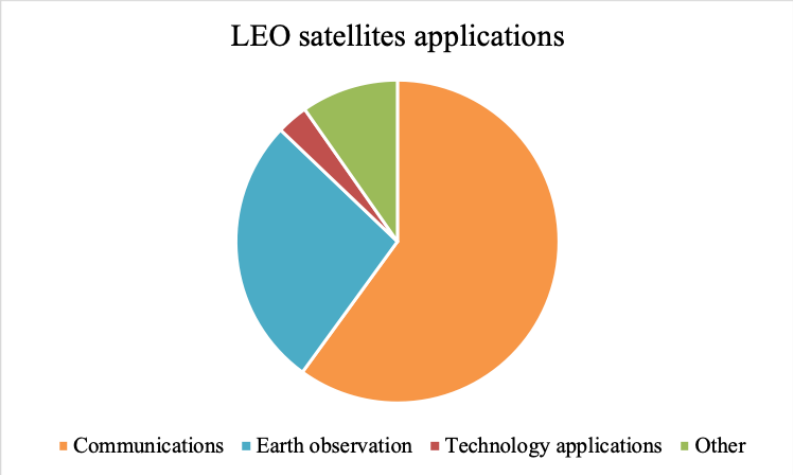

Figure 2.3: LEO satellites applications. Source: Own development

Therefore, as clarified previously, communications and Earth observation are the main applications of LEO satellites; the 60,01% and 27,13%, respectively, of the total number of satellites located in these orbits, cover these two markets.

Telecommunications

Since the launch of Telestar in 1962 and Syncom in 1963 [16], the market for satellite telecommunications has continued to evolve. Logically, the benefits of those first satellites, limited to transporting the signal between television studios and establishing long-distance telephone systems, are not comparable with the performance of the current ones.

Satellite communications are essential in today's society, which is why they are very present on a day-to-day basis. Traditionally, these telecommunication services have been provided by satellites located in GEO orbits, since, being so far from Earth, they are capable of covering large areas of the planet. In addition, this has the advantage that, unlike lower orbits, it is not necessary to use as many to observe the entire globe. In fact, a single satellite located in GEO covers 42% of the Earth [6].

However, the current trend is changing radically and LEOs are gaining importance in this sector of satellite telecommunications. It is worth noting that these communications satellites which operate in these low orbits are usually part of a long combination or constellation of satellites, since it is the only way they can offer constant coverage throughout the planet.

Being part of this network means developing telecommunication activities correctly because if not, the very high speed of the satellites in these orbits would greatly complicate their tracking from ground stations. That said, the constant increase of telecommunications satellites in LEO orbits is due to their countless advantages related to signal speed and their ability to offer uninterrupted connectivity to any corner of the world at a very affordable cost.

Earth observation

Earth observation is essential to improve many sectors of today's society. Undoubtedly, reducing the orbital altitude improves the image resolution and increases the revisit period, which is the time elapsed between observations made by a satellite on the same point on Earth [17]. This directly influences the monitoring of land and crops, as well as contributing to the improvement of surveillance and security services, both maritime and civil protection.

Nowadays, 800 million people face food scarcity, for various reasons [18]. Monitoring the land, together with weather models and more terrestrial information, would improve agricultural management and food supply by creating food security alerts that would help solve this problem. Furthermore, observation of the Earth from lower orbits would help to detect possible dangers for the community or different illegal activities by land and sea more effectively, such as border control and piracy.

Therefore, revolutionizing Earth observation means improving risk management, territory control and defence, as well as producing a positive impact on agricultural, forestry, geological and environmental activities.

2.2.3 Advantages and disadvantages

As mentioned above, LEOs present a series of very favourable characteristics regarding Earth observation and the field of telecommunications, their two most direct applications. Despite the benefits, there are also some drawbacks, as discussed below:

Advantages

- There is considerable improvement in the quality of Earth observation. The fact that the spatial resolution of the cameras is directly related to the distance of the target [19], means that decreasing the altitude of the orbit automatically improves the resolution of the images captured by the satellites.
- Communication is improved due to very short round-trip delays; this is low latency [20]. The fact that the altitude of the orbit is reduced makes LEO much more useful in terms of signal speed than traditional telecommunications systems, located in GEO orbits, at a greater distance from the Earth's surface.
- Satellites in LEO provide a greater bandwidth per user than satellites located in GEO orbits [21] since they use higher frequency bands to a greater extent; the Ku and Ka bands, which allow transmitters to send more information per second [22].
- In LEO, less transmission energy is required because satellites, being closer to the Earth, suffer less path losses [23] and provide better signal strength [24].
- The costs of launching satellites to orbits at a much lower distance than GEO, are considerably reduced by the fact that the launchers do not have to be as powerful. Additionally, LEO satellites are much smaller in size and mass than traditional GEO satellites [23].
- LEO satellites should not always follow a particular path, as their plane can be tilted [9]. Because of this, unlike GEO satellites, they have a greater range of routes, which clearly favours communications and Earth observation.

Disadvantages

- Achieving full coverage throughout the planet from low orbits requires many spacecrafts, that is, having a constellation of satellites working with each other [21]. With this, the issue that the coverage cone offered by a LEO satellite is much lower than that provided by a GEO satellite, is solved. However, launching a constellation of satellites is very expensive, which can be detrimental to deployment.
- Launching constellations of satellites at low orbits leads to greater complexity in de-orbiting the satellites when their efficacy ends. Many more operations require additional studies, which can often be simultaneous. Furthermore, a bad desorbitation of the satellites would increase the amount of space debris at altitudes already heavily affected by the space junk [25], in turn increasing the risk of collision in these orbits.
- LEO satellites have a very low orbital period; as the lower the altitude, the shorter the orbital period. The fact that they move at such speed reduces the time window in which they are visible at a certain point on the planet [23]. Undoubtedly, this phenomenon of intermittent contact and constant movement complicates communications with ground stations, which must be established in multiple points of the

globe to maintain good service performance.

- Due to its space environment, satellites in LEO have a shorter life span than satellites in higher orbits [20]. The reason for this is that, as explained in subsection 2.2.1, as the altitude decreases, the atmospheric drag increases and leads to loss of orbit. Furthermore, if the LEO orbit was very low, around 500 km for example, the erosive effect of atomic oxygen on the materials on the surface of the satellite should need to be considered [26].

2.3 Business model overview

This section defines what a business model is through the CANVAS Business Model, which is used in later sections of this thesis to carry out an in-depth and detailed study on how the Telesat company intends to take advantage of its Lightspeed project, the constellation of low-orbiting satellites.

In the book *Business Model Generation* by Alexander Osterwalder and Yves Pigneur [27], a business model is defined as the tool used to describe how an organization creates, delivers, and captures value in economic, social, cultural or other contexts [28]. However, they argue that the best way to fully describe a business model is by analysing the four main areas of a business: customers, offer, infrastructure and financial viability. For this, the CANVAS Business Model, developed by Osterwalder and Pigneur, proposes 9 building blocks through which the study is carried out.

It should be noted that the CANVAS Business Model, which is a canvas on which a business is simulated, divides the 9 building blocks into two groups, as can be seen in Figure 2.4. On the one hand, the value side, to the right of the representation, refers to those activities in which the company or organization deals with external factors. On the other hand, located on the left side of the illustration, the cost side groups together those blocks related to the functionality and efficiency of the company or organization.

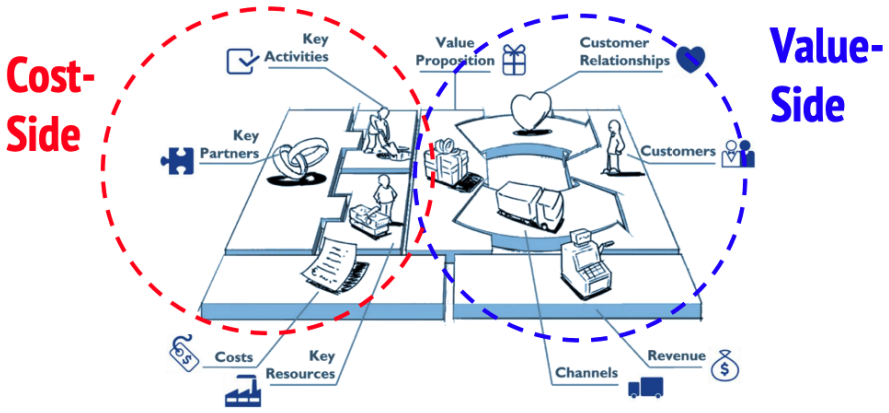

Figure 2.4: Business model CANVAS overview. Source: [28]

The 9 blocks identified in Figure 2.4 are defined below:

2.3.1 Value side

1) Customer segments

This block defines the different groups of people or organizations with which the business intends to derive value from the product or service it offers [27]. There are different types of customer segments for business models, and they are the following [27]:

- Mass market: business models focus on a very large group of customers with similar needs and problems.
- Niche market: business models focus on customers with unique needs and very specific requirements.
- Segmented: business models are based on a market sector with different needs, being able to create different value propositions to satisfy the demand of all its clients.

In turn, the customer segments presented can be divided into [27]:

- Diversified: when the market includes clients with very different needs and problems.
- Multi-sided platforms (or multi-sided markets): when organizations serve more than one interdependent customer segment.

Finally, it is worth highlighting that when a company is business to business (B2B), the organization offers the product to other companies; when it is business to customers (B2C), that product has another target, private or individual users; and when it is business to governments (B2G), the customer is the government.

2)Value proposition

The value proposition is the reason why the client opts for the product or service of the company or business and not for the competition, and it helps them to satisfy their demand [28]. It is the way to create value for a customer segment, so being unique and different is key.

3) Channels

Channels are the mechanisms through which companies or businesses communicate with customers and provide them with their value proposition. The two types of channels are:

- Direct channel: the producer and the consumer interact directly.
- Indirect channel: there are intermediaries between the producer and the consumer.

4) Customer relationships

This section defines the types of relationships that the company establishes with its customers [27]. Logically, a quality relationship favours the operation of the business and,

as long as the product or service continues to be chosen, it helps to retain customers and increase revenues.

5) Revenue streams

This block represents the cash the company generates from each customer segment [27] thanks to its value proposition. Therefore, it refers to what the customer is willing to pay for the product or service. They are classified into the following categories [28]:

- Transactional revenues: based on a one-time customer payment.
- Recurring revenues: results from ongoing payments to either deliver a value proposition to customers or provide post-purchase customer support.

Companies have a wide range of options to generate revenue streams; from the use of fees for subscriptions, use or advertisements, to asset sales, which derive from selling ownership rights to a physical product [27].

Finally, each revenue stream has a payment mechanism, which can be classified into one of the following two options [28]:

- Fixed pricing: they are predefined prices based on features and demand.
- Dynamic pricing: prices can be negotiated and vary according to market conditions.

2.3.2 Cost side

6) Key resources

In this section the most important elements for the business model to work are described [27]. That is, the necessary resources that create and deliver the value proposition are defined. They are classified as follows [28]:

- Physical: plant and equipment.
- Financial: borrowing capacity and internal funds.
- Technology: patent, copyrights, technical and scientific employees.
- Reputation: brands, customer loyalty and company reputation.
- Human: experience, commitment, and adaptability of employees.

7) Key activities

These are the fundamental activities that make the business model function, from an attractive value proposition to the generation of revenue. They are classified into the following groups [27]:

- Production: activities related to designing, manufacturing, and delivering the product with the best possible quality.

- Problem solving: activities based on solving individual customer problems.
- Platform/network: networks, software and matchmaking, activities, among others.

8) Key partnerships

Key partnerships are the necessary stakeholders that, by reducing risks and getting access to key resources, improve the optimization of the business model. The different types are [28]:

- Strategic alliances: partnerships between non-competitors to add value to the product.
- Coopetition: partnerships between competitors to improve their industry.
- Joint ventures: to develop new businesses by joining complementary products.
- Buyer-supplier relationships: to make sure reliable supplies.

9) Cost structure

This section describes all costs incurred to operate a business model, both fix and variable costs. They are grouped into the following categories [27]:

- Cost-driven: these business models are focused on minimizing the costs wherever possible.
- Value-driven: the business model is more focused on the value creation rather than the cost implications.

Chapter 3

State of the art

In this section of the project, a study of the evolution of satellites over the years is elaborated. Once their current situation is understood, the companies that, through constellations of satellites, intend to revolutionize the telecommunications sector and that present themselves as the competition of Telesat Lightspeed, are examined. Finally, the external factors that affect this sector of spatial communication are identified through a PESTEL analysis.

3.1 Satellite industry evolution

The successful launch of Sputnik 1, the first artificial satellite to orbit the Earth was a significant moment in human history. Since the Soviet Union achieved this historic milestone on October 4, 1957 [29], satellites have evolved alongside technology to the point of becoming essential elements of today's society.

Even though the use of satellites over time has varied according to the needs of the time, the field of communications has been present since the beginning. As mentioned previously in the telecommunications point in subsection 2.2.2, Telestar, launched in 1962, was the world's first active communications satellite and the world's first commercial payload in space [30].

Traditionally, GEO satellites have been responsible for providing all telecommunications services. However, the need to establish a broadband high-speed network anywhere on the planet makes the GEO system insufficient. For this reason, non-geostationary orbits are gaining importance, which, based on a constellation of satellites located mainly in LEO, might become essential to satisfy today's demand.

In fact, as can be seen in Table 3.1, LEO is by far the orbit with the most operational satellites. The reason for this has to do with the need to redefine the telecommunications system. It should be noted that of the 4.550 satellites available in the satellite database [15], the 57 with elliptical orbits were not included in the study.

Table 3.1: Number of satellites in the different orbits. Data extracted from [15]

Type of orbit	Number of satellites	Percentage (%)
VLEO	377	8,39
LEO	3.413	75,96
MEO	139	3,09
GEO	564	12,55
TOTAL	**4.493**	**100**

From Table 3.1, the information is represented in a graph:

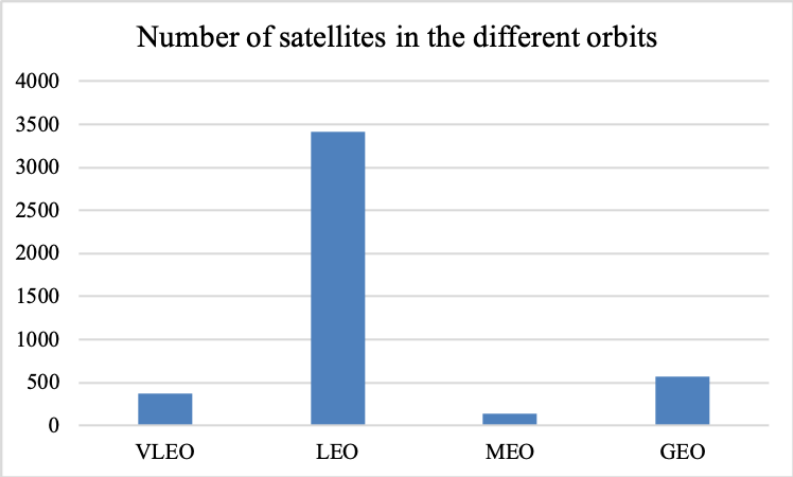

Figure 3.1: Number of satellites in the different orbits. Source: Own development

The functions of these satellites located in the different orbits are presented below, following the procedure used in the previous Table 2.1:

Table 3.2: Applications and satellites per orbit. Data extracted from [15]

Purpose	VLEO	LEO	MEO	GEO	Total	Percentage (%)
Communications	315	2.039	21	469	2.844	63,30
Communications/Maritime Tracking		5			5	0,11
Communications/Navigation				1	1	0,02
Communications/Technology Development		4		1	5	0,11
Earth Observation	21	914	1	45	981	21,83
Earth Observation/Communications		2		1	3	0,07
Earth Observation/Technology Development	2	7			9	0,20
Earth Observation/Earth Science		1			1	0,02
Earth Observation/Space Science		1			1	0,02
Earth Observation/Communications/Space Science		1			1	0,02
Earth Science	3	16			19	0,42
Space Observation	1	4		3	8	0,18
Space Science	11	70			81	1,80
Surveillance		9			9	0,20
Navigation/Global Positioning			116	20	136	3,03
Navigation/Regional Positioning				12	12	0,27
Platform		1			1	0,02
Satellite Positioning		1			1	0,02
Signals Intelligence		1			1	0,02
Technology Demonstration	1	33			34	0,76
Technology Development	23	299	1	10	333	7,41
Mission Extension Technology				2	2	0,04
Unknown		5			5	0,11
TOTAL	**377**	**3.413**	**139**	**564**	**4.493**	**100**

Again, the applications are grouped into the four groups defined by colors, and Table 3.2 is rewritten as:

Table 3.3: Grouped version of the applications and number of satellites in each orbit

Purpose	VLEO	LEO	MEO	GEO	Total	Percentage (%)
Communications	315	2.048	21	471	2.855	63,54
Earth observation	23	926	1	46	996	22,17
Technology applications	15	107	116	35	273	6,08
Other	24	332	1	12	369	8,21
TOTAL	**377**	**3.413**	**139**	**564**	**4.493**	**100**

Therefore, as can be seen in Table 3.3, most of the satellites' purpose is communications, whose sector has experienced significant growth in recent years. This evolution can be seen in Figure 3.2, which shows the number of currently operational communication satellites launched over the years. As indicated in the orange row of Table 3.3, 315 are VLEO, 2.048 are LEO, 21 are MEO and 471 are GEO.

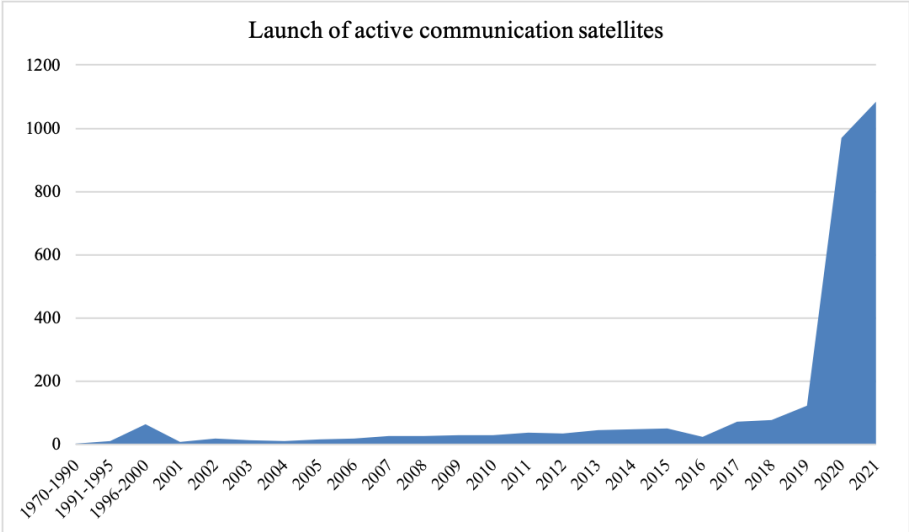

Figure 3.2: Number of active communication satellites launches over the years. Source: Own development with data extracted from [15]

Figure 3.2 shows the exponential growth suffered by the sector: in 2020 the number of launches was multiplied by almost 8 compared to the year before, reaching 970; and until the end of August 2021, which is when the latest data is available, 1.083 more communications satellites were launched. This increase is motivated, as already explained, by the commitment to constellations of satellites in low orbits. One of the most obvious cases is that of the company SpaceX, which has launched a total of 1.553 satellites into LEO and VLEO orbits [15] during these two years.

According to [15], the years 2020 and 2021, in addition to exemplifying the growth of communications in non-geostationary low orbits, have shown that launching smaller satellites to feed mega constellations allows more than one satellite to be put into orbit

for each launch. On the one hand, in 2020, to launch 970 satellites it was necessary to carry out 34 launches, of which only 9 were for single-satellite missions. On the other hand, in 2021, to launch 1.083 satellites only 31 launches were needed, with 7 being for single-satellite missions.

The number of communications satellites launched to each type of orbit in 2020 and 2021 is presented below:

Table 3.4: Number of communication satellites launched in 2020 and 2021 to the different orbits. Data extracted from [15]

Type of orbit	**Number of satellites 2020**	**Number of satellites 2021**
VLEO	63	250
LEO	893	824
MEO	0	0
GEO	14	9
TOTAL	**970**	**1.083**

Many of these communications satellites operate within constellations to be able to carry out their activity correctly. Although it did not prosper, this system was attempted to be implemented during the 1990s, when non-geostationary satellite orbit smallsat constellations such as Globalstar, Iridium or Teledesic tried to develop their projects, which did not materialize because of the financial failure due to the excessive time and cost to bring them to market [31].

In this day and age, thanks to technological advances and the rise in demand, constellations of communications satellites such as Telesat Lightspeed intend to offer quality internet and broadband connectivity anywhere on the planet, thus improving the lives of its inhabitants.

3.2 Telesat Lightspeed business competence

Competition analysis is a very important tool for any company because it is the process that is put into practice to know how to act in the competitive environment. Recognizing competitors and determining their main objectives, strategies, strengths and weaknesses is one of the most relevant aspects when it comes to promoting sales of the product or service being offered.

Consequently, for companies to be successful in a highly competitive market, all decisions related to marketing strategies and tactics that they are going to implement must be also based on the way their competitors act and react.

A good analysis of the competition, therefore, is based on identifying competitors, understanding, and evaluating their way of acting within the market and, finally, determining ways to confront them. It is worth noting that there are different types of competitors and there are many classifications. However, they are mainly classified in two big groups [32]:

- Direct competitors: when two or more businesses offer the same service or product to the same customers; they compete for the same market.
- Indirect competitors: when two or more businesses offer the same set of benefits using completely different products to the same customers; they compete for the same market.

This section analyses the competence of Telesat Lightspeed, a high performing LEO satellite network that aims to offer global broadband connectivity. At present, there are several companies with projects like Telesat's that intend to revolutionize communications through constellations of satellites in low orbits. Next, in Figure 3.3, the non-geostationary satellite orbit smallsat constellations planned and/or under development from 2010 to July 2020 are presented.

Constellation	System design parameters[b]	Status
Amazon Kuiper[c]	3236 sats: 784, 1296, & 1156 at 590, 610 & 630 km, resp., in 98 planes	Under development
Boeing V-band	2956 sats	Undisclosed
LeoSat	78–108 sats with optical ISLs at 1400 km	Canceled
OneWeb	648–900 sats in 18 planes at 1200 km	Bankrupt[d]/Being restructured
O3b	20 sats in the equatorial plane at 8063 km	Operational
O3b mPOWER	20 sats in two planes at 8063 km	Under development
Samsung	4600 sats	Undisclosed
SpaceX Starlink	4425 sats with optical ISLs in 83 planes at 1000 km + with 1600 sats at 550 km (to accelerate deployment)	540 launched to date[e]
SpaceX VLEO (very-LEO)	7518 sats at 346 km + 30 000 sats[f]	Under development
Telesat LEO	117 sats with optical ISLs in 11 planes at 1000 & 1200 km	Under procurement
Telesat V-band	292–512 sats	Undisclosed
ViaSat LEO[g]	288 sats at 1300 km	Under development

Figure 3.3: NGSO smallsat constellations between 2010-2020. Source: [31]

Of the constellations included in Figure 3.3, those that are presented as Telesat Lightspeed competition should be selected and analysed. It should be said that neither the constellations whose status is *undisclosed*, nor those that have been cancelled, are part of the study. Neither are O3b, a constellation located in MEO orbits, nor the traditional GEO telecommunications satellites, as the study is limited to LEO.

The constellations of Amazon Kuiper and SpaceX Starlink satellites operate at a lower altitude than Telesat Lightspeed. However, OneWeb and ViaSat LEO do have altitudes similar to Telesat's LEO satellite network. Being aware of this is important because altitude influences innumerable factors, from the number of satellites to the quality of service. Explained below are these four constellations, whose main objective is to reduce the digital divide by offering low latency, high speed broadband connectivity around the world.

Amazon: Project Kuiper

Kuiper Systems LLC is a subsidiary of Amazon, known worldwide for being an American multinational technology company, that was created in 2019 in order to deploy the Project Kuiper, a constellation of LEO satellites to provide reliable, affordable broadband service everywhere [33].

Table 3.5: Project Kuiper main characteristics

Customer segment		Business to customer
Satellites orbit		LEO: 590 km, 610 km and 630 km [34]
Number of satellites	Total constellation	3.236 [34]
	Launched	None yet. Expected date: 2022 [35]

SpaceX: Starlink

Starlink is the huge constellation of VLEO and LEO satellites that SpaceX, the American private spaceflight company, is developing to provide low cost internet everywhere in the world. Despite that in 2016, SpaceX filed an application with the Federal Communications Commission (FCC) for a license to operate 4.425 satellites in orbits ranging from 1.100 km and 1.300 km [36], the company now aims to deploy up to 42.000 satellites to lower altitudes. However, the U.S. FCC has granted permission to fly 12.000. The first 60 satellites of the constellation were launched to an orbit 550 km high in 2019, aboard the SpaceX Falcon 9 rocket [37].

Table 3.6: Starlink main characteristics

Customer segment		Business to customer
Satellites orbit		VLEO and LEO: 258 km to 569 km [15]
Number of satellites	Total constellation	42.000 [37]
	Launched	1.791 [38]

ViaSat LEO

ViaSat, founded in 1986 [39], is an American communications company that aims to develop a LEO satellite constellation able to deliver high quality internet all around the Earth. Nowadays, ViaSat is also working on 3 ultra-high-capacity satellites that will cover much of the globe and will enable the company to provide global broadband cover [40].

Table 3.7: ViaSat LEO main characteristics

Customer segment		Business to customer
Satellites orbit		LEO: 1.300 km [31]
Number of satellites	Total constellation	288 [31]
	Launched	None yet [31]

OneWeb

OneWeb was founded in 2012 with the objective of delivering broadband satellite internet services worldwide. In 2020, it entered bankruptcy and was acquired by the UK Government and the Bharti Group [41], a global telecommunications company with operations in 18 countries across South Asia and Africa [42]. As a wholesale business, OneWeb also works alongside distributors to provide their service, focusing on business to business, but also on the business to government.

Table 3.8: OneWeb main characteristics

Customer segment		Business to business
Satellites orbit		LEO: 1.200 km [41]
Number of satellites	Total constellation	648 [43]
	Launched	322 [43]

As can be seen in the analysis, only OneWeb focuses on the business to business market, in the same way as Telesat Lightspeed. This fact clearly makes it a competitor to the Canadian company; in their direct competition. Otherwise, Project Kuiper, SpaceX, Starlink and ViaSat LEO are presented as constellations that have the same mission as Telesat Lightspeed but have a different target because they are business-to-customer oriented projects. However, they are potential competitors since they can change their market at any given moment. Table 3.9 presents the Telesat Lightspeed competition:

Table 3.9: Telesat Lightspeed competitors

Type of competence	**Satellite constellation**
Direct	OneWeb
Potential	Project Kuiper, Starlink, ViaSat LEO

3.3 PESTEL analysis

In this section of the project a PESTEL study, which is a variation of the PEST analysis created by Harvard professor Francis Aguilar in 1967 [44], is carried out. A PESTEL analysis is the tool that, by examining the political, economic, social, technological, environmental and legal factors, monitors the external marketing environment elements that have an impact on the company or organization [45].

It should be noted that the PESTEL analysis presented below must be completely oriented to the communication satellites sector and, specifically, to the low-orbit constellations that intend to revolutionize the internet service throughout the entire planet.

Political

Political factors refer to the influence governments have on businesses [46]. This is, trade policies, internal political issues, foreign trade policies and regulation trends, among other aspects [45].

Undoubtedly, this sector is subject to certain actions and interests of a political nature. This fact is proven by the Space Race, a hectic technological competition involving those who were the two world powers of the moment, the U.S. and the USSR, to conquer outer space, and whose shared goal was the arrival to the Moon in 1969 [47].

- There are space programs that define the political actions of countries or organizations and that provide very relevant socio-economic benefits. This is the case, for example, of the program established by the European Union (2021 - 2027). It has the following objectives [48]:
  - Create jobs and boost growth and investment in Europe.
  - Facilitate security and defence policies.
  - Promote the industry and the digital sector.
  - Assist with economic recovery after the COVID-19 pandemic.
  - Combat climate change.
- The current development is for private and public sectors to cooperate with each other and work together, so that governments provide initial support in the exploration and the advancement of critical technologies, and in the construction of space infrastructure [49].

Economic

Economic factors are determinants of a certain economy's performance [44]. Economic factors refer to inflation and interest rates, job growth and unemployment, projected economic growth and impact of globalization, among other elements [45].

Having financial resources is essential in any project. However, it is only invested in markets that can generate very important economic benefits. As can be seen from the following information, the space industry is one of them.

- The space sector, from exploration missions to satellite communications, is a market that continues to grow and in which investment is continued. Proof of this is the €6,49 billion [50] that the European Space Agency (ESA) had as a budget for 2021, and which is part of the largest budget in the agency's history; an economic plan of €14,4 billion for the period 2020-2026 [51].
- Despite the COVID-19 pandemic, private investment in space companies in 2020 set a new annual record with $8,9 billion [52].
- Global satellite communication market size was valued at USD 65,68 billion in 2020 and is projected to reach USD 131,68 billion by 2028, growing at a compound annual growth rate of 9,10% from 2021 to 2028 [53].

Social

Social factors describe how the population the companies work with is [44]. Demographics, consumer buying patterns and opinions, socio-cultural changes and living standards are just a few of them to consider [45].

- Having an effective communication service has become a necessity for much of today's society. In an increasingly connected and globalized world, where working, shopping, and socializing can be done remotely, it is essential to create a safe, fast, accessible, and affordable network that covers all needs.
- The evolution of society is based on education, and this could be positively affected if all communities had quality internet. Having an internet connection network can help to combat misinformation and provide resources and tools to education systems.
- There is a need to close the digital divide between the rural world and the urban world to generate wealth in both.
- There has been a huge increase in satellite launches during the last years in order to start working on the deployment of constellations.

Technological

Technological factors are innovations in technology that can have a positive or negative impact on the industry operations and performance [44]. They have a direct impact on how goods and services are produced and distributed, as well as the way companies communicate with their target markets [45].

- The digital divide between rural and urban areas is difficult to eliminate with the technology that is most used today to provide quality internet; carrying out a fibre optic installation in rough terrain can be complex and, above all, expensive. Furthermore, considering that the rural population represents a small percentage of the total, this makes it even more difficult to establish it throughout the territory.
- The market for satellite connection is in full growth and low-orbit constellations made up of hundreds and thousands of smallsats to cover the entire planet and provide connectivity services anywhere is a reality today. The American company SpaceX, as seen in Section 3.2, is leading the development of this technology.
- 5G technology has recently been boosted by mobile and telecommunications network operators.

Environmental

Environmental factors are important to preserve the planet and maintain a balanced and pollution-free ecosystem. Environmental factors are key to fight the scarcity of raw materials and do business in a sustainable and ethical way [45].

Some applications of the space market are valuable to combat the environmental factors

that affect the planet. However, despite the efforts being made, the ecological footprint left by this market must still be reduced, especially around the planet.

- The rising population of space debris increases the potential danger to all space vehicles and poses a threat to Earth observation and communication systems. With more than 27.000 [54] pieces of space junk identified; these elements must be taken into account when operating in Earth orbits. For the safety of operations, the European Space Agency has promoted a space mission that will deorbit and eliminate space debris; it is called ClearSpace-1 and will be released in 2025 [55].
- Some scientists argue that air pollution from re-entering mega constellation satellites could damage the ozone layer by the chemical elements released when a satellite burns in the atmosphere [56]. This makes it necessary to propose an alternative strategy for the satellites that are in disuse.

Legal

Legal factors appeal to specific laws, to health and safety, to equal opportunities and to consumer rights [45]. The most prominent of the space sector are:

- The Committee on the Peaceful Uses of Outer Space was created in 1959 to govern the exploration and use of space for the benefit of all humanity [57]. Their most notable recent contributions are the space debris mitigation guidelines, a document created in 2010 to deal with this type of pollution.
- The Federal Communications Commission is an independent government agency that regulates communications in the United States [58], the country leading the launch of communications satellites to low orbits. This body works together with other entities such as with the European Community, with whom it has an agreement on mutual recognition to operate more efficiently [59]. As mentioned in Section 3.2, the FCC has required SpaceX to reduce the number of satellites planned for the Starlink constellation from 42.000 to 12.000.

Chapter 4

Case study: Telesat

This section of the project carries out a detailed study of the Telesat company and its constellation of low-orbit satellites, Telesat Lightspeed. The analysis includes the most important elements of the company: its history, philosophy, management, workers, as well as its external partners and clients. The satellite telecommunications market is examined in-depth through Telesat Lightspeed, as it describes the general characteristics of its LEO satellites, what the constellation and the space-earth communication system will be like. The value of the product offered by Telesat, the financial status and economic risks of the company, as well as its environmental policy are the last points discussed in this study.

4.1 Company overview

The history and philosophy of Telesat, as well as the owners and workers of the company are discussed below, thus establishing an overview of the company.

4.1.1 History

Telesat was established by the Canadian Parliament in 1969 as a commercial company with a mandate to provide satellite communications services to Canada [60]. Nowadays, it has become a global satellite operator that provides reliable and secure satellite-delivered communications solutions worldwide, as well as technical consultation and support services to different industry stakeholders [61].

The following are Telesat's historical milestones; these are innovations that have contributed greatly to the growth of the satellite communications market over the years [60]:

- 1972: Anik A1 was launched. It was the world's first commercial domestic communications satellite in geostationary orbit.
- 1978: The first commercial Ku-band satellite was launched. It offered the first direct-to-home television service.
- 1981: Two satellites were co-located in a single orbital slot for the first time.

- 2004: Anik F2, the first satellite to provide consumer Ka-band broadband services was launched.
- 2007: Telesat Canada and Loral Skynet merged to become the fourth largest financial software and systems operator in the world $\longrightarrow$ Significant benefits such as more geographic coverage, fleet depth and commercial resources.
- 2009: Telestar 11N was launched as the first satellite to provide Ku-band coverage of the Atlantic Ocean from the Arctic Circle to the Equator.
- 2013: Anik G1 - the first commercial satellite with substantial X-band coverage of the Pacific Ocean and Hawaii.
- 2015: Telestar 12 VANTAGE was launched. It was the first of Telesat's high throughput satellites (HTS) to combine HTS and broad beams to maximize efficiency, flexibility and throughput.
- 2018: Phase 1 LEO satellite was launched.
- 2019: Telesat conducted the world's first 5G backhaul demo over LEO satellite.
- 2020: In-orbit demonstration for LEO satellites was carried out.
- 2021: Thales Alenia Space was chosen to manufacture Telesat Lightspeed.
- 2021: Telesat became a public company.

4.1.2 Business statement and philosophy

Telesat is one of the most prominent global satellite operators. The company works to deliver critical connectivity solutions that address the world's most demanding communications challenges and collaborates with its customers to provide numerous benefits from its services that enhance their operations and drive growth. In addition, as previously stated, it has a technical assistance and consultation service for satellite operators and insurers, among other interested parties in the sector.

Nowadays, Telesat aspires to redefine global satellite connectivity with its low Earth orbit network, which is designed to meet the rigorous telecommunications, maritime, aeronautical and government requirements imposed by its customers. Telesat's LEO constellation of satellites, named Telesat Lightspeed, aims to bring broadband internet to rural and remote communities with speeds similar to fibre.

Therefore, the company's philosophy is based on generating benefits for its clients through the services it offers. The most innovative of them, the Telesat Lightspeed project, is proposed as the solution to close the digital divide between urban and rural areas. This satellite network will offer quality connectivity anywhere in the world and will provide high-speed, low-latency internet at low cost. It is also worth highlighting the fact that Telesat Lightspeed will facilitate backup connectivity where there is fibre and will extend coverage for the 4G and 5G networks that are important in today's society.

The following figure perfectly illustrates the ideas that have previously been discussed and how, thanks to its satellites, Telesat can contribute to establishing a wireless ecosystem capable of providing quality connectivity in remote areas, in addition to greatly strengthening the terrestrial infrastructure that has traditionally been used to offer broadband connection for internet access (copper, coax and fiber).

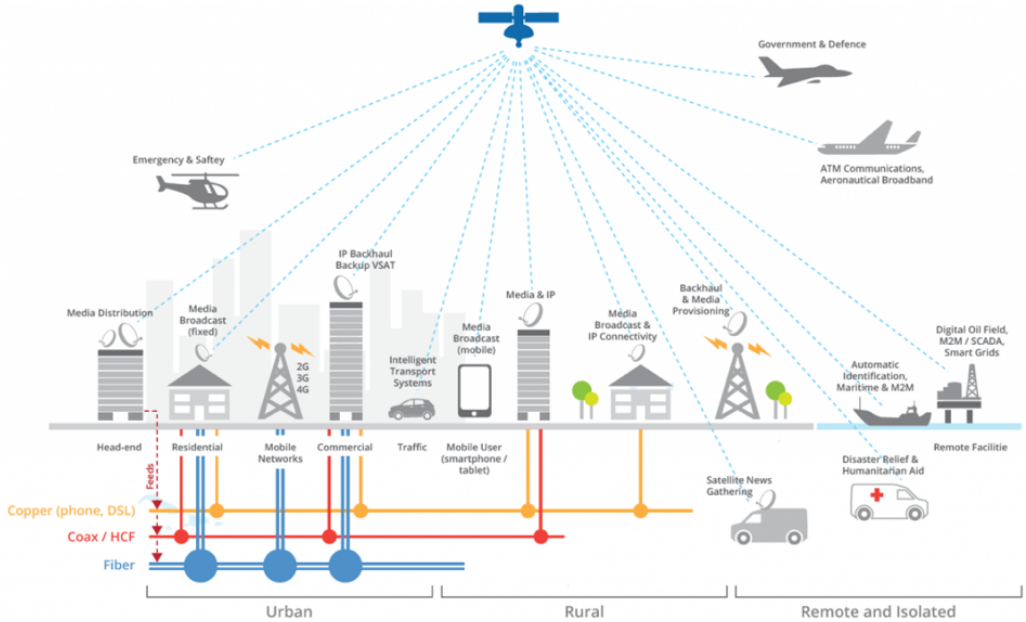

Figure 4.1: Connectivity ecosystem. Source: [62]

4.1.3 Ownership and employees

This section contains information regarding the property of the company and its workers. These two fundamental blocks are analysed below.

Ownership

To understand Telesat's current situation, the history of the company should be explained. Created in 1969, Telesat was jointly owned by the Canadian telecommunications consortium, the Stentor Canadian Network Management, and by the federal government. In 1992, Alouette Telecommunications, a company owned by Spar Aerospace and Stentor, which included Bell, bought the federal government's stake. A few years later, in 1998, Bell acquired 100% ownership of Telesat. In 2007 Loral Space & Communications, along with the Public Sector Pension Investment Board of Canada, completed the acquisition of Telesat, with Loral owning 63% of the company and PSP Investments owned the remaining 37% [63]. Nevertheless, in 2020, Telesat announced that it was going to become a public company to be able to achieve the funding for Telesat Lightspeed [64].

Since November 19, 2021, the global satellite operator began trading on the Nasdaq Global Select Market and the Toronto Stock Exchange, becoming a public company. This comes after both Loral and PSP Investments exchanged interests and reached agreements within this new Telesat public participation structure. As of today, Telesat Canada (PSP

Investments and other shareholders) and Loral are subsidiaries of Telesat Corporation, the Canadian controlled and incorporated public holding company.

Despite recent changes, Telesat Corporation will continue to be led by Dan Goldberg, President and Chief Executive Officer of Telesat since 2006. Along with him, the rest of the company's management team [65]:

- Michèle Beck: Senior Vice President, Canadian Sales.
- Andrew Browne: Chief Financial Officer.
- Chris DiFrancesco: Vice President, General Counsel and Secretary.
- Tom Eaton: President, Telesat Government Solutions.
- John Flaherty: Vice President, Business Planning & Marketing.
- Erwin Hudson: Vice President, Telesat Lightspeed System Development.
- Glenn Katz: Chief Commercial Officer.
- Michael Schwartz: Senior Vice President, Corporate and Business Development.
- David Wendling: Chief Technical Officer.

Employees

In December 2021, Telesat had a total of 579 employees, having experienced a growth in its workforce compared to the previous month, when it had 547 workers [66]. This growth in the workforce has been occurring for months and is motivated by factors such as the recovery from the pandemic and Telesat's commitment to the Government of Canada to create jobs due to the investment agreement for its low-orbit satellite project.

Telesat is headquartered in Ottawa, Canada, but has sales offices around the world. They are located in Singapore (1); London, United Kingdom (1); Rio de Janeiro, Brazil (1); North Bethesda and Arlington, United States of America (2); and Ottawa and Toronto, Canada (2) [67].

4.2 External partnerships

The association between sectors is essential when it comes to strengthening and enhancing the value of the product or service offered by a company. In fact, working together is key to improve, grow and face the challenges presented by the market. Due to this, Telesat has reached agreements with different companies with the aim of consolidating its Telesat Lightspeed project, the constellation of LEO satellites with which it intends to revolutionize the satellite communications sector. Telesat's most prominent external partnerships are presented below:

Thales Alenia Space

Thales Alenia Space is a joint venture between Thales (67%) and Leonardo (33%), one of the world's major players in aerospace, defence, and security [68], which also collaborates with Telespazio to form the "Space Alliance" of the parent companies, and that offers a wide range of services [69]. With more than 40 years of experience and 7.700 employees present in 10 countries, Thales Alenia Space suggests efficient solutions for telecommunications, navigation, Earth observation, environmental management, exploration, science, and orbital infrastructures.

Thales Alenia Space collaborates with governments and private companies to design satellite systems that allow connection and location anywhere in the world and at any time, among many other applications. In fact, it is a world benchmark when it comes to provide the world's most efficient services for mobile connectivity, backhauling of 4G and 5G communications, enterprise communications and government networks [69].

For this reason, Thales Alenia Space will work together with Telesat and will make its knowledge in flight proven systems, digitalization of payloads, inter-satellite links and industrial capabilities dedicated to constellations available to the Telesat Lightspeed project. Once the in-house design and engineering tasks are completed by Telesat, Thales Alenia Space will establish itself as the prime contractor to manufacture the LEO network of 298 satellites that will offer professional broadband and high-efficiency services throughout the planet. It will not only provide the space and mission segments, but it will also carry out the network performance and the related systems specifications [69].

Blue Origin and Relativity

Blue Origin, founded and backed by Amazon founder Jeff Bezos [70], is a company whose objective is to develop partially and fully reusable launch vehicles that are safe, economically viable and carry out essential tasks for society, trade, and defence. Blue Origin believes that humanity will need to expand, that the future involves working and living in space for the benefit of the Earth. [71].

Telesat and Blue Origin reached an agreement in January 2019 where it was determined that the powerful New Glenn rocket, a reusable heavy-lift launch vehicle, will be the one that carries out multiple launches of satellites of the Telesat Lightspeed constellation [70]. New Glenn, powered by 7 BE-4 engines with the capability to deliver 45 metric tons (45.000 kg) to LEO [70], is expected to have its maiden flight in Q4 2022 [72].

Telesat, in the same way as Blue Origin, has also contracted the Relativity company to carry out the satellite launches of its LEO constellation. Relativity, an autonomous rocket factory and a launch service leader, will make the Terran 1 rocket, the world's first fully 3D printed rocket, available to Telesat [73]. This rocket, which plans to carry out a test flight in March 2022 [74], will have the following payload characteristics [75]:

- Max payload: 1.250 kg to 185 km.

- Nominal payload: 900 kg to 500 km.
- High altitude payload: 700 kg to 1.200 km.

NSSLGlobal

NSSLGlobal, with over 50 years of experience and headquartered in the United Kingdom, is an independent provider of satellite communications and IT solutions. The company employs over 230 staff worldwide and has offices in 10 countries [76]. The agreement between NSSLGlobal and Telesat does not only consist of a long-term strategic co-operation to collaborate on the commercial and technical features of Telesat Lightspeed, but also of integrating the satellite constellation services into NSSLGlobal's value-added network, providing an expanded service portfolio that delivers increased resiliency, performance, and flexibility for customers [77].

Moreover, NSSLGlobal will provide a European end-user testing and trials facility for Telesat Lightspeed services and, from this facility, will support Telesat with service testing, performance validation and customer onboarding. Finally, it will conduct field testing of user terminals from different providers and will intend to market the LEO satellite network servides into the European Maritime and Defense markets [77].

SatixFy

SatixFy, established in 2012 by leading entrepreneurs in the satellite industry and currently located in 4 countries, designs next-generation satellite communication systems based on in-house developed chipsets [78]. Telesat and SatixFy have recently announced an agreement to deploy SatixFy baseband modem equipment for Telesat Lightpseed gateway Earth stations network. This equipment will not only optimize Telesat's landing station size and capacity, but it will also reduce deployment and operating costs [79].

Ciena

Ciena is a networking systems, services, and software company [80] that supplies hardware and software which provides high-speed, high-capacity connections to governments, telcos, mobile operators, and other enterprise customers for the delivery of 5G, cloud computing, video, and other bandwidth-intensive broadband services [81].

Ciena has agreed with Telesat to deploy its routing and switching platforms on Telesat Lightpseed terrestrial backhaul network. This technology will ensure flexible, reliable connectivity between Earth station antennas and points of presence throughout the world, creating a seamless integration between on-ground data networks and the satellites [81].

ThinKom Solutions

ThinKom Solutions, based in California and with over 130 employees, manufactures low-profile antennas engineered expressly for high-speed connectivity in any kind of environment [82]. This is the reason why this company and Telesat announced an agreement to collaborate on integrating ThinKom's aeronautical antennas with Telesat Lightspeed.

In fact, these antennas will operate on the fully integrated 298 satellite and ground network and are expected to be a user terminal solution. Despite this, they have already been tested on Telesat's Phase 1 LEO satellite, validating tracking of the satellites, extremely high spectral efficiencies, and ultra-low latency of 20-40 msec [83].

Finally, it is essential to highlight in this section all the companies that have collaborated with Telesat since the launch of the first LEO satellite in January 2018. This satellite is being very useful because it is supporting live demonstrations across a variety of markets and applications that allow Telesat customers and LEO hardware vendors test a wide range of parameters such as low-latency, high throughput performance and satellite tracking [84].

The demonstrations that have been carried out to date and the external partnerships with which Telesat has worked to achieve these actions are set out below. The information contained in the following Table has been extracted from the reference [84]:

Table 4.1: LEO demonstrations between Telesat and some of its partners.

Partnership	**Date**	**Achievement**
Global Eagle	October 2018	Telesat pioneer first ever in-flight broadband connectivity via LEO satellite.
Vodafone & University of Surrey	May 2019	World's first 5G backhaul demonstration over LEO satellite.
ThinKom	July 2019	Thinkom's successful antenna technology validation on Telesat LEO satellite.
NSSLGlobal	October 2019	Confirmation of ultra-low latency of Telesat's LEO system for government applications.
Department of the U.S. Navy	November 2019	Live testing of Intellian's advanced antenna technology with Telesat LEO and the U.S. Navy.
Gilat	November 2019	Fastest modem speeds are achieved (1.2 Gbps over Telesat LEO satellite).
	February 2020	Gilat's first-to-flight ESA terminal achieves another industry-first with in-flight connectivity over NGSO.
C-COM Satellite Systems	February 2020	Live testing confirms advantages of new C-Com transportable antenna system.
Motorola	February 2020	Halton-Peel initiated Public Safety Broadband Network (PSBN) and Motorola Extend Service over Telesat's LEO satellite.
Telefonica	June 2020	Telefonica puts Telesat's Phase 1 LEO satellite to the test, confirming fiber-like performance for high-end satellite services.
TIM Brasil	May 2021	Telesat and TIM Brazil partner for first-of-its-kind LEO Test in Brazil.
Telenor Maritime	May 2021	Validation that LEO satellites may start a new era of high-speed internet at sea.
Speedcast & Petrobras	June 2021	Speedcast completes oil and gas industry performance testing on Telesat Phase 1 LEO satellite for Petrobras.

4.3 Customer base

Telesat has many customers because it is undoubtedly one of the largest and most successful global satellite operators. In addition to developing Telesat Lightspeed, which will improve

satellite communications with advantages such as global coverage, high reliability, low cost, and low latency that the network will offer, it also has a fleet of GEO satellites that provides coverage and connectivity. For years, Telesat has served the needs of broadcast, corporate, telecom and government customers.

In addition to the clients that the company has had throughout its existence, their new Telesat Lightspeed project ensures new market opportunities, as it is an attractive, useful, and innovative value proposition. However, the company also offers technical assistance and consultation services for satellite operators, for example, which makes the number of those interested in Telesat even higher.

Now focusing on the connectivity solutions that Telesat can offer, specifically with its constellation of low-orbit satellites, the most prominent clients are those involved in aeronautical, maritime, business, telecommunications, and government networks. Therefore, it is clear that Telesat establishes a business to business and business to government structure.

Data and telecommunication customers

Telesat offers internet service providers reliable and cost-effective satellite connectivity to extend secure community connectivity, establishing an economically viable structure for the most underserved communities and ensuring that they have a good internet connection. In addition, in places where, thanks to Telesat Lightspeed, internet service providers have fibre, there will also be backup connectivity.

Mobility customers

This section refers to inflight, maritime and oil and gas connectivity. Telesat works with clients in these sectors to facilitate their services. For example, in the case of inflight connectivity, Telesat offers satellite connectivity for aeronautical service providers to connect airlines and meet passenger demand. Additionally, it supports applications such as engine monitoring or flight crew operations.

In the maritime, oil and gas industries, Telesat once again emphasizes its commitment to providing the organizations involved in these markets with their services. The company guarantees connectivity in offshore operations for exploration and seismic vessels, as well as in oil fields where there are oil platforms; that is, it will always meet the remote connectivity requirements.

Governments

Governments present themselves as Telesat clients because thanks to the connectivity services that the company offers, they can better face the challenges that exist in terms of population, defence and first aid. Regarding the latter, Telesat works together with first responders and public safety officers to help in critical situations [85].

Regarding universal connectivity, 48,8% of the world's population does not have access to affordable, reliable, high-speed internet. In Canada, 1,9 million households are affected by this problem, which keeps them away from the digital economy and limits aspects as important as the education system or access to health information [86].

Resilient connectivity is crucial for defense missions. Telesat offers governments worldwide a secure infrastructure to support situational awareness, intelligence gathering as well as morale, welfare, and recreation connectivity for troops [87]. In fact, Telesat Government Solutions, subsidiary of Telesat, provides the U.S. government and allies a reliable and secure global communications network used for real-time operation management, among other applications [88].

Finally, expanding on what has already been commented at the beginning of this section, Telesat has a consulting service for commercial organizations and governments to carry out their activities. That is to say, Telesat has spacecraft and terrestrial consulting services, as well as satellite launch and testing facilities, where it works with launch vehicle providers [89]. Moreover, broadcasters and programmers need Telesat satellites to provide reliable distribution of thousands of SD and HD channels to North American viewers on a continuous basis [90].

4.4 Telesat Lightspeed analysis

This section discusses the operational part of the Telesat Lightspeed constellation. In addition to developing the network of low-orbit satellites, Telesat also has a fleet of GEO satellites. Despite the latter, this study only includes the architecture of the Telesat Lightspeed project because it is the one that applies directly to the interests of this thesis.

4.4.1 Satellite characteristics

The satellites of the Telesat Lightspeed constellation will incorporate sophisticated and cutting-edge technology to meet the objective of providing services that will undoubtedly transform the telecommunications sector. The manufacturer of the satellites is Thales Alenia Space, and although the project is still under development, the specifications of the satellites are already known. Its most outstanding features are presented below, making use of the reference [91]:

- Satellite size
  - Each satellite has a mass of 700 kilograms $\longrightarrow$ There is an obvious difference in size and weight between the satellites of the Telesat Lightspeed constellation, which are much smaller, and the satellites located in GEO orbits. For example, from Telesat's fleet of GEO satellites, Anik F2 has a mass of 5.950 kg, Nimiq 6 weighs 4.500 kg and Telestar 19 Vantage, 7.080 kg [92].
  - The prime power of the satellite is approximately 4 kW.

- Satellite fuel and orbit raising
  - Krypton gas ⟶ Although the conventional fuel would be xenon because it offers a very high performance, krypton gas can be bought at just one-tenth the cost of xenon because it is more abundant; obviously, the economic factor is vital for the company.
  - Electric thrusters are used.
- Design life
  - Each satellite has an operational life of 10 years ⟶ Again, there is a very clear difference between the operational life of the satellites of the Telesat Lightspeed constellation and the GEO satellites of the Telesat company. To give an example, Anik F2 has been in service since 2004, indicating that GEO satellites operate for more years [92].
  - Each satellite will be 12 years in orbit, including orbit raising, orbit storage and end of life de-orbit.

4.4.2 Constellation main features

According to Telesat CEO Dan Goldberg, Telesat Lightspeed will launch its first satellite in around two years, 2023, and will enter commercial service the first half of 2024 at higher latitudes. The polar satellites will be launched first, followed by those in an inclined orbit, and the full global coverage will be achieved in early 2025, a date which, of course, is subject to the progress the company makes on securing its financing [93], something that has already caused some delays.

Telesat Lightspeed plans to have a total of 298 satellites in a combination of polar and inclined orbits, optimized for complete global coverage, including polar areas, and with higher capacities where more population lives [91]. It is, indeed, a highly innovative global network seamlessly integrated with on-ground data networks [94]. The following table shows the distribution of the satellites in the different orbits and the altitude at which they are located [91]:

Table 4.2: Telesat Lightspeed constellation main features

Type of orbit	**Orbit's altitude (km)**	**Satellites**	**Planes**	**Satellites per plane**
Polar	1.015	78	6	13
Inclined	1.325	220	20	11

In addition, some notable features of the constellation are [91]:

- Telesat Lightspeed has global priority Ka-band spectrum rights, which is very useful because it means that smaller antennas on board will still be able to maintain strong links.

- The combined capacity of the 298-satellite network is 15 Tbps, which makes high bandwidths possible.
- Focusing on data rates, up to 7,5 Gbps can be offered to a single terminal and up to 20 Gbps to a single hot spot site, such as seaports, airport hubs and remote communities.

Undoubtedly, it is essential to highlight, apart from the main features of the constellation, its cutting-edge technology, which adds value to Telesat's proposal and makes the services it offers better. These state-of-the-art technologies are:

- Phased array antennas ⟶ Sophisticated antennas on each satellite with hopping beams scan the Earth to provide full coverage and can dynamically focus capacity precisely where users require it [94], where the demand is high.
- Optical inter-satellite links ⟶ Data can travel at the speed of light from one satellite to another, resulting in a fully interconnected global mesh network that allows customers to access the Telesat Lightspeed Network no matter where they are [94]. This is because nearly 1200 high-capacity optical links interconnect the satellites with unique transport paths [91].
- Data processing in space ⟶ Full digital modulation, demodulation, and data routing occurs in space, resulting in higher capacity and flexibility [94].

4.4.3 Terrestrial networks: ground stations and user terminals

Here, the terrestrial architecture of Telesat Lightspeed is explained, that is, both the technology and the operation of ground stations and user terminals. These are fundamental elements of the constellation because they are responsible for establishing communication with satellites. Therefore, the proper functioning of operations depends directly on the service. The following figure illustrates the architecture of the network in which, as can be seen, the interconnection is established between both the landing stations and the user terminals with the satellite nodes:

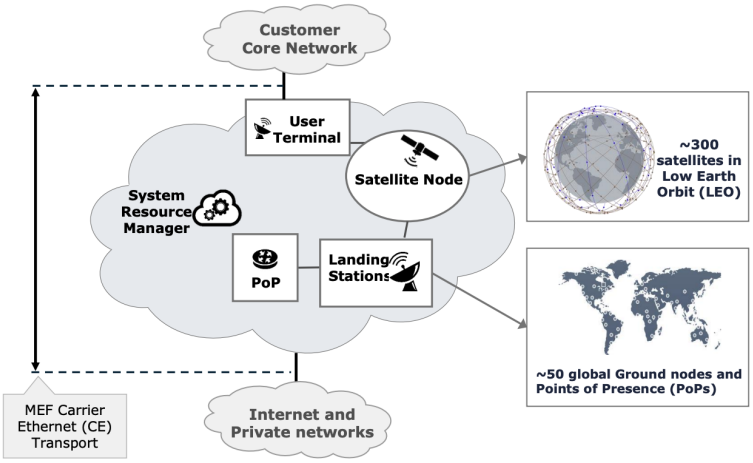

Figure 4.2: Internet architecture. Source: [95]

Ground stations

A ground station, also known as teleport (telecommunications port) is an Earth station with multiple parabolic antennas, their main goal is to connect a satellite or geocentric orbital network with a terrestrial network to provide high-quality satellite communication services [96].

Although Telesat already has a teleports network for its GEO satellites, the Telesat Lightspeed constellation will have up to approximately 50 global ground nodes and points of presence (PoPs), as shown in Figure 4.2. In fact, Telesat will use Ciena's CPE platforms to provide MEF-compliant services at its PoPs, as well as terrestrial connectivity to the 50 Earth-based landing stations [81]. Here, CPE stands for customer premise(s) equipment, and will deliver gigabit ethernet service capability to the network structure. MEF, which promotes empowering digital transformation, is an industry forum leading the development of a global federation of network, cloud, and technology providers [97].

As mentioned above, in the absence of expanding its infrastructure, Telesat already has several ground stations, which are illustrated in the following figure. Most of them are concentrated in North America, mainly in Canada, where Telesat is, logically, a very prominent company.

Figure 4.3: Telesat Earth stations. Source: [98]

User terminals

User terminals are devices that are used to access the services provided by the network [99]. Telesat has ensured that its LEO satellite constellation terminals will be easy to deploy and will fully support both electronically and mechanically steered antennas while keeping the cost-effective, high-performing philosophy of the company [84].

As seen in the partnerships section, ThinKom Solutions and Telesat agreed to integrate Ka-band antennas on Telesat Lightspeed satellite network focusing on the aeronautical platform customer base. With Thinkom's Ka2517 antenna, which have already been successfully tested on Telesat's Phase 1 LEO satellite [83], aircraft connectivity is ensured because it will deliver exceptional network flexibility and consistently high performance for

global inflight broadband [100]. Its key features are presented below, according to reference [101], where all the technical specifications can be found:

- Pole-to-pole coverage.
- Interoperability among LEO, MEO and GEO constellations.
- Long-term reliability.
- Ultra-low profile to reduce drag and associated fuel costs.
- Gate-to-gate operation.
- High throughput: up to 400 Mbps down and 100 Mbps up.
- High spectral efficiency (up to 3 bits/Hz).

Figure 4.4: Thinkom's Ka2517 antenna. Source: [100]

4.5 Online platform

This section discusses two fundamental aspects of the Telesat Lightspeed infrastructure. It explains what elements are essential to make internet delivery possible as well as the value-added services that the company offers.

4.5.1 Internet delivery

Being able to enjoy connectivity and internet services depends on many elements, all of them indispensable. However, to guarantee the operation of the network, it is necessary to have technological devices that are responsible for facilitating the delivery of internet through the antennas located in the landing stations. These elements are modems, and the one that the Telesat Lightspeed constellation will use is explained below.

However, before starting the analysis, it is important to highlight that modem operation is based on taking signals that come from the internet service provider (ISP), which in this case is the LEO satellite constellation, and translating them into an internet connection, converting the information it receives into a digital signal [102].

The company SatixFy, presented in the partnerships section, will be the one that delivers advanced modems for 288 landing station antennas across the global Telesat Lightspeed terrestrial network. Because of the modems, each of these antennas will be able to transmit 12 Gbps on the forward link and receive 6 Gbps on the return link [79].

SatixFy proposes to use Sx3099 landing station modems, which are capable of processing up to 1.6 GHz of bandwidth in each direction by supporting [79]:

- 10 wideband carriers.
- Uplink power control and adaptive coding and modulation.
- Network data processing.

Figure 4.5: SatixFy's Baseband Modem for Landing Stations. Source: [79]

4.5.2 Value-added services

Value-added services (VAS) are used by telecommunication companies to stimulate demand for core services by providing operational and/or administrative synergy among its range of services [103]. In the case of Telesat, it is very clear that its operations, and more so with Telesat Lightspeed, are fully focused on offering its customers a secure, reliable, and cost-effective connectivity system. It makes sense that all the VAS that the company has are focused on enhancing the quality of its network.

Telesat teleport services must be considered as value-added services of the company, since they are a series of facilities that provide added value to Telesat's services and in turn improve, protect, and provide security to the equipment used by its customers and the actions they carry out. These VAS teleport services are [104]:

- Uplinking $\longrightarrow$ Transmitting video and data to one or more Telesat satellites is possible because of the large antennas and radio frequency equipment at the teleports.
- Co-location services $\longrightarrow$ Rack space, conditioned power, security, and support for servers as well as solutions that enable remote management of equipment. Customers can add remotes, change performance parameters and security levels on their own, or use Telesat support.
- SCPC (Single Channel per Carrier) service $\longrightarrow$ Service dedicated to internet protocol bandwidth to remote areas using modems provided by Telesat at the teleport end.

- Hub-based services ⟶ Telesat operates hub platforms that can support many high-performance networks at the same time. Moreover, it assures maximum availability to all critical components by integrating high levels of redundancy.
- VNO (Virtual Network Operator) and hosted VNO services ⟶ Telesat provides the hub hardware that is needed at teleport locations to support VNOs.

4.6 Economic study

The analysis presented in this section aims to assess the economic situation of Telesat in relation to the financing of the Telesat Lightspeed constellation and the economic risks that may affect the company. In fact, the satellite telecommunications sector presents great challenges that companies will have to face to be able to operate in a very competitive market.

4.6.1 Financial status of the company and constellation investments

All the amounts in this part of the study are in Canadian dollars. It must also be taken into consideration that the following information is provided by Telesat reports results [105].

On November 5, 2021, Telesat announced its financial results. For the quarter ended September 30, 2021, Telesat reported a consolidated revenue of $192 million, a decrease of 5% ($10 million) compared to the same period in 2020. This revenue decrease is due to the several factors presented below:

- Reduction of service for one of Telesat's North American DTH customers.
- Reduction of certain services in the enterprise segment.
- Lower consulting revenue.

For the nine-month period ended September 30, 2021, Telesat reported a consolidated revenue of $571 million, a decrease of 8% ($48 million) compared to the same period in 2020. These revenue decreases were driven by the same factors discussed above for the quarter.

Despite the modestly lower economic results of the company, Dan Goldberg, Telesat's president and CEO, said that he was pleased with the results given the fact that the COVID-19 pandemic continued to restrain certain business activities. Furthermore, he said that significant progress was made on the financing of Telesat Lightspeed constellation, welcoming a $1,44-billion investment from the Government of Canada.

Following the financing of Telesat Lightspeed, the company has put a 6,3 billion Canadian dollars price tag on the constellation [106]. Telesat guarantees that about two-thirds of the overall expected cost (around $4 billion) have already been raised with [107]:

- Government of Canada's $1,44 billion investment, which is comprised of a $790 million loan and an investment of $650 million in preferred equity.
- $1,7 billion of cash contribution from Telesat investments made to date, cash on hand and proceeds expected from the U.S. C-band clearing process.
- $400 million investment from the Government of Quebec.

According to Goldberg, the remaining capital needed to deploy the constellation will be generated by the fact the company has gone public very recently, which will attract new sources of investment [93].

4.6.2 Economic risks

As mentioned in the introduction of this section, the economic risks which companies that offer satellite broadband internet services are exposed to are remarkable and, without a doubt, can jeopardize the operation and viability of companies if they do not face them in the appropriate way.

Firstly, companies engaged in satellite telecommunications must invest large amounts of money to put their entire infrastructure into operation, from low-orbit satellites to the smallest detail of the terrestrial network. However, the risk is that they must be prepared to face possible losses, since it is a very recent market in which recovering the initial investment and starting to generate income may take time.

Constellations such as Project Kuiper from Amazon, or Starlink from SpaceX, might have enough economic resources, but Telesat is currently struggling to complete the constellation financing, which indicates that it must manage this possible threat robustly and establish a good customer base.

Secondly, Telesat faces the risk of having to comply with and maintain its affordable price economic policy because, although the company has not made the rates of its service public, it has already committed to its customers.

To give an example, and knowing that Starlink does not have the same customer base as Telesat Lightspeed, the SpaceX constellation has set a price of U.S. $99 monthly for the service and U.S. $499 for the equipment customers need to connect to the satellites [108].

As just mentioned, Telesat Lightspeed does not have the same clients as Starlink, as it is not a business to customer company. However, the figures offer an idea of what people can afford when they hire these facilities. In the case of Telesat, the company will sell its service to internet providers, among others, and it will be them who set a price for individuals; this is the risk. Telesat, therefore, must ensure that the prices of this entire chain are suitable if it does not want to lose prominence in the market.

The following graph is a good representation that shows that, in order to achieve the goal of providing quality internet in all corners of the planet, it is strictly necessary that services are economically viable. To this day, however, this is still not the case:

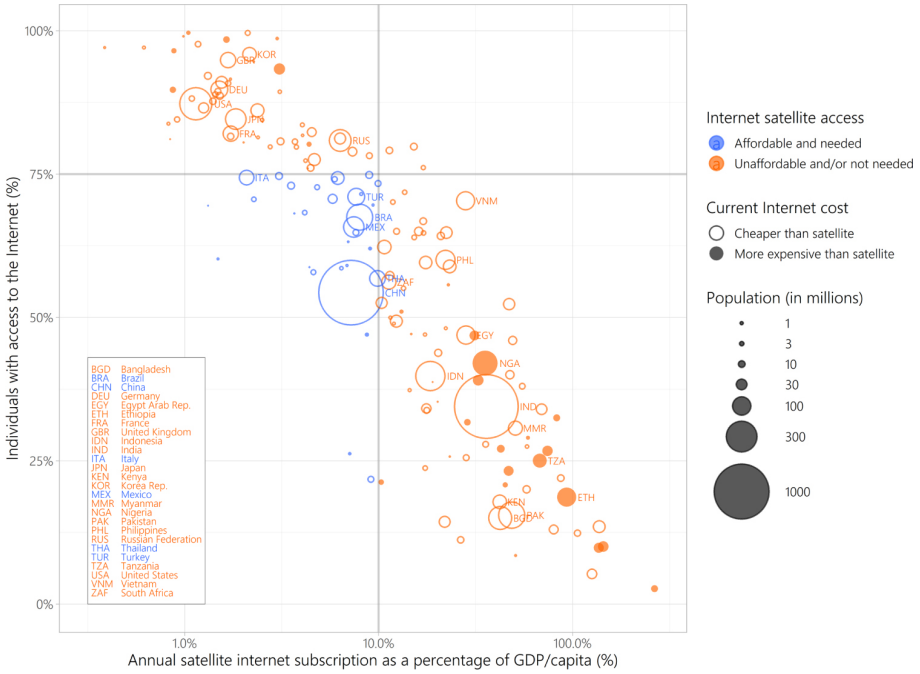

Figure 4.6: Internet access. Source: [109]

4.7 Environmental philosophy

In this section of the analysis, Telesat's environmental safety policy must be presented. However, as the exact measurements are confidential information, only a brief study is carried out on what is the real impact of the Telesat Lightspeed constellation on the terrestrial and space environment.

Undoubtedly, Telesat works with the commitment to comply with space restrictions and align with the parameters of the spectrum licenses to operate leaving the minimum possible environmental footprint. In addition, the company works following the restrictions and additional regulations imposed by governments to address environmental concerns about these LEO constellations.

Regarding the latter, the risks associated with LEO constellations are mainly related to space debris and light pollution, among other factors. Mega-constellations of satellites can collide with space junk, which is comprised of human-generated objects such as pieces of space craft, tiny flecks of paint from a spacecraft, parts of rockets or satellites that are no longer functioning [49]. Light pollution due to sunlight reflection on satellites poses a threat to astronomy because mega-constellations could cause scientists to miss out on key discoveries.

Furthermore, despite Telesat aims to deploy its constellation satellites with cutting-edge launchers New Glenn and Terran 1, reusable and completely 3D printed vehicles, respectively, the rocket emissions will also set a huge threat on the environment.

The corresponding action measures and a deeper study is offered in subsection 8.1.

Chapter 5

Business model CANVAS implementation

Based on the wide analysis that has been carried out in the previous section on the company Telesat, now its business model canvas is carried out. As mentioned in subsection 2.3 of this document, where the entire theoretical basis is described, the following study will identify how the organization creates, delivers, and captures value in any context.

5.1 Value side

The value side includes 5 blocks that explain how organizations deal with external factors. All of them are presented below:

5.1.1 Customer segments

The content of this point has been discussed in detail in subsection 4.3, where Telesat's broad customer base was identified and the services that each of them needs. However, despite having already done this work, this part of the Canvas adds very relevant information about the profile of the company's customers.

Telesat has technical assistance and consultation with satellite operators, but, without a doubt, its biggest business model revolves around satellite connection services. Although the company has a fleet of GEO satellites that meet the needs of broadcast, corporate, telecom and government customers, its big project is Telesat Lightspeed, the constellation of LEO telecommunications satellites. As this project is the focus, the analysis is oriented to this network of low-orbit satellites.

Telesat's approach is different from that of other LEO providers. It is a company that has always decided on enterprise verticals, serving fewer customers with bigger links. In fact, it has always worked with integrators, mobile network operators, internet service providers, telecommunication companies and governments, which clearly makes it a business to business and business to government company.

Moreover, Dan Goldberg assures that Telesat does not plan to launch a direct selling initiative, since the current design of the company, which has led them to be very successful, is not optimized for consumers. However, he says that if an end-user customer goes to them on their own, Telesat will quote them and inform the integrator partner that serves the customer [93]. It is clear, therefore, that it is not a business to customer company.

The following table illustrates and combines all the study that has been developed on Telesat's customers, both in subsection 4.3, and in this point of the document:

Table 5.1: Telesat Lightspeed's customer base

Type of business	**Customer segment**	**Telesat client**	
Business to government	Government	Governments around the world	
Business to business	Enterprise networks	Mobility market	Aeronautical and maritime internet service providers
		Data and telecommunications	Telecommunication operators
			Mobile network operators

Of the clients in the table above, one governmental and one of a business nature are given as examples. That is, a brief comment is made on two closed agreements that Telesat has; the first is with the Government of Canada and second, with OmniAccess, a leading specialized maritime connectivity solutions provider.

Government of Canada

Through its partnership with Telesat, the Government of Canada will invest in Telesat Lightspeed, but it will also create high-skilled jobs, enabling innovation and helping to unlock economic and social opportunities in Canada's rural and remote areas. At the same time, the LEO satellite technology will enable advanced high-speed broadband, Long Term Evolution (LTE) and 5G connectivity to its citizens regardless of where they are [110].

The agreement between both Telesat and the Canadian government is a win-win operation. Telesat will be able to deploy its LEO constellation, and the Government of Canada will reach its goal of connecting all Canadians households to quality internet by 2030, bringing social, economic, and cultural prosperity to several communities [110].

OmniAccess

OmniAccess, the first broadband provider worldwide to contract for Telesat's LEO services [111], was founded in Palma de Mallorca in 2001, where it started providing Wi-Fi to superyachts in ports in Palma and the Mediterranean. Nowadays, due to the new satellite broadband technology, the company operates an advanced global VSAT (Very Small Aperture Terminal) [112]. This provides the highest service levels, offering integrated maritime IT (Internet Technology) networks, broadband services, and IPTV (Internet Protocol Television) solutions to over 350 vessels [111].

The agreement with Telesat will allow OmniAccess to deliver an unsurpassed broadband

service to its customers. Moreover, Telesat LEO will have the ability to concentrate capacity into the highest demand areas, such as major seaports [111].

5.1.2 Value proposition

Telesat has different ways to generate value for its customer group. As mentioned, it has a technical assistance and consultation service, has GEO satellites and, finally, is developing the Telesat Lightspeed satellite constellation. Because Telesat is betting its future on Lightspeed, this section focuses on its value proposition and highlighting the most notable features with which the company aims to meet the demand of its customers.

As mentioned in subsection 4.1.2 of the Case Study, where Telesat's objectives were discussed, the company wants to establish a satellite network capable of providing universal connectivity and facing the biggest challenges in the world of telecommunications, whether they are aeronautical, maritime, governmental, or social. Therefore, the LEO Telesat Lightspeed satellite constellation aims to bridge the digital divide between urban and rural communities, thus helping to improve people's quality of life; it will guarantee, regardless of place and time, reliable, safe, flexible, permanent, and fast connectivity to all users.

The following are the characteristics of the Telesat Lightspeed value proposition:

- Global coverage: Telesat Lightspeed hybrid orbits, a combination of polar and inclined orbits, results in a complete global coverage, including polar areas, with higher capacity where most of the world's population lives.
- High throughput: Enterprise-grade connectivity anywhere in the world is ensured by gigabits per second speeds to a remote and multiple Tbps of capacity in the network [84].
- Low latency: Telesat Lightspeed network is about 20-times more responsive than today's GEO satellites and similar to fiber networks [84].
- Flexible and focused: The network is able to dynamically allocate bandwidth to areas with high traffic demand such as airport hubs, maritime ports or large communities [84].
- Always connected: Connectivity is always ensured due to highly resilient, secure network. Interconnection between satellites and ground nodes make uninterrupted connection a reality [84].
- Affordable: LEO satellite technology is more cost-effective for ubiquitous reach than fiber and microwave alternatives [84].
- Quick service deployment: compliant with MEF standards for seamless plug-and-play integration [84].

5.1.3 Channels

Telesat has several mechanisms to communicate with its customers and facilitate their value proposition. These are direct channels in which the interaction between the seller and the buyer is carried out directly, without intermediaries.

The most direct way to contact Telesat is through its website, where enterprises must fill out a form to make a query. In that form, in addition to having to provide the data of the company concerned, the reason for the query must be specified; this is, Telesat services, career opportunities, U.S. Earth Station submission, corporate communications, investor relations, media relations or other. From there on, Telesat gives all the details regarding the constellation.

In addition, the Telesat website also has a section in which it shows the telephone numbers of the offices it has and a technical support section. Finally, Telesat has established new communication channels related to social networks; this is the case of Twitter, LinkedIn, and Vimeo.

However, as Telesat collaborates and offers its services to large entities in the broadcast and telecommunications sector, as well as to governments around the world, it is logical to think that there are very strong links and that the value proposition is delivered in conferences and fairs.

5.1.4 Customer relationships

It is essential to value the more than 50 years that Telesat has been at the service of its customers. Telesat works hand in hand with other companies and governments to meet their needs and enhance their development.

The great relationship that Telesat has with its customers is based both on the quality of the service it offers, which is excellent, and on the commitment it acquires when it comes to contributing to the growth of other businesses. All this has been essential to generate the good reputation it has and establish contacts that, both in the short, medium, and long term, ensure income.

5.1.5 Revenue streams

In the absence of information on the exact mechanisms used by Telesat to achieve revenue streams, a good option is to consider the case of the company OmniAccess, which, as has been stated previously, is the first company to bet on the connectivity services offered by the Telesat Lightspeed constellation. On the 13th of March 2019, OmniAccess signed a multi-year contract with Telesat for broadband service [113]. Therefore, everything indicates that Telesat will use contracts to build customer loyalty and ensure income for years.

Moreover, in the case of governments, it is logical to think that there could be room for negotiating future concessions to operate for years.

5.2 Cost side

The cost side refers to the 4 blocks that are responsible for the functionality and efficiency of the organization. All of them are presented below:

5.2.1 Key resources

Telesat has a series of resources that allow it to carry out its business activity and generate an attractive value proposition for its customers. These elements, classified into 5 categories, are presented below:

- Physical resources
  - Telesat's global infrastructure of teleports.
  - Corporate headquarters in Ottawa.
  - Sales offices in Toronto, Singapore, London, Rio de Janeiro, North Bethesda and Arlington.
- Financial resources
  - 6,3 billion Canadian dollars are needed to deploy the Telesat Lightspeed constellation. $1,44 billion is invested by the Government of Canada, $1,7 billion belong to Telesat's internal funds and $0,4 billion is invested by the Government of Quebec [106] and [107].
  - Telesat has recently become a public company, trading on the Nasdaq Global Select Market and the Toronto Stock Exchange. This operation rationalizes the corporate structure and provides access to the public equity markets, enhancing Telesat's ability to execute on its compelling investment opportunities [114].
  - The company's financial results announced on November 5, 2021 showed a decrease of 8% compared to the same period in 2020. Telesat reported consolidated revenue of $571 million for the nine-month period ended September 30, 2021; $48 million less than the previous year. Despite the decline, the company is in a good financial situation [105].
- Technology resources
  - Telesat retains all right, title and interest to any Telesat patent, trade-mark or other intellectual property right [115].
  - The company has several patents for the technologies it develops [116].
- Reputation resources
  - Telesat, backed by more than 50 years of experience, enjoys a great reputation and worldwide recognition.

- Human resources
  - Telesat has a great workforce team that combines the experience and leadership of the management team with the excellent work capacity and knowledge of its employees.
  - Highly qualified employees $\longrightarrow$ Engineers in: network software, user terminal systems, senior LEO satellite bus, DSP, sales, RF/antenna and satellite operations, among others. Also, satellite controllers and repair, TCC and teleport technologists [117].

5.2.2 Key activities

The only way for Telesat to guarantee quality services to its customers is by carrying out all its activities efficiently. The extensive register of activities extends from the tracking of satellites to the commercialization of the services offered by the company, also covering the production chain and the development of cutting-edge technology, in addition to economic aspects.

Telesat's key activities are presented below:

- Completing the financing of the Telesat Lightspeed constellation.
- Ensuring that its partners comply with the agreements and there are no setbacks in production; Thales Alenia Space oversees manufacturing Telesat Lightspeed's LEO satellites and other companies such as SatixFy, Ciena and ThinKom Solutions must develop cutting-edge technology to make the project a reality.
- Carrying out a sound market strategy to get their service offerings to enlarge the customer base.

In addition to the activities related to the Telesat Lightspeed constellation, Telesat must continue to carry out others such as the following:

- Ensuring the company offers 24-hour satellite monitoring, security, and redundant power systems, while keeping in control the network and remotes, with its teleport service. This service must also offer customers several global infrastructure advantages such as powerful antennas and diverse internet backhaul [104].
- Guaranteeing a leading consulting service in the satellite sector through training programs where customers customize content to meet their specific requirements [89].

5.2.3 Key partnerships

Telesat's partnerships have been studied in detail in subsection 4.2. All of them collaborate with the company to make the Telesat Lightspeed project a reality. They are as follows:

- Manufacturer partner: Thales Alenia Space.

- Launching partners: Blue Origin and Relativity.
- Commercial (and other facilities) partner: NSSLGlobal.
- Terrestrial network partners: SatixFy, Ciena and ThinKom Solutions.
- Investment partners: Government of Canada and Government of Quebec.

In addition, there are other legislative agreements, regulated by state agencies such as the Federal Communications Commission and NASA, which establish the number of launches and satellites that a constellation can have, and promote programs to reduce space pollution.

5.2.4 Cost structure

Telesat's operational costs serve to guarantee the proper functioning of the company and meet its objectives. Thanks to a consolidated cost structure, Telesat can carry out its key activities. Below are the costs:

- Partnership collaborations: satellite manufacturing and launching.
- Leading ground network plan and technology.
- Investigation and development.
- Equipment and infrastructure.
- Marketing strategy.
- Human resources.
- Patents.

Finally, all the information presented in this section is grouped into a template to show, in a graphic and synthesized way, the entire Telesat business model.

Figure 5.1: Telesat Lightspeed's business model CANVAS

Chapter 6

SWOT analysis

In this section, once the studies referring to the Telesat Lightspeed constellation in terms of structure, business model, competition and other external factors all have been carried out, it is time to carry out the SWOT analysis, which helps to evaluate the competitive position of the company in the market and develop its strategic plans.

The SWOT analysis, which stands for strengths, weaknesses, opportunities, and threats, is a very useful tool to identify both the internal and external factors, as well as the current and future potential of the company and obtain key information to enhance the growth of the business. Strengths and weaknesses are part of the internal study of the company, opportunities and threats make up the part of the external analysis. These four blocks are briefly defined as follows [118]:

- Strengths: characteristics that give the business an advantage over others.
- Weaknesses: characteristics that place the business at a disadvantage relative to others.
- Opportunities: elements in the environment that the business could exploit to its advantage or increase profitability.
- Threats: elements in the environment that could endanger the integrity and profitability of the business.

This analysis is usually presented in a matrix form so that it is very visual and representative. As its content must be presented clearly and concisely, being as explicit as possible, the following SWOT is developed for the LEO satellite constellation of Telesat, Telesat Lightspeed:

POSITIVE | **INTERNAL** | **NEGATIVE**

STRENGTHS

- Regarding the market competitors:
  - Telesat is more experienced in satcom business.
  - Global coverage is achieved with fewer satellites (higher altitude); more compact and optimized network.
- Regarding the constellation technology:
  - Fast connectivity.
  - High reliability service.
  - Powerful ground stations.
- Regarding economic factors:
  - New investment sources now the company is publicly traded.
  - Service with affordable prices.
- Specific and defined customer base
- Telesat partners focus on what they are specialized in, resulting in a constellation that meets all its goals and becomes a world benchmark.

WEAKNESSES

- Dependence on partnerships:
  - Satellite manufacturing
  - Launching services
  - Leading edge technology equipment
- Dependence on the customer segment; having fewer customers but with strong links means that, in case of losing any, economic loses would be huge.
- Large investment is needed to deploy the constellation:
  - Funding is pending completion.

OPPORTUNITIES

- The fact Telesat is now a public company may be useful to attract new customers and alternative investment sources.
- There is worldwide demand for quality connectivity:
  - Explore the B2C market.
- New technologies encourage LEO satellites market growth.
- Make use of hypersonic launchers to deploy the satellites; based on air-breathing propulsion, they would cause less harmful emissions than the current launchers.

THREATS

- Strong competition; other companies can cover the same market segment and cause a loss of customers.
- Satellite and space debris collision risk.
- Environmental challenges limit LEO constellation growth:
  - Light pollution.
  - Space debris regulation.
  - Satellite launchers emissions.

EXTERNAL

Figure 6.1: Telesat Lightspeed's SWOT analysis

Chapter 7

Risk study

This section carries out the analysis of risks associated with the Telesat Lightspeed constellation. Risks are uncertain events, negative or positive, which can affect the objectives of the project. Undoubtedly, carrying out this study is key to adequately face the threats and opportunities of the business; the response to these events can define the future of the company, being essential to mitigate threats and enhance opportunities.

The structure of this risk analysis is as follows:

a) Identify risks, both the negatives (threats) and the positives (opportunities).

b) Evaluate them using the risk matrix.

c) Define a response for all of them with the aim of reducing the risk of threat and increasing the risk of opportunity.

d) Perform a reassessment and analyze the new results.

7.1 Risk identification

To carry out this section, the SWOT analysis developed in the previous section is used, considering that, in addition to threats and opportunities, some weaknesses and strengths can also become risks.

All identified risks are presented below; the threats (negative risks) are labeled as T_X and the opportunities (positive risks) are labeled as O_X:

Threats

- T_1: There is obvious competition in the satellite telecommunications sector; and, as has already been commented on previous occasions, although Telesat does not cover the business to customer segment, some of its customers do compete with constellations such as Starlink or Project Kuiper to offer internet to end consumers. Therefore, the threat is that, if the prices set by the internet service providers that

hire Telesat are not competitive, consumers will opt directly for companies that have their own constellation (SpaceX or Amazon), losing customers to Telesat.

- T_2: Telesat also competes against companies of the same style (OneWeb); that is, business to business and business to government satellite operators, which, again, may lead to a loss of customers.

- T_3: The exponential growth of the number of space debris, especially in LEO orbits, as shown in Figure 7.1, poses a constant threat to the integrity of satellites and their components; any impact or collision can have devastating consequences due to high speeds.

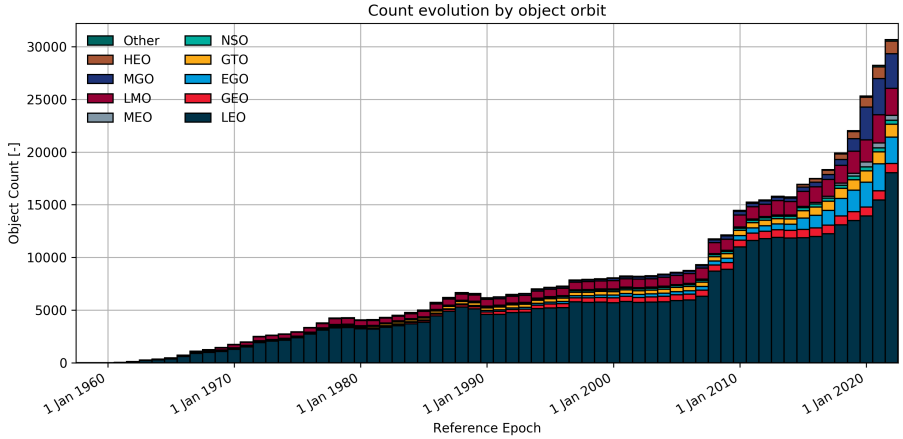

Figure 7.1: Number of space debris over the years. Source [119]

- T_4: Environmental challenges limit the growth of satellite constellations; new regulations are applied to regulate light pollution and combat the problem of space debris. Although the threat is not being able to grow much more, Telesat Lightspeed still has a small margin to grow to match the current competitors level because it is a constellation of only 298 satellites.

- T_5: Telesat has a huge dependence on external partnerships to manufacture and launch the constellation satellites, as well as to create a powerful ground network with the most cutting-edge technology. Therefore, many vital activities of the project are in the hands of other companies, so it is essential that all operate correctly so that there are no delays in the deployment of the constellation and the quality of the service is excellent.

- T_6: Telesat also depends on its customer base; having fewer customers but with powerful economic resources implies that, in case of losing any of them, the company would suffer from the loss of that source of income.

- T_7: Not being able to complete Telesat Lightspeed funding.

- T_8: Have too much success and be unable to meet all the customer demand, which would lead to lose them.

- T_9: Lightspeed, among other constellations, is a pioneer project on low Earth orbits; the associated threat is that technology fails to deliver the expected connectivity solutions and ends up falling short, resulting in a huge loss of invested money.

Opportunities

- O_1: The fact Telesat has recently gone public can attract new sources of investment and opens the possibility for the company to strengthen its economic capacity, as well as its customer base, which would help the interests of its constellation.
- O_2: Having a quality connectivity service is, a worldwide need nowadays; the demand is very high, and Telesat Lightspeed must be able to cover it.
- O_3: Any community, no matter how isolated, should be able to enjoy fast, accessible, and secure internet; Telesat Lightspeed can therefore become a benchmark in the sector thanks to the delivery of these services.
- O_4: Great technological advances drive the creation of projects such as Telesat Lightspeed and also support the global environment climate change initiatives around the market of satellite telecommunications in low orbits.
- O_5: Although Telesat's satellite constellation is designed for a business-to-government or business-to-business market, there is the option to explore the business to customer segment.
- O_6: Telesat could stop depending on external entities for the construction of Telesat Lightspeed satellites, as well as creating the technological components that the network needs in new research and production plants.
- O_7: Based on air-breathing propulsion, hypersonic launchers could be used to deploy the constellation satellites. This technology is expected to improve the emissions, as well as the performance, efficiency and reliability, of the current propulsion systems, resulting in a lower environmental impact.

7.2 Risk assessment

To evaluate the level of risks described above, the risk matrix is used, a representative matrix that is composed of the threats and the opportunities, that has a probability scale and an impact scale.

On the one hand, probability assesses the possibility of a risk occurring. The scale is 1%-100% and is divided into 5 groups: (1-20) % means very low probability; (21-40) %, low; (41-60) %, medium; (61-80) %, high; and (81-100) % means it is a fact.

On the other hand, impact measures the impact that a risk can cause on the objectives of a project. Again, the scale is divided into 5 groups and goes from 1-5: 1 means negligible impact; 2, minor; 3, moderate; 4, significant; and 5 means it is severe.

The combination of both scales gives rise to the risk matrix presented below, being optimal that on the part of threats the risks are in the lower left and in the part of opportunities, top left, in the area colored in dark blue:

Table 7.1: Risk matrix

	Threats					**Opportunities**				
	Impact									
Probability	1	2	3	4	5	5	4	3	2	1
(81-100) %	Low	Mod	High	Ext	Ext	Ext	Ext	High	Mod	Low
(61-80) %	Min	Low	Mod	High	Ext	Ext	High	Mod	Low	Min
(41-60) %	Min	Low	Mod	High	High	High	High	Mod	Low	Min
(21-40) %	Min	Low	Low	Mod	High	High	Mod	Low	Low	Min
(1-20) %	Min	Min	Low	Mod	High	High	Mod	Low	Min	Min

To make the matrix you must consider the 3 types of risk that there are and how they are counted:

- I_Q: Quality impact score (1-5) $\longrightarrow$ 40% because Telesat Lightspeed's value proposition is based on the quality of its service.
- I_S: Schedule impact score (1-5) $\longrightarrow$ 20% because Telesat Lightspeed is already delayed and both quality and cost prevail.
- I_C: Cost impact score (1-5) $\longrightarrow$ 40% because Telesat Lightspeed is a business and its main goal is to generate profit.

Therefore, the mathematical expression that calculates the total impact score is:

$$\boxed{I_T = 0,4 \cdot I_Q + 0,2 \cdot I_S + 0,4 \cdot I_C}$$

Table 7.2, presented below, indicates how to locate the risks within the matrix:

Table 7.2: Risk evaluation

		Impact (rounded value)				
ID	**Probability**	IQ	IS	IC	**Total**	**Risk matrix**
T1	(61-80) %	1	1	5	3	Moderate
T2	(21-40) %	1	1	5	3	Low
T3	(1-20) %	2	2	4	3	Low
T4	(41-60) %	4	1	1	2	Low
T5	(81-100) %	3	5	4	4	Extreme
T6	(21-40) %	1	1	5	3	Low
T7	(21-40) %	5	5	5	5	High
T8	(1-20) %	1	1	5	3	Low
T9	(1-20) %	5	5	5	5	High
O1	(61-80) %	5	5	5	5	Extreme
O2	(61-80) %	3	4	5	4	High
O3	(61-80) %	5	2	5	4	High
O4	(41-60) %	5	3	4	4	High
O5	(1-20) %	1	3	5	3	Low
O6	(1-20) %	4	4	5	4	Moderate
O7	(21-40) %	2	3	3	3	Low

Finally, the risk matrix is defined as follows:

Table 7.3: Risk matrix assembly

	Threats					**Opportunities**				
	Impact									
Probability	1	2	3	4	5	5	4	3	2	1
(81-100) %				T_5						
(61-80) %			T_1			O_1	O_2/O_3			
(41-60) %		T_4					O_4			
(21-40) %			T_2/T_6		T_7			O_7		
(1-20) %			T_3/T_8		T_9		O_6	O_5		

7.3 Definition of the measures taken

As mentioned above, the idea is to reduce the risk of threats and enhance the risk of opportunities. In terms of the matrix, this means locating the threat items in the lower left, where the probability and impact is as low as possible; and the opportunity items in the upper left area of their part of the matrix, where the probability and impact is greater.

To carry out these changes, it is necessary to act on the risks that can harm business activity and jeopardize the project. The possible responses to the different risks are as follows [120]:

- Avoidance: used for threats, it eliminates the risk by accepting another alternative.
- Mitigation: used for threats, it reduces the probability and/or impact through active measures.

- Transfer: used for threats, it reduces the probability and/or impact by transferring ownership of the risk to another party.
- Acceptance: used for both, threats and opportunities, it adopts a wait-and-see attitude and act when triggers are met.
- Share: used for opportunities, it shares with another party that can increase the probability and/or impact.
- Enhance: used for opportunities, it increases the probability and/or impact.
- Exploit: used for opportunities, it takes advantage of them.

The responses presented below are proposals without any feasibility assessment, because this would be part of a wider risk management process and remediation activity. Considering this, the proposed measures for the risks identified in the Telesat Lightspeed constellation are as follows:

Threats response

It should be noted that threats T_2, T_3, T_4, T_6 and T_8 do not pose a severe risk and are well placed in the matrix. However, it is still necessary to propose a response in case it would be needed to act.

Threats and their associated response are presented in order of severity, according to the results obtained in Table 7.2:

- T_5 – Mitigation: Expand the operational capacity of the company and manage the high value activities related to Telesat Lightspeed internally. To do this, it would be necessary to expand the current logistics system and increase the workforce.
- T_7 – Mitigation: Obtain a public-private investment to finance the constellation. Moreover, intensify the marketing campaign and promote services through the most important business platforms within the telecommunications sector, as well as increase contacts with governments around the world.
- T_9 – Mitigation: Carry out a more extensive amount of reliability tests before deploying the whole constellation in order to make sure the technology is able to support the strong connectivity demand.
- T_1 – Mitigation: Receive B2B capital to help fund the initial costs of the constellation in order to initially compete with lower prices of the competition in the end-user sector.
- T_4 – Mitigation: Renegotiate the number of satellites of the constellation claiming that Telesat Lighstspeed does not even have half the number of satellites of its maximum competitor's constellation (OneWeb).

- T_2 – Mitigation: Intensify customer relationships and strengthen ties through good communication, assistance and quality in order to establish a closer association than other companies.
- T_6 – Mitigation: Extend the customer base to able to face possible losses and negotiate a future increase of prices.
- T_3 – Mitigation: Equip satellites with collision avoidance systems and monitor them from land to guarantee their security. Moreover, reinforce the most sensitive subsystems to protect them in case of impact // Transfer: ESA is investigating the space debris issue.
- T_8 – Mitigation: Increase the investment in R+D technology so the 298 satellites network is enough to satisfy all the customers needs and/or also renegotiate the total number of satellites.

Opportunities response

It should be noted that opportunities O_1, O_2, O_3 and O_4 already pose a positive risk and are well placed in the matrix. However, it is still necessary to propose a response in case it would be needed to bring them into reality.

Opportunities and their associated response are presented in order of worth pursuing to take maximum advantage, according to the results obtained in Table 7.2:

- O_5 – Enhance: Create a new business model: redesign the constellation, manufacture more satellites, and place them in lower orbits, following the model of constellations such as Starlink or Project Kuiper.
- O_7 – Share: Provide investment for launch partners to develop this kind of propulsion technology, free of harmful emissions.
- O_6 – Exploit: Gain economic muscle through the exploitation of the services of the GEO satellite fleet and the technical assistance offered by Telesat to create a new production chain and research at the inter-company level.
- O_4 – Share: Agree with competing companies to work together and share point solutions for a common goal: develop technologies that enhance the quality of the connectivity services provided by the LEO satellite constellations.
- O_2 – Enhance: Increase the operational capacity of the company by hiring more qualified employees capable of managing all the demand.
- O_3 – Exploit: Make use of the more than 50 years of experience that Telesat has as a satellite operator and establish links in order to be a role model.
- O_1 – Exploit: Intensify the marketing strategy, attend conferences and trade fairs in order to increase the probability of interested investors and customers.

7.4 Reassessment

If the proposed measures previously described were realised to address the risks, it will have an impact and modify the location of the threats and the opportunities within the matrix. The study is reformulated below, and the results are presented:

Table 7.4: Risk evaluation implementing the responses

		Impact (rounded value)				
ID	**Probability**	IQ	IS	IC	**Total**	**Risk matrix**
T1	(41-60) %	1	1	3	2	Low
T2	(1-20) %	1	1	3	2	Minimum
T3	(1-20) %	2	2	2	2	Minimum
T4	(21-40) %	4	1	1	2	Low
T5	(1-20) %	4	3	3	3	Low
T6	(21-40) %	1	1	4	2	Low
T7	(1-20) %	3	3	3	3	Low
T8	(1-20) %	1	1	2	1	Minimum
T9	(1-20) %	3	3	3	3	Low
O1	(81-100) %	5	5	5	5	Extreme
O2	(61-80) %	5	4	5	5	Extreme
O3	(81-100) %	5	2	5	4	Extreme
O4	(61-80) %	5	3	4	4	High
O5	(81-100) %	4	3	5	4	Extreme
O6	(21-40) %	5	3	5	5	High
O7	(41-60) %	2	3	3	3	Moderate

Therefore, the reassessed risk matrix is as follows:

Table 7.5: Reevaluated risk matrix assembly

	Threats					**Opportunities**				
	Impact									
Probability	1	2	3	4	5	5	4	3	2	1
(81-100) %						O_1	O_3/O_5			
(61-80) %						O_2	O_4			
(41-60) %		T_1						O_7		
(21-40) %		T_4/T_6				O_6				
(1-20) %	T_8	T_2/T_3	$T_5/T_7/T_9$							

As can be seen, most threats are concentrated in the lower left of the matrix, which indicates that the risks are controlled. On the other side of the matrix, opportunities are located at the top left, where positive risks are reinforced.

Chapter 8

Environmental footprint

Assessing the ecological, social, and economic impact that Telesat can have with its constellation of low-orbit satellites is the main purpose of this analysis. The study presented in this chapter is based, both on the environmental impact generated by Telesat Lightspeed (the information in subsection 4.7 is expanded), and on the role it can play in relation to the Sustainable Development Goals established by the United Nations.

It is important to note the fact that this analysis applies, to some extent, to any constellation of telecommunications satellites.

8.1 Telesat Lightspeed environmental impact

Light pollution, the increase in objects within low orbits and the impact generated by satellite launches are the main environmental problems associated with Telesat Lightspeed and any other constellation of LEO satellites.

Light pollution

First, the light pollution generated by satellites and other space objects is due to the reflection of sunlight on the surface of bodies. Logically, the more there are and the closer they are to Earth, the greater the brightness of the night sky, affecting astronomical tasks of space observation.

However, despite this issue, Telesat Lightspeed has two advantages over other constellations. The first is that it has only 298 satellites, representing a 0,71% of those of Starlink (42.000 satellites), 9,21% of those of Project Kuiper (3.236) and 45,99% of those of OneWeb (648 satellites). The second advantage is that Lightspeed's satellites are placed in higher orbits than the satellites of the other constellations, except for OneWeb.

Therefore, it can be said that Lightspeed's satellites will not pose a major threat in this regard, unlike other constellations that will produce a huge light impact. In fact, to try to mitigate this adverse effect, one solution is to darken the surfaces of satellites which in turn reflects less sunlight.

Saturation of Earth's orbits

As it has been mentioned throughout the project, the amount of space debris in low orbits has been increasing rapidly over the years. One of the reasons that has contributed to filling these regions of space with artificial objects is the launch of satellites, the number of which has grown exponentially in recent years.

Saturating Earth orbits can have disastrous consequences, again, for astronomical studies, and for the very safety of satellite operations since any collision would mean the destruction of equipment and systems on board due to high speeds.

Telesat Lightspeed, in addition to operating under the stipulated regulations, does not generate as much risk as other constellations, since it has fewer satellites. However, it does contribute to this saturation of low Earth orbits, so it must respect the control measures always established.

Satellite launch pollution

Another obvious environmental risk is the pollution produced by the rockets that launch the satellites; In the case of Telesat Lightspeed, New Glenn and Terran 1 will oversee carrying out the launches.

In general, rockets produce different emissions among which are suspects such as CO_2, water vapor, carbon soot, carbon monoxide, NO_X, chlorine, alumina, and sulfuric compounds [121]. Some can destroy the ozone layer and others remain and damage various areas of the atmosphere, intensifying the danger associated with climate change. For these reasons, reducing the number of launches is key to producing the minimum possible environmental impact.

Solution: Air breathing propulsion

To combat the pollution caused by current launchers, hypersonic technology must be considered. NASA designed a project to overcome one of the greatest aeronautical research challenges: air-breathing hypersonic flights [122]. With this propulsion system, it would be possible to improve the performance, efficiency, and reliability, but mainly the emissions, caused by the launchers [123]. So, future investigations could try to exploit this possibility and reduce the environmental impact associated with this phase of the constellation project.

8.2 United Nations SDGs met by Telesat Lightspeed

In September 2015, the United Nations created the 2030 Agenda for Sustainable Development, a 15-year plan of action for people, planet, and prosperity to tackle the most important challenges in terms of economic, social, and environmental factors [124]. The 17 Sustainable Development Goals (SDGs) are the main objectives of the agenda, and are presented below:

Figure 8.1: United Nations SDGs. Source: [125]

Of the 17 SDGs in the figure, Telesat Lightspeed positively influences four of them, as shown in Table 8.1, and negatively in the SDG number 13 (climate action), considering the explanations in the previous section.

Table 8.1: Telesat Lightspeed's positive impact on the SDGs

SDG	**Description given by [124]**	**Telesat Lightspeed's positive impact**
4	"Ensure inclusive and equitable quality education and promote lifelong learning opportunities".	The constellation will improve education in regions where fast, stable, and secure internet is not yet available.
8	"Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".	Lightspeed will create jobs and help develop the economy of those places that do not yet have a quality connectivity service.
9	"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation".	The constellation's terrestrial and space infrastructure will be both innovative and robust. It will be formed using the most powerful technology, which will facilitate the company's business activities.
10	"Reduce inequality within and among countries".	The project itself aims to provide its services to any community and fights to close the digital divide between rural and urban areas, thus reducing social and economic inequalities between those regions.

Chapter 9

Conclusions

This project has been based on studying how Telesat, through its constellation of Telesat Lightspeed satellites, has developed a business model with which it aims to provide a universal connectivity service capable of closing the digital divide between urban and rural areas, boosting the economic growth of the community and facing the more demanding challenges of aeronautical, maritime, and governmental connection.

To achieve this objective and prepare the thesis, first a thorough research and documentation work has been carried out; a theoretical framework has been established based on the study of the types of orbits, emphasizing low Earth orbits, and a business model has been defined through the Business Model Canvas.

Studying the evolution and importance of satellites in the telecommunications industry, seeing how Telesat participates in this market and knowing what competition it has, as well as carrying out a PESTEL analysis to know what external factors influence the sector, have been fundamental aspects to form this first phase of the document.

However, the theoretical structure could not be completed until the detailed study of the company Telesat and its constellation of low-orbit satellites, Telesat Lightspeed, had been carried out. The history of the company, its value proposition and philosophy, as well as its directors and employees, have been studied in this section. So have its collaborators, its customer base and all the technical details of the satellites, the constellation, and the elements of the terrestrial network. The economic analysis and environmental philosophy of the entity have completed the theoretical study of the thesis.

The second part of the project has been purely practical; from Telesat's Case Study, its Business Model Canvas has been designed, representing how the organization creates, delivers, and captures value. In addition, both the SWOT analysis of Lightspeed has been carried out, identifying the strengths and possible challenges of the constellation, and the analysis of risks associated with the company's most ambitious project. Its environmental impact has been the end of this work.

Therefore, having already developed each of the points described above, it can be said that Telesat is a unique company. Its Lightspeed constellation, made up of 298 satellites equipped with the best technology in existence, aims to redefine global connectivity and ensure quality internet service anywhere in the world. For this, it is essential that this network of satellites operates in LEO orbits; the fact that it is 35 times closer to Earth than the GEO, makes an unprecedented connection speed possible. In addition, it is an intelligent network, since Telesat Lightspeed will be able to identify the points with the most demand and adapt dynamically providing more bandwidth in areas where it is required, such as airport hubs.

Undoubtedly, LEO satellite constellations have revolutionized the satellite telecommunications sector, which has experienced exponential growth in recent years. Telesat understands the great market opportunity that exists and knows who to deliver its value proposition to. On the one hand, to governments, which can benefit from defense missions, first response operations and to boost the economic growth of its communities. On the other hand, big enterprise networks such as aeronautical and maritime internet service providers and mobile network operators, among others. These are its customers, who make it a company that operates business to government and business to business.

With more than 50 years of experience, many more than its main competitors, Telesat remains one of the most important satellite operators in the world, it has reached a series of agreements with different entities to complete the Lightspeed project. It is the only company that operates in this way and, thanks to the specialization of its partners in specific aspects of the constellation, Lightspeed will be the most compact and optimized satellite network that exists.

Finally, it should be noted that Telesat is now a publicly traded Canadian incorporated and controlled company because it seeks new sources of investment to finish the financing of Lightspeed. The company intends to fulfill this necessity as soon as possible and to deploy the entire constellation by the beginning of 2025. From there, they will work with the aim of enhancing their virtues and squeezing the opportunities that are presented, as well as reducing the threats that such a demanding market will surely bring.

Considerations for the future

To safeguard the future deployment of these constellations of LEO telecommunications satellites, success will lie in developing a business model that has minimal impact on the environment. Telesat already operates with this objective, but it is necessary to continue working to minimize the terrestrial and space ecological footprint associated with this industry if they wish to continue delivering services and maintain their market position.

Therefore, any future project should follow this line of research; reduce pollution caused by satellite launch vehicles and combat both light pollution of constellations and the risk of collapsing low Earth orbits with so many satellites.

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