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Study of the benefits and applications of passenger supersonic transport vehicles: Case Study of Supersonic 2.0-Virgin Galactic

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Abstract

The commercial supersonic passenger transport business has regained momentum in recent years. With the emergence and development of state-of-the-art technologies, many aerospace companies are now confident of being able to overcome all the technical and economic problems experienced by Concorde, the last supersonic aircraft to operate commercially and the benchmark for all current designs. In this sense, aspects such as the reduction of operating and maintenance costs, the ability to adapt to existing airport infrastructures and compliance with international regulations will be key to the success of the business. In addition, today's companies will have to face the new challenges of today's mobility, such as efficiency and sustainability. This study provides an overview, as well as a subsequent global comparison, of the different solutions presented by the various companies that are expected to enter the market in the coming years, consisting of supersonic and hypersonic aircraft capable of delivering performances that were unthinkable just a few years ago, such as being able to travel from London to New York in just 90 minutes in a safe, comfortable and sustainable manner.

On the other hand, the study later focuses on a much deeper analysis of the world's first commercial spaceline, Virgin Galactic, and the business model it is intended to implement for the commercial supersonic transport market. This analysis provides an overview of the company that enables to see how, although Virgin Galactic currently focuses the vast majority of its technological, human and economic resources on the space travel business, the company could take advantage of the capabilities, technologies and expertise developed within this business to be capable of successfully implementing its business model for the supersonic commercial travel market, the Supersonic 2.0 business model. The detailed study of this business model using the Business Model Canvas tool allows to identify the key aspects for its operation, as well as the differential features that the company should enhance. Finally, it is observed that Virgin Galactic, as well as most of its competitors, will have to be able to overcome the many risks inherent in the passenger supersonic transport market. For this reason, the company's ability to demonstrate the safety, efficiency and sustainability of its design will be crucial to gaining consumer confidence.

El negoci del transport comercial supersònic de passatgers ha recuperat impuls en els últims anys. Amb l'aparició i el desenvolupament de tecnologies d'última generació moltes empreses aeroespacials confien ara a poder superar tots els problemes tècnics i econòmics experimentats pel Concorde, l'últim avió supersònic que va operar comercialment i el referent de tots els dissenys actuals. En aquest sentit, aspectes com la

reducció dels costos operatius i de manteniment, la capacitat d'adaptació a les infraestructures aeroportuàries existents i el compliment de la normativa internacional seran claus per a l'èxit del negoci. A més, les empreses actuals hauran d'afrontar els nous reptes de la mobilitat actual, com l'eficiència i la sostenibilitat. Aquest estudi ofereix una descripció general, així com una posterior comparativa global, de les diferents solucions presentades per les diverses companyies que esperen entrar al mercat en els propers anys, consistents en avions supersònics i hipersònics capaços d'oferir prestacions impensables fa tan sols uns anys, com ara poder viatjar de Londres a Nova York en només 90 minuts de forma segura, còmoda i sostenible.

D'altra banda, l'estudi se centra posteriorment en una anàlisi molt més profunda de la primera companyia espacial comercial del món, Virgin Galactic, i el model de negoci que aquesta pretén implementar per al mercat del transport comercial supersònic. Aquesta anàlisi proporciona una visió general de la companyia que permet veure com, tot i que actualment Virgin Galactic centra la gran majoria dels seus recursos tecnològics, humans i econòmics en el negoci dels viatges espacials, la companyia podria beneficiar-se de les capacitats, tecnologies i experiència desenvolupats dins d'aquest negoci per poder implementar amb èxit el seu model de negoci per al mercat de viatges comercials supersònics, el model de negoci Supersònic 2.0. L'estudi detallat d'aquest model de negoci mitjançant l'eina Business Model Canvas permet identificar els aspectes clau per al seu funcionament, així com els trets diferencials que l'empresa hauria de potenciar. Finalment, s'observa com Virgin Galactic, així com la majoria dels seus competidors, haurà de ser capaç de superar els molts riscos inherents al mercat del transport supersònic de passatgers. Per aquest motiu, la capacitat de l'empresa per demostrar la seguretat, eficiència i sostenibilitat del seu disseny serà crucial per guanyar-se la confiança dels consumidors.

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Acronyms

ANA HD ANA Holdings
ATR Air Turbo Rocket
BAC British Aircraft Corporation
BMC Business Model Canvas
CEO Chief Executive Officer
DLR German Aerospace Center
DMR Dual Mode Ramjet
ESG Environmental, Social and Governance
FAA Federal Aviation Administration
FAI Fédération Aéronautique Internationale
H2020 Horizon 2020
HTHL Horizontal Take-off and Landing
ISS International Space Station
LH2 Liquid Hydrogen
LOX Liquid Oxygen
MCR Mission Concept Review
MOU Memorandum of Understanding
NASA National Aeronautics and Space Administration
P2P Point-to-Point
R&D Research and Development
SAF Sustainable Aviation Fuel
SAIC Science Applications International Corporation
SPCE Virgin Galactic Holdings, Inc. common stock
TBCC Turbine-Based Combined Cycle
TRL Technological Readiness Level
VMS Virgin MotherShip
VPC Value Proposition Canvas
VSS Virgin Space Ship

Chapter 1

Introduction

1.1 Object

The aim of this project is to identify the benefits and applications of passenger supersonic transport vehicles compared to other point-to-point transport passengers in order to study the Supersonic 2.0 business model opportunities from Virgin Galactic. In this sense, the project focuses on an in-depth case study of Virgin Galactic with the goal of understanding the companys's operation and assessing its ability to commercialize and implement its business model.

The subsequent development of the Supersonic 2.0 business model study is aimed to determine and examine the key aspects for its successful operation. The identification of these elements is crucial in order to maximize and enhance the strengths of the business model, as well as those that can provide a more differentiated value proposition. Thus, this project intends to provide a comprehensive vision of Virgin Galactic and its business model for the commercial supersonic transport market, and expects to become a valuable tool for future studies developed in the same direction.

1.2 Scope

The project will include the following aspects:

- An exhaustive state of the art where the main characteristics of current supersonic vehicles and concept aircraft will be analyzed and compared.
- An overview of Virgin Galactic's history and philosophy, as well as the identification of its ownership and partnerships.
- A market segmentation in order to identify customer preferences, demands and expectations as well as future requirements of the sector.
- A stakeholder analysis through the use of Mendelow's matrix, in which the role and prominence of stakeholders will be studied.

- A detailed description of the production system and value chain processes, focusing on the required resources and key activities respectively.
- An overview of the current financial status of the company.
- An exhaustive study of the BMC (Business Model Canvas) fundamental building blocks in order to obtain a comprehensive understanding of Virgin Galactic's Supersonic 2.0 operation and value proposition.
- An in-depth risk analysis to identify, classify and evaluate the risks of the Supersonic 2.0 business model in order to provide an efficient response plan.
- A study of the environmental impact of the Supersonic 2.0 business model, including the description of Virgin Galactic's environmental philosophy and the main environmental challenges that its supersonic aircraft will face.

The project will not include the following parts:

- The economic feasibility study of the Supersonic 2.0 project, as it's still in its initial phases and results impossible to collect all the necessary information.
- The business model study of the companies that own the supersonic vehicles or concepts mentioned in the state of the art.
- A technical evaluation of the structural or aerodynamic characteristics of Virgin Galactic's supersonic aircraft concept.
- Interviews with any person involved or related with the development of the project.

1.3 Requirements

The final solution of the project must follow these specific constraints:

- State of the art section must be completed with a summary table in order to provide a general comparison of all the vehicles described.
- The analysis of Virgin Galactic's stakeholders and development of the subsequent management strategy must be executed through the use of a Mendelow Matrix.
- Virgin Galactic's Supersonic 2.0 business model must be studied through the detailed description of the building blocks that integrate the Business Model Canvas.
- The study of the Supersonic 2.0 business model must culminate with the resulting Business Model Canvas document.
- Customer Segment building block must include an empathy map for the target customer persona.
- Value Proposition building block must be completed with the development of the Value Proposition Canvas document.

- Risk analysis section must be developed through the use of a risk matrix. The section must also provide a response plan to the identified risks, as well as the resulting risk re-assessment.

1.4 Justification

Two decades ago, the Concorde, the last supersonic aircraft to operate commercially, made its last commercial flight. Since then, the market for commercial supersonic transportation and the development of new and improved technologies for this purposed have been abandoned. However, in recent years multiple companies have declared their intention of entering the market by presenting promising high-speed aircraft designs, and, although the commercial supersonic transport sector is just re-emerging, the demand and interest for this type of travelling is expected to grow exponentially in the coming decades. Supersonic aircraft concept from Virgin Galactic, based on Concorde's design, aims to lead the race of passenger supersonic transport with the intention of using sustainable aviation fuel. Considering that achieving this goal could suppose the beginning of a profound transformation of the industry, it is necessary to develop a comprehensive feasibility analysis of the business model behind this proposal. In this sense, although this project does not have the capacity to evaluate technical aspects of Virgin Galactic's supersonic aircraft concept, it can result very useful on understanding the operation of the company's business model and help on the identification of the key assets for the success of the business.

On the other hand, while there are already similar studies focused on companies with the same purpose, for our university working group represents the first work in the study of the viability, both economic and environmental, of supersonic passenger transport vehicles implementation and commercialization. For this reason, and given the significant growth that this industry could experience in the future, this project has the potential to become the antecedent of future studies focused in the same direction.

Chapter 2

State of the art

Now that it's two decades since the last commercial supersonic flight, numerous companies are trying to lead the race of supersonic transport industry revival with the unveiling of promising supersonic aircraft designs. For this reason, this section focuses on the general description and comparison of the proposals of Virgin Galactic's possible competitors. However, an overview of supersonic transport background is provided first in order to identify and understand the basis of current designs, as well as the main challenges facing companies at present.

2.1 Commercial supersonic transport background

The goal of regular commercial operation at supersonic speeds started to become a reality more than 50 years ago, when two supersonic aircraft, the Anglo-French Concorde and the Russian Tupolev Tu-144, made their first flights. The battle for being the first to achieve it began in the 1950s, when the first design studies focused on the development of a supersonic airliner by the UK industry and the subsequent accusations of espionage against the Russians led to the start of an international rivalry. Finally, although the Soviets managed to fly their supersonic airliner first, the first supersonic passenger-carrying commercial flight is credited to Concorde, which completed its first scheduled supersonic passenger services flying from London to Bahrain and from Paris to Rio de Janeiro on January 21, 1976 [1].

2.1.1 Concorde

The Concorde prototype construction, developed by the British Aircraft Corporation (BAC) and Aerospatiale, began in 1965 after the formal agreement of British and French industries in 1962. The resulting delta wing aircraft, considered a technological marvel at the time, made its first flight on March 2, 1969, just two months after the first flight of the Tupolev Tu-144, but didn't achieve supersonic speed until October of that year [2]. A total of twenty aircraft were constructed, of which only fourteen were finally used as a commercial passenger-carrying aircraft.

Figure 2.1: Concorde supersonic aircraft

The Concorde had a capacity of up to 128 passengers and was able to cruise at speeds up to Mach 2.04 (2,499 km per hour) at 18,000 m altitude, thereby saving four of the standard seven hours required by subsonic airliners to fly from London to New York. During the years of its operational life, in which a fleet of only twelve Concordes accumulated about 350,000 hours of flight time with high reliability, it was concluded that the technology generally satisfied or exceeded the expectations at the start of the project [3]. Nevertheless, the development and maintenance costs added to the high fuel costs per seat-kilometer meant that the aircraft was never financially profitable.

On July 2000 a Concorde suffered an engine failure after a damage on the wing fuel tank structure, resulting in a crash where all the 109 people on board and 4 people on the ground were killed. In 2003, after 27 years of commercial operations, the low passenger numbers following the crash added to the rising maintenance costs and the modification costs expected in that year, made both British Airways and Air France conclude that continuation of its services was no longer commercially justified. Finally, on October 24, 2003, Concorde made its last commercial passenger flight travelling from New York to London, which today is still standing as the last commercial supersonic flight.

2.1.2 Tupolev Tu-144

The Tupolev Tu-144, designed by Andrei Tupolev and his son Aleksey, was the first supersonic transport aircraft, successfully completing the first test flight on December 31, 1968. It also became the first passenger aircraft to exceed the speed of sound when it flew supersonic for the first time in June 1969. Although the development of a supersonic airliner was years ahead of what the Soviet aviation industry was capable of at the time [2], the Russians managed to built a total of sixteen airworthy aircraft between 1967 and 1983. However, the solutions to the problems Concorde's engineers also had to solve were much less sophisticated.

Figure 2.2: Tupolev Tu-144 supersonic aircraft

The Tu-144 was designed to carry up to 140 passengers at a cruising speed of Mach 2.15 (2,634 km per hour). Even though the design of the Tupolev Tu-144 was clearly influenced by Concorde's, there were notable differences (see figures 2.1 and 2.2). The Tu-144 was bigger and more powerful, what consequently also made it more than 20 tones heavier than an empty Concorde. Moreover, compared to the Concorde, engine control and braking system were inferior and the aerodynamics were not as good. On the other hand, while the engines were quite more powerful than Concorde's, they were also known to be fuel inefficient and noisy, leading passengers to complain that "made conversation impossible" [2].

For all the reasons above mentioned, summed to the several accidents and incidents that affected its service, the Tu-144 only flew commercially from 1977 to 1978, in a period in which it made 102 commercial flights of which only 55 carried passengers.

2.2 Industry competitors

In the last ten years, multiple companies have emerged with the aim of revolutionizing the aviation industry through the development of impressive supersonic aircraft, capable of flying point-to-point (P2P) much faster than any commercial aircraft available today. Next, an overview of the most promising companies is given in order to compare the advantages and disadvantages of their innovative designs, as well as to identify the value proposition of each. Since it's very difficult to assess which company owns the most advanced proposal, the aircraft are presented sorted by the maximum altitude at which they are designed to fly, as it represents a good indicator of the main characteristics of the vehicle and its performance

2.2.1 Boom Supersonic: Overture

Boom Supersonic, founded in Denver in 2014, has partnered with numerous industry leader companies around the globe in order to develop the Overture, a supersonic airliner optimized for speed, safety and sustainability [4]. The Symphony, the Boom-developed supersonic engine specifically for Overture, has the ambitious goal to operate at net zero carbon using 100% sustainable aviation fuel (SAF), in addition to meet all applicable noise standards, including Chapter 14 noise levels for quiet operation. Symphony is being developed under collaboration with three world leader companies in their sector (Florida Turbine Technologies (FTT), GE Additive and StandardAero) and is expected to offer a significant 25% improvement in time on wing in addition to much lower engine maintenance and repair costs, thereby reducing total airline operating costs by a minimum of 10%.

Before the production launch of the Overture awaited for 2024, Boom Supersonic is expected to fly the XB-1, its supersonic demonstrator used to identify and study all the key aspects for an optimized supersonic performance. The collected data will be used, if possible, to improve the Overture's design, which already includes innovative traits such as a compound modified delta planform to maximize safety and efficiency, and gull wings to minimize the aircraft drag. With all the mentioned features, Overture is designed to achieve Mach 1.7 speeds at 60,000 ft (18.3 km) cruising altitude, with a predicted maximum capacity between 65 and 80 passengers. As Boom has already announced, Overture is scheduled to make its first flight in 2027 and aims to begin operating in 2029 once achieved the type certification.

Figure 2.3: External design for the Overture supersonic aircraft

2.2.2 Exosonic: supersonic jet

The American startup company Exosonic, established in 2019, is developing the world's first low boom, quiet supersonic passenger airliner using shaped sonic boom technology [5]. In this direction, the US Air Force's Presidential and Executive Airlift Directorate has partnered with Exosonic to develop a supersonic executive jet that could be used as Air Force One.

The interior of the Exosonic executive model cabin is designed to have a capacity of 31 passengers and include two private suites: one capable of holding meetings and equiped with video teleconferencing, and a second suite with lie-flat seats to allow passengers to sleep on board. Alternatively, the commercial configuration used for commercial flights (see figure 2.4b) is capable of carrying up to 70 people within a dual-class cabin arrangement that includes 10 lie-flat seats and 60 premium-economy style seats. Both models of the Exosonic jet, identical in terms of supersonic technology used, are capable of reaching Mach 1.8 speeds and cruising altitudes of 60,000 ft. On the other hand, the supersonic jet is expected to be powered by the sustainable fossil-free E-Jet fuel developed by the innovative Twelve company.

(a) External shape of the aircraft (b) Interior design of the commercial mode

Figure 2.4: Exterior and interior configuration of Exosonic's supersonic commercial jet [6]

In order to achieve low boom capabilities and an acceptable noise level to fly overland, Exosonic's supersonic aircraft is designed with sonic boom shaping technology to mute the sonic boom. As the company assures, by the time the sonic boom reaches the ground it will be no louder than a car door closing down the street, meaning that typical city traffic will be able to drown out the sound of the sonic boom produced by the aircraft [6].

2.2.3 Hermeus: Halcyon

Hermeus company was founded in 2018 by former SpaceX engineers with the aim of developing hypersonic aircraft technology in order radically accelerate air travel. In 2021, Hermeus signed contracts with the National Aeronautics and Space Administration (NASA) and United States Air Force for the research and development of a series of autonomous hypersonic aircraft.

In November 2022, Hermeus demonstrated turbojet to ramjet transition within Chimera, its proprietary turbine-based combined cycle (TBCC) engine, proving it to be capable of flying at Mach 5 speeds. The roadmap of the company follows with the testing of the Chimera engine in the Quarterhorse, a small remotely piloted aircraft as well as the first aircraft of the company. Then, once successfully flight tested the Quarterhorse, the next step is focused on the developing of a mid-size autonomous aircraft designed for defense and intelligence uses, the Darkhorse.

The incremental product roadmap of Hermeus is expected to take its last step in 2029 with the unveiling of its hypersonic passenger aircraft, the Halcyon. The aircraft is designed to have a maximum capacity of 20

passengers and is capable of reaching cruising speeds of Mach 5 at a flight altitude of 90,000 ft (27.4 km). As stated by Hermeus, Halcyon is capable of travelling over 125 trans-oceanic routes at hypersonic speeds [7], which means completing the New York to Paris route in just 90 minutes.

Figure 2.5: Hermeus hypersonic aircraft design from Halcyon [7]

2.2.4 STRATOFLY: MR3

Funded by the European Comission and under the framework of the Horizon 2020 (H2020) Program, the highly multi-disciplinary STRATOFLY project has been created with the objective of assessing the feasibility of high-speed passenger stratospheric transport with respect to key technological, societal and economical aspects. Moreover, this project also aims to refine the design and the concept of operations of STRATOFLY MR3, the reference vehicle of the H2020 STRATOFLY project, in order to reach the ambitious goal of Technology Readiness Level (TRL) 6 by 2035 [8].

Figure 2.6: STRATOFLY MR3 external configuration design [8]

STRATOFLY MR3 is a conceptual hypersonic aircraft designed to be able to cruise at Mach 8 (9,800 km/h) at stratospheric altitudes of above 30 km, carrying up to 300 passengers as a payload. The propulsion system that allows to reach such incredible speeds consists in high-speed air-breathing engines which integrate a combination of 6 Air Turbo Rocket (ATR) engines and a Dual Mode Ramjet (DMR). The ATR engines

are used to propel the aircraft during the take-off, subsonic cruise and supersonic acceleration, while the DMR engine starts in the transition phase at a cruise speed of Mach 1.5 and provides the full thrust at cruise speeds above Mach 4.5, once the ATRs are shut down. In addition, the STRATOFLY MR3 engines use liquid hydrogen as propellant, which guarantees a complete reduction in carbon dioxide emissions even though emitting greenhouse gases such as water vapor and nitrogen oxides.

The use of multiple bubble multi-functional structure for most parts of the aircraft, the devising of noise reduction strategies based on nozzle-airframe integration, and the implementation of an innovative Thermal and Energy Management Subsystem (TEMS) are other examples of the STRATOFLY MR3 multi-objective optimization from both operational and technological design, which aims to assure environmental sustainability, economic viability and overall safety aspects.

2.2.5 ANA HD - PD AeroSpace: PEGASUS

ANA HOLDINGS (ANA HD), the largest airline group in Japan and H.I.S, one of Japan's biggest travel agencies, have announced their partnership with PD AeroSpace to develop supersonic commercial space flight [9]. PD AeroSpace has patented the world's first engine that can switch between jet combustion mode and rocket combustion mode based on detonation technology, and aims to develop an spacecraft featuring this type of propulsion system. The first target of the company is to develop the PEGASUS X08 concept focused on sub-orbital space tourism flight, which consists in a fully-reusable winged vehicle with a capacity of up to 6 passenger and capable of horizontal take-off and landing (HTHL) [10].

Figure 2.7: PEGASUS X08 suborbital spaceplane concept from ANA-HD and PD AeroSpace

On the other hand, the second target of the company is to adapt the vehicle to reach intercontinental P2P hypersonic flight, focusing on passenger transport. The X10 conceptual version of the aircraft is expected to be capable of flying at a speed of over Mach 5 at altitudes up to 80 km. As in the case of the X08 version, the X10 aircraft will also benefit from the pulse detonation engine developed by the same company. According to ANA HD and PD AeroSpace companies, the hypersonic aircraft will be powered by biofuels, making it an eco-friendly and sustainable alternative to traditional aircraft.

2.2.6 DLR: SpaceLiner

The German Aerospace Center (DLR) is developing the SpaceLiner vehicle, a hypersonic, reusable, passenger aircraft capable of flying from Europe to Australia in 90 minutes. The SpaceLiner main goal is to offer P2P intercontinental transportation reducing the time needed for travelling by 75% to 80% compared to conventional subsonic airliner operation [11]. Although the Australia - Europe mission has been used as the reference case SpaceLiner mission has been divided into three classes that include other potentially interesting routes:

- Class 1: Australia - Europe reference mission, 50 passengers passengers orbiter and large reference booster, up to 17,000 km
- Class 2: Dubai - Denver mission, increased 100 passengers orbiter and large reference booster, up to 12,500 km
- Class 3: Trans-Pacific mission, increased 100 passengers passengers orbiter and reduced size booster, up to 9,200 km

Since it was first conceived in 2005, Spaceliner concept has been under constant development and upgrades, leading it to the definition of the next generation configuration SpaceLiner7 in 2012. This latest version of the SpaceLiner is composed by two major components: booster stage and passenger stage (see figure 2.8). The first one consists in 9 staged combustion cycle rocket engines and 2 internal tanks separately containing liquid oxygen (LOX) and liquid hydrogen (LH2). On the other hand, the passenger stage includes the pressurized passenger cabin and 2 more liquid rocket engines.

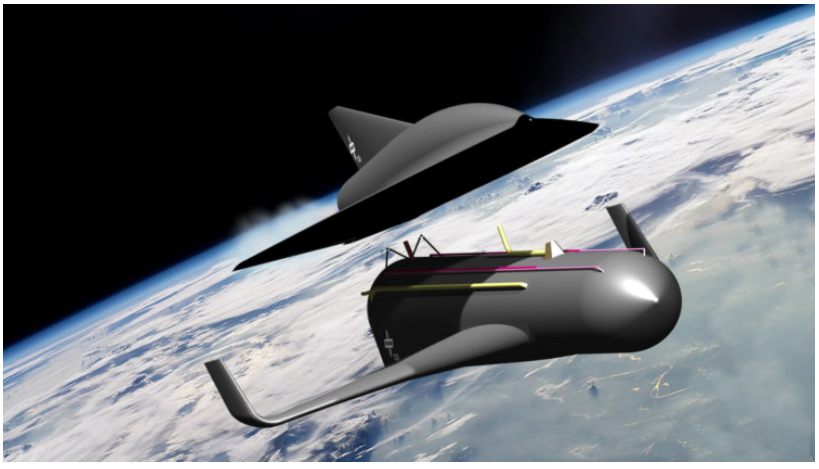

Figure 2.8: SpaceLiner conceptual aircraft composed by two stages

After booster separation, approximately at Mach 12.5 speeds, the empty booster stage is expected to be captured during subsonic descent by an airplane and finally released for an autonomous gliding landing on runway [12]. Then, once the aircraft has reached the flight's apogee at an approximate altitude of 80 km, the main engines are shut down and the passenger stage starts a gliding flight in which speeds beyond Mach 20 are reached. In this phase of hypersonic gliding through the upper atmosphere temperatures up to 3,000 K are predicted, so advanced cooling technologies for the leading edge and nose areas definitely will need to be

implemented. Despite the last phase of the Spaceliner flight consists on a horizontal landing the aircraft is deisgned for a vertical take-off, which means that SpaceLiner will be limited to launch on sites with inhabited areas down range.

2.2.7 SpaceX: Starship

SpaceX, the aerospace company founded by Elon Musk, has been developing the Starship project, which is based on the fully reusable transportation system constituted by the Starship spacecraft and its Super Heavy rocket. Starship, which will be the world's most powerful launch vehicle ever developed, is designed to take people and cargo to Earth Orbit, the Moon, Mars, and beyond [13].

Figure 2.9: Starship spacecraft at SpaceX's Boca Chica, Texas facilities

As seen in the figure 2.9, the Starship is a massive spacecraft, measuring 50 meters in length, 18 meters in height and 9 meters in diameter. It has a total payload volume of 1,100 m^3 and a payload capacity of over 100 tons, making it ideal for transporting heavy cargo and equipment to space. This payload volume can be also configured for passengers, making the spacecraft capable of carrying up to 100 people in a single trip. On the other hand, Super Heavy rocket, the booster of the Starship launch vehicle, is powered by its highly efficient propulsion system composed of 33 Raptor engines which use sub-cooled liquid methane as fuel.

Another notable feature is the reusability, as the Super Heavy is capable of re-entering Earth's atmosphere to land at the launch site due to its advanced avionics and autonomous landing capabilities. Moreover, Starship is constructed using lightweight materials which allow it to tolerate the extreme conditions of space travel and perform multiple trips, thereby reducing the cost of space travel considerably.

Starship is main designed for space applications, such as delivering satellites to space, delivering both cargo and people to and from the International Space Station (ISS), transporting cargo to the Moon on future missions, or carry people on interplanetary flights. Nevertheless, Starship also aims to become a big competitor in the commercial supersonic transport industry, as the spacecraft can also be used for rapid P2P transport to carry both passengers and cargo between destinations on Earth.

2.3 Supersonic passenger aircraft summary

Company	**Aircraft**	**Max. altitude** $[ft]$	**Max. speed** $[Mach]$	**Capacity** $[passengers]$	**Engine(s)**	**Propellant**	**Value proposition**	**Project schedule**
BAC - Aerospatiale	Concorde	60,000	2.04	128	Olympus 593 turbojet (x4)	Kerosene jet fuel	First commercial supersonic flight	1976-2003: Operational life
Tupolev	Tu-144	52,000	2.15	140	NK-144 turbofan (x4)	Kerosene jet fuel	First supersonic airliner	1977-1978: Operational life
Boom Supersonic	Overture	60,000	1.7	65-80	Symphony (4x)	100% SAF	Net zero carbon operation aircraft	2029: Achieve type certification
Exosonic	Supersonic jet	60,000	1.8	70	Off-the-shelf engine (x4)	Fossil-free E-jet fuel	Low boom, quiet supersonic aircraft	2029: Aircraft certification
Hermeus	Halcyon	90,000	5	20	Chimera TBCC	Off-the-shelf SAF	Mach 5 engine capable of turbojet to ramjet transition	2029: Halcyon first flight
STRATOFLY	MR3	$>$ 98,000	8	300	Air Turbo Rocket (x6) and Dual Mode Ramjet	LH2	Hypersonic aircraft based on multi-objective optimization	2035: Reach TRL = 6
ANA HD - PD Aerospace	PEGASUS	263,000	$>$ 5	6	Detonation, combustion mode switching	Biofuels	Patented combustion mode switching engine	2029: First commerical flights
DLR	SpaceLiner	263,000	$>$ 20	50 - 100	Liquid rocket engine (x11)	LOX and LH2	Aircraft capable of intercontinental long routes in 1.5 hours	2035: First flight
SpaceX	Starship	Mars and beyond	25	100	Raptor (x33)	Sub-cooled liquid methane	World's most powerful launch vehicle, fully reusable	2023: First orbital launch

Table 2.1: Main features of the state-of-the-art supersonic passenger aircraft

Chapter 3

Case Study: Supersonic 2.0 - Virgin Galactic

The following chapter represents the main part of the thesis and is focused on an in-depth study of Virgin Galactic and its business model. The development of this section includes a comprehensive analysis of both economic and environmental aspects in order to understand the economic situation and operation of Virgin Galactic, as well as to assess the feasibility of implementing Supersonic 2.0.

3.1 Virgin Galactic overview

Virgin Galactic is the world's first commercial spaceline [14] and was founded in 2004 by British billionaire entrepreneur sir Richard Branson, with the purpose of offering accessible and affordable commercial suborbital space tourism flights, as well as contributing to space research and exploration.

3.1.1 Virgin Group

Virgin Galactic operates within Virgin Group, a global, growth investor [15] and conglomerate with a wide range of businesses. The Virgin brand was born in February 1970 as Virgin Records, when Richard Branson and his friend Nik Powell chose the name "Virgin" for the mail order record shop they just created, as they considered themselves virgins in business. The continuous growth of Virgin Records throughout the 1970s led to the launching of Virgin Atlantic in 1984, which quickly became a fierce competitor for the established airlines with its innovative marketing campaigns. Despite the sale of Virgin Records in 1992, throughout the 1990s and the 2000s Virgin continued to expand into new industries, including telecommunications, finance, travel, healthcare and space.

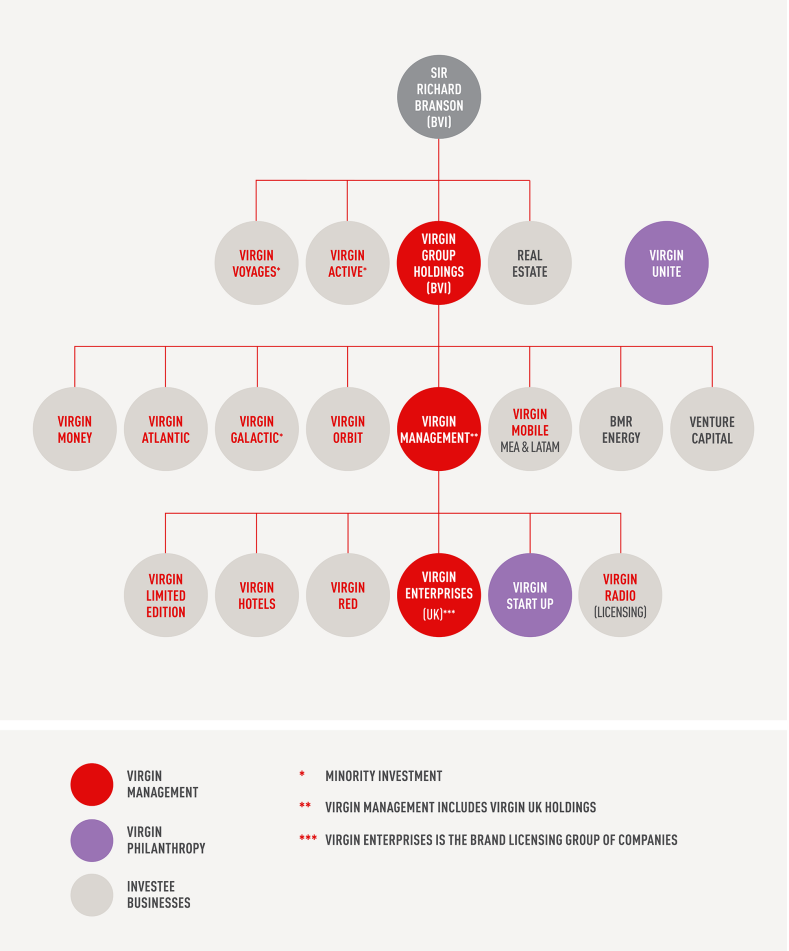

Figure 3.1: Overview of the Virgin Group structure [15]

Today, Virgin Group is one of the largest companies in the world, with a portfolio of companies that span multiple industries (see figure 3.1) and generate billions of dollars in revenue each year. The main activities of the company consist in investment management and brand licensing. Moreover, part of the profits from sales are reinvested to support and develop new and existing business. Virgin Group is also committed with a positive long-term impact on the society and the planet, aiming all Virgin branded companies to achieve a net zero emissions by 2050 or sooner.

3.1.2 Virgin Galactic's history

Virgin Galactic was officially founded by Richard Branson on September 27, 2004 [16] , but the history of the company began some decades ago, when 19-year-old Branson witnessed the Apollo 11 moon landing in 1969. As Branson stated in an interview for Sky News "it was transformational" and assured that "if the moon landing had not taken place it would not have inspired me to want to go into space" [17]. In June 2004, looking for spacial business ventures to explore, Branson sponsored the first flight of the Scaled Composites' SpaceShipOne, on the first suborbital space flight in history. Finally, a few months later Richard Branson managed to launch its own spaceflight company, with the intention of developing a variation of SpaceShipOne for private space flights.

With the formation of Virgin Galactic, the next phase was aiming the creation of a spacecraft capable of carrying passengers to space. In this direction, in July 2005 Richard Branson and Burt Rutan, the founder of Scaled Composites, reached an agreement to create a new aerospace production company, The SpaceShip Company, jointly owned by Virgin Galactic (70%) and Scaled Composites (30%). The spacecraft design focused on the six-passenger, two-pilot SpaceShipTwo and its carrier airplane, WhiteKnightTwo [18]. Although Branson first predicted that first commercial flights would take place in 2007, after some delay in the production due to a ground test incident the first SpaceShipTwo vehicle, named Virgin Space Ship (VSS) Enterprise, was officially unveiled on December 7, 2009.

Figure 3.2: SpaceShipTwo spacecraft and its carrier aircraft WhiteKnightTwo

SpaceShipTwo's flight testing program began in 2010, when on October 10 of that year the spacecraft was successfully released from the WhiteKnightTwo at 13,700 meters of altitude, before gliding to a safe landing at Mojave Air and Space Port in California. After completing 16 free flights and successfully testing the feathered reentry system, in September 2012 The SpaceShip Company confirmed the end of subsonic unpowered flight tests of the SpaceShipTwo. One month later, after Northrop Grumman company purchased Scaled Composites, Virgin Galactic announced that it was taking full ownership of The Spaceship Company by acquiring the remaining 30% stake held by Scaled Composites. On April 29, 2013, SpaceShipTwo completed its first powered flight reaching supersonic speeds. The hybrid engine powering the spacecraft used solid rocket fuel and liquid nitrous oxide (N_2O) as oxidizer.

The path of VSS Enterprise vehicle drastically ended on October 31, 2014, when it suffered a mid-air break-up resulting in a fatal crash over the Mojave Desert in California. The accident killed the co-pilot Michael Alsbury and caused severe injuries to the pilot, Peter Siebold. A subsequent investigation concluded that the crash occurred due to an early deployment of the feathering mechanism that resulted in the in-flight separation of the wings and vehicle [18].

By the time the crash occurred, the manufacturing of the second SpaceShipTwo vehicle was already about 65% complete. Obviously, the VSS Enterprise accident caused all efforts to be focused on speeding up the

construction of its replacement. On February 19, 2016, the new SpaceShipTwo was unveiled with the name of VSS Unity, chosen by the professor Stephen Hawking as he hoped that it would "help to create a new unity". After properly completing ground testing VSS Unity made its first gliding flight on December 3, 2016. VSS Unity first powered flight, the first such flight since the fatal crash of October 2014, took place on April 5, 2018, reaching a top speed of Mach 1.87 and altitude of 25,686 meters, achieving higher speed and altitude than any previous powered flight of the VSS Enterprise [19].

On December 13, 2018, SpaceShipTwo Unity reached suborbital space for the first time, reaching 82.72 km altitude and Mach 2.9 speeds. Two months later, on February 22, 2019, VSS Unity conducted its second suborbital flight, exceeding in altitude (89.9 km) and speed (Mach 3.04) its previous flight. Following the two successfully completed suborbital flights, in February 2020 Virgin Galactic decided to move its operations from Mojave Air and Space Port in California to Spaceport America in New Mexico, which is home of Gateway to Space terminal, a spaceflight operations hub as well as a welcome center for customers prior to their flight to space. VSS Unity and its carrying vehicle WhiteKnightTwo, renamed Virgin MotherShip (VMS) Eve, were also transferred to Gateway to Space, where VSS Unity underwent two additional glide flight tests to evaluate the vehicle performance for future commercial space flights from the new operating base in New Mexico [20]. Simultaneously, final modifications to the spacecraft commercial cabin were completed and the interior of the vehicle was publicly revealed in July 2020.

On March 30, 2021, the company unveiled the VSS Imagine vehicle, the first SpaceShip III in its growing fleet. The rollout of VSS Imagine allowed to see vehicle's innovative design, finished entirely with a mirror-like material designed to provide thermal protection while being naturally appealing to the human eye (see figure 3.3). The construction of SpaceShip III class vehicles was intended to improve performance in terms of maintenance access and flight rate, as well as to lay the foundation for the design and manufacture of future vehicles [21].

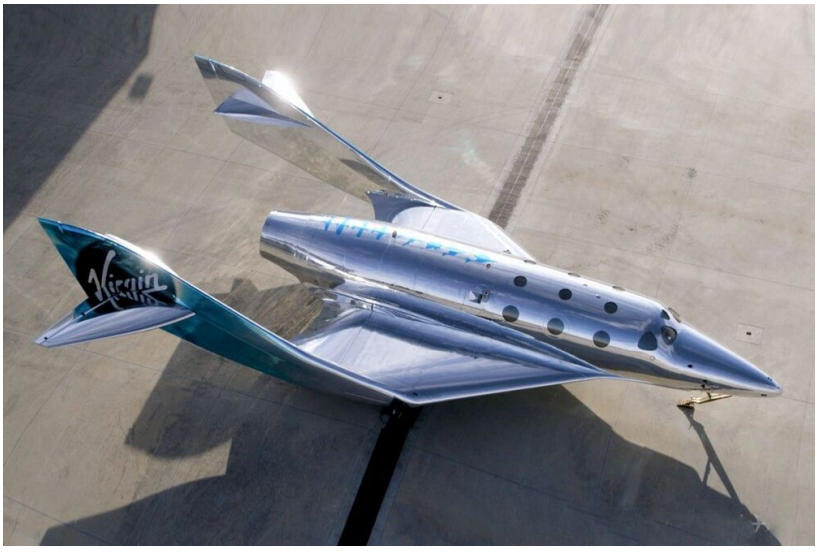

Figure 3.3: Virgin Galactic's VSS Imagine vehicle

Following another successful test flight on May 22, 2021, Virgin Galactic announced that the Federal Aviation Administration (FAA) provided the company the license needed to fly commercial passenger on future spaceflights [22]. On July 11, 2021, VSS Unity finally conducted a fully crewed suborbital space flight, making it the first commercial private flight to space. The flight also meant a special achievement for the company, as among the six SpaceShipTwo crew was Richard Branson, finally achieving his dream to reach space and becoming the first spaceflight company founder to fly to space on his own company's spacecraft (see figure 3.4).

Figure 3.4: Virgin Galactic's founder Richard Branson on the first commercial private space flight

However, some debate was generated over whether this flight officially reached space, as VSS Unity reached its apogee at 86.189 km altitude, above the 80 km defined by U.S. and NASA as the boundary of space but below the outer space boundary defined by all other countries and the Fédération Aéronautique Internationale (FAI), at 100 km altitude and known as Kármán line [23]. This fact was appointed by Blue Origin founder Jeff Bezos, which months before also had announced his intentions to be on the first crewed flight to space of its company.

Despite Virgin Galactic first aimed to begin full commercial service on 2020, Covid-19 emergence pushed back commercial passenger service to early 2022. Nevertheless, in May 2022 the company announced that commercial spaceline operations would be postponed to 2023, due to supply chain and labor constraints [24]. In the same statement, Virgin Galactic confirmed to have about 800 reservations for future commercial spaceflights, setting prices at $450,000 per person with an initial deposit of $150,000. In a press release on January 12, 2023, Virgin Galactic stated that commercial service was remaining on track to launch in Q2 2023 [25].

Although Virgin Galactic's activity has been primarily focused on space tourism business, in August 2020 the company announced an agreement with NASA and Rolls-Royce to develop a supersonic aircraft for P2P transport. Virgin Galactic's supersonic aircraft, whose conceptual design was released along the announcement of the agreement, is aimed to disrupt the commercial airline market by competing with the state-of-the-art vehicles previously studied in Chapter 2.

3.2 Business statement and philosophy

Virgin Galactic's main business statement is presented on the company's official website and reads as follows:

> "Our mission is to connect people across the globe to the love, wonder and awe created by space travel." [14]

Virgin Galactic's Annual Reports, registered by Virgin Galactic Holdings, Inc., are also publicly available on its official website [26]. These documents contain forward-looking statements that may concern the company, its investors and customers, discussing goals, intentions and expectations based on management's current beliefs and information currently available to it. The 2022 Annual Report, published on April 25, 2023, provides more information about Virgin Galactic's business statement, in which the what, who and why of the company can be identified:

> "We intend to offer our customers a unique, multi-day experience culminating in a spaceflight that includes several minutes of weightlessness and views of Earth from space. We are an aerospace and space travel company offering access to space for private individuals, researchers and government agencies. We believe the commercial exploration of space represents one of the most exciting and important technological initiatives of our time." [27]

Virgin Galactic is committed to lowering the prices of spaceflight that until now have limited the availability to private individuals, making them affordable to many more people. With a statement by the Professor Stephen Hawking, the company defines its philosophy as well as one of the main reasons to take more humans into space:

> "Taking more and more passengers out into space will enable them, and us, to look both outward and back but with a fresh perspective in both directions." [14]

In addition, Virgin Galactic assures that witnessing planet Earth from space produce an inner shift defined by many astronauts as the "Overview Effect", a cognitive transformation that can help people to comprehend its place within the world and provide countless benefits to life on our planet.

On the other hand, regarding the business vision of the company Virgin Galactic also states its intention and commitment to use its proprietary technologies for other potential business applications, such as Supersonic 2.0 project:

> "While our primary focus for the foreseeable future will be on commercializing human spaceflight, we have invested certain of our resources in developing new technologies, services, products and offerings, such as high speed point-to-point travel and expect that we may invest a more significant amount of resources to those purposes in the future." [27]

> "Among other opportunities, we believe our technology could be used to develop high-speed vehicles. We believe a significant market opportunity exists for vehicles with this capability, as they could be used to drastically reduce international travel times." [27]

3.3 Virgin Galactic's Ownership

Along with the information available from the 2023 Proxy Statement of Virgin Galactic [28], the data provided in this section has been collected from three different financial companies trusted by global investment leaders [29] [30] [31]. All the information obtained has been compared and contrasted between the sources in order to obtain the most current and reliable data.

As of March 31, 2023, Virgin Galactic Holdings, Inc. (NYSE: SPCE) had a total of 281,664,887 outstanding shares trading at $4.01 per share, representing a total market capitalization of $1129.48M. Virgin Investments Limited, which is wholly owned by Richard Branson's Virgin Group Holdings, is the largest shareholder of Virgin Galactic Holdings stock, owning 30,745,494 shares that represent 10.92% of the company. SPCE ownership also includes institutions, mutual funds and retail investors, as well as Virgin Galactic's directors and executive officers.

3.3.1 Institutional owners and shareholders

SPCE shares have 411 institutional owners, holding a total of 101,708,937 shares that represent 36.11% of the total outstanding stock. The following table sets information with respect to the ten largest institutions owning shares of SPCE outstanding stock as of March 31, 2023:

Owner name	Shares	% of ownership	Value
BlackRock, Inc.	20,034,830	7.11%	$80.34M
The Vanguard Group	19,982,247	7.09%	$80.13M
State Street Corporation	17,308,278	6.14%	$69.410M
Geoide Capital Management, LLC	4,294,552	1.52%	$17.22M
Morgan Stanley	2,451,345	0.87%	$9.83M
Goldman Sachs Group, Inc.	2,222,681	0.79%	$8.91M
Two Sigma Investments, LP	2,216,278	0.79%	$8.89M
Northern Trust Corporation	2,160,344	0.77%	$8.66M
Norges Bank	1,887,566	0.67%	$7.57M
Charles Schwab Investment Management, Inc.	1,783,262	0.63%	$7.15M

Table 3.1: Largest institutional owners of SPCE stock

3.3.2 Beneficiary directors and executive officers

In March 2022, Virgin Galactic's Compensation Comittee adopted stock ownership guidelines for its executive officers and non-employee directors, being the ones within 5 years of service in their position expected to acquire shares of SPCE with a market value equal to a multiple of their base salary or annual retainer. In its 2023 Proxy Statement [28], Virgin Galactic provides information of its beneficial ownership as of March 31, 2023. The data obtained, presented in the table below, does not include the percentage of ownership of each individual, as they all account for less than 1%:

Name	Position	Shares
Adam Bain	Board Director	1,200,000
Mike Moses	President, Space Missions and Safety	824,244
Michael Colglazier	Chief Executive Officer (CEO) and President	592,868
Swami Iyer	President, Aerospace Systems	175,696
Dough Ahrens	Executive Vice President, Chief Financial Officer (CFO) and Treasurer	111,699
Wanda Austin	Board Director	38,106
Craig Kreeger	Board Director	38,106
George Mattson	Board Director	38,106
Alistair Burns	Senior Vice President, Chief Information Officer	29,890
Aparna Chitale	Executive Vice President, Chief People Officer	28,157
W. Gilbert West	Board Director	7,025
Tina Jonas	Board Director	6,173
Wanda Sigur	Board Director	3,590
All Directors and Executive Officers as a Group		3,093,660 (1.10%)

Table 3.2: Beneficial owners of SPCE stock

3.4 Virgin Galactic's partnerships

In recent years, the appearance of the Supersonic 2.0 business model following the target of commercial supersonic operation have made Virgin Galactic entering into strategic partnerships with industry major companies. However, Virgin Galactic's alliances are not only focused on this goal, but encompass several projects with the intention of pushing the company to lead the sectors in which it operates.

3.4.1 Supersonic 2.0 business model partnerships

- **Boeing**

  Virgin Galactic and Boeing announced the creation of a strategic partnership on October 8, 2019, consisting of a $20 million Boeing investment in Virgin Galactic. The collaboration arose with the objective of supporting and facilitating Virgin Galactic's efforts on two key targets: a broader access to space with the commercialization of human spaceflight, and the implementation of supersonic travel as a new form of safe and efficient transportation.

  Boeing is the world's largest aerospace company and leader on the delivering of commercial airplanes, defense, space and security systems, and global services. The company has extensive experience on the industry, as it serves as NASA's main contractor for the ISS and has been assigned the development of the new, reusable, Starliner space capsule for launch to the ISS. Boeing shares with Virgin Galactic the aim of changing how people travel on Earth and space, broadening the access to space travel and high-speed mobility in safe and environmentally responsible ways [32].

- **NASA**

  On May 5, 2020, Virgin Galactic stated the signing of a Space Act Agreement with NASA to promote the development of high speed technologies. The Space Act Agreement established the alliance between NASA, Virgin Galactic and its wholly owned subsidiary The Spaceship Company, in order to "support the United States' efforts to produce technically feasible, high Mach vehicles for potential civil applications" [33].

  NASA has decades of experience with supersonic vehicle technology and is currently working on its experimental quiet supersonic aircraft X-59 QueSST, which is expected to collect data that reaches acceptable noise levels to fly over land. With this collaboration, the U.S. agency hopes to help Virgin Galactic to take advantage of its advanced technologies for the next-generation of safe and efficient high-speed air travel, centering the efforts on sustainability. Referring to this important agreement George Whitesides, CEO of Virgin Galactic declared: "This is the beginning of an important partnership for Virgin Galactic and The Spaceship Company that will support the future development of aviation technology. We see this as an area with tremendous growth potential that we will continue to invest in, alongside our commercial spaceflight operations" [33].

- **Rolls-Royce**

  On August 3, 2020, following the successful completion of its Mission Concept Review (MCR), Virgin Galactic announced the first stage design scope for the construction of its commercial supersonic aircraft and unveiled its initial design concept. The announcement included the signing of a non-binding Memorandum of Understanding (MOU) with Rolls-Royce, assigning the company the design and development of engine propulsion technology for the aircraft [34]. The two companies stated their goal of achieving a Mach 3 aircraft capable of using sustainable aviation fuel, in order to provide sustainable, safe, and reliable high-speed travel.

  Rolls-Royce is an industry leader and pioneer in providing clean and safe solutions to customers around the world. Furthermore, it is a proven company on the delivering of high Mach propulsion, having powered the first commercial supersonic aircraft, the Concorde, during its 27 years of operational life. Rolls-Royce is committed to reaching net zero carbon operations in 2030, as well as operating net zero carbon by 2050 in space travel and high-speed transport sectors. Following the announcement of the collaboration between the two companies, Rolls-Royce North America Chairman and CEO Tom Bell assured that the company is prepared to offer propulsion systems needed to power high-Mach travel, and declared, "We are excited to partner with Virgin Galactic to explore the future of sustainable high speed flight" [34].

3.4.2 Other alliances

- **Land Rover**

  Partners since 2014, Land Rover vehicles are part of daily life for the Virgin Galactic team, towing the space vehicles, transporting astronauts and supporting day-to-day operations. In 2019, the two

companies unveiled the Range Rover Astronaut Edition, offered exclusively to Virgin Galactic Future Astronauts. On March 30, 2021, coinciding with the unveiling of VSS Imagine supported by a Range Rover Astronaut Edition, Land Rover announced the extension of Virgin Galactic global partnership to 2024 [35].

- **Under Armour**

  On January 24, 2019, Under Armour published the agreement to serve as the Technical Spacewear Partner of Virgin Galactic, creating a new generation of custom space suits and footwear for Virgin Galactic passengers and pilots [36], designed for ultimate comfort and maneuverability during weightlessness. Another aspect of the agreement included the design and implementation of fully-immersive training programs for astronaut physical preparation and recovery, provided by Under Armour's athletic performance team.

(a) Under Armour spacesuit (b) Under Armour space boots

Figure 3.5: Under Armour's spacewear for future Virgin Galactic space tourists

- **Aurora Flight Sciences**

  On July 6, 2022, Virgin Galactic announced a partnership with Aurora Flight Sciences, a Boeing subsidiary, for the design and manufacturing of its future motherships. The agreement, consisting in a two-vehicle contract, followed previous months of preparation in which design specifications and resource requirements were developed. Aurora Flight Sciences brings more than 30 years of experience in aircraft technologies and manufacturing processes, and is specialized in innovative aircraft configurations and complex composites [37].

- **Virtuoso**

  Virtuoso announced its collaboration with Virgin Galactic on July 21, 2022. The partnership enables Virtuoso, a global travel agency network specialized in luxury experiental travel, to offer a limited number of tickets for Virgin Galactic's spaceflight experience to its upscale clientele [38]. With more than 2,200 luxury travel partners and normalized annual sales of 25−30 billion, Virtuoso is the leading company in the luxury travel industry.

- **Axiom Space**

  On November 3, 2022, Axiom Space signed an agreement with Virgin Galactic for a microgravity research and training mission, taking advantage of Virgin Galactic's opportunities for scientific exploration in a suborbital space environment. Axiom Space is a U.S.-based commercial space company focused on expanding the international community of space explorers and building human spaceflight programs. Moreover, the company is currently working on the construction of Axiom Station, the first permanent commercial space station in Earth's orbit [39].

3.5 Market segment and Requirements

Market segmentation is a business practice that consists in aggregating potential clients into groups with common characteristics or requirements. Segmenting the market is crucial as it enables companies to identify their target customers, as well as their wants and needs. In addition, market segmentation can also contribute to minimize risks and increase overall effectiveness by evaluating which products or services may have the most potential with target consumers and how best to deliver them to the market.

Virgin Galactic's main efforts and investments are currently focused on the commercial human spaceflight market, which the company considers to be significant and untapped. Despite space travel access has historically involved great personal expense and risk, Virgin Galactic is committed to the development of manufacturing and operating efficiencies to offer more affordable prices. The multiple successfully completed flights of the VSS Unity along the ongoing development of the VSS Imagine represent huge steps towards Virgin Galactic's regular commercial operation, for which more than 800 reservations have already been made.

On the other hand, the company is also intended to pursue market opportunities within the high-speed travel business. Although the sector is even earlier in its development, several companies have already expressed their intentions to lead the industry in the coming years, presenting state-of-the-art designs potentially capable of efficient, safe and reliable supersonic operations. Virgin Galactic may therefore be subject to intense competition in commercial supersonic transport market, facing companies with greater monetary and knowledge resources than Virgin Galactic has and expects to have in the future to allocate to the development of these technologies [27].

For this reason, Virgin Galactic declares its intention to use its proprietary cutting-edge technologies to explore additional potential applications such as high-speed travel, thus expanding market opportunities and addressable markets. The company believes that leveraging its advanced technology, as well as its extensive design, engineering and manufacturing experience, could enable Virgin Galactic to compete successfully on the market. On the other hand, the company also notes the existence of some risks, such as the limited experience on the business strategies and technologies involved, new regulatory challenges and the unproven profitability of the additional expenses.

The two aforementioned markets in which Virgin Galactic aims to operate are studied below, as their differentiation can be taken as an initial segmentation criteria. In this case, this study focuses on the vehicles expected to lead Virgin Galactic's business projects, analyzing the requirements for these products as well as the potential market opportunities they may generate. All the specific data related to the company is provided by Virgin Galactic's 2022 Annual Report.

3.5.1 Space travel market

In February 2022, Virgin Galactic opened ticket sales to the general public at a base price of $450,000 per seat. Months later, the company announced having closed the year with approximately 800 spaceflight tickets reservations and $103.3 million raised in deposits and membership fees. Within this scenario, Virgin Galactic continues evaluating and developing its marketing strategy and is confident of profitable and fast-growing commercial operations, scheduled to begin in the second quarter 2023.

Virgin Galactic is intended to start commercial operations with its current spaceflight system, consisting of a single spaceship, the VSS Unity, and a single mothership carrier aircraft, the VMS Eve. As explained in Chapter 4.1.2, this spaceflight system already managed to successfully complete its first commercial space flight in July 2021, demonstrating its reliability for safe transportation to space. Although the two aircraft are expected to be sufficient to meet Virgin Galactic's initial operational plan, the company points out that the annual flight rate will be limited by the available capacity of this system. In this regard, Virgin Galactic plans to grow its spaceflight fleet once commercialization is achieved by developing the first SpaceShip III vehicle, the VSS Imagine, which would allow to reduce the capacity constraint associated with having a single spaceflight system [27].

VMS Eve - VSS Unity

VMS Eve is a twin-fuselage, custom-built aircraft designed to carry spaceships up to an altitude of approximately 45,000 feet, where they are released for flight into space. The use of VMS Eve instead of a standard ground-launch rocket allows the energy requirements for suborbital launch to be reduced, as the spacecrafts do not have to propel through the lower atmosphere, where air density is higher. While all the mothership's pilots are situated on the right fuselage, Virgin Galactic believes that the left boom of the aircraft, currently empty and unpressurized, could be used in future operations to accommodate additional crew, research experiments or astronauts training.

On the other hand, VSS Unity spaceship is a reusable rocket-powered winged vehicle designed to achieve a maximum speed of over Mach 3. The vehicle is characterized by its unique "wing-feathering" system, which is used to orient the spaceship during the re-entry phase. VSS Unity missions begin after being released from VMS Eve and have an approximate duration of up to 90 minutes, just before completing a standard runway landing. The spacecraft is powered by a hybrid rocket motor that uses a solid fuel grain and a liquid oxidizer, designed to provide the required mission performance capability focusing on safety, reliability and economy. Both VSS Unity and VMS Eve are built of all-composite materials that provide lightness and durability, and with the exception of the motor's fuel and oxidizer, the vehicles are designed to be fully reusable.

Figure 3.6: VSS Unity attached to its twin-boom carrier mothership, the VMS Eve

In addition to the two pilots, the spacecraft can accommodate up to six passengers, one of whom is expected to be a Virgin Galactic employee on commercial flights. The cabin has been designed for maximum passenger safety and comfort and includes a dozen windows in the cabin sides and ceiling, offering customers astonishing views form the space and form the Earth below [27].

- **Human space travel**

  To date, only about 640 humans have traveled to space above the Earth's atmosphere. This fact is because access to space has been strictly controlled by government space agencies, limiting availability to private individuals. While the private space market has experienced explosive growth in recent years, high prices continue to restrict space access to a select group of people. Examples include Virgin Galactic's main competitors, such as Blue Origin, which in 2021 sold its first commercial ticket for a suborbital flight at a price of $28 million, or SpaceX, which currently prices its orbital missions at around $50 million to $75 million per seat [27].

  With the aim of changing this background, Virgin Galactic is intending to offer an unmatched, safe, and affordable journey to space to a broader global population. Virgin Galactic's proposal consists on a unique, multi-day experience that culminates in a transformative space flight, with no prior experience or significant prior training and preparation required for its costumers. The costumer journey begins at Spaceport America, the world's first purpose built commercial spaceport, where each future astronaut spends multiple days of personalized pre-flight training focused on the familiarization with the systems, procedures, equipment and personnel that will be involved in the flight. During these days, Virgin Galactic provides luxury accommodations to host the client's family and guests. The program ends with the spaceflight experience, which includes several minutes of weightlessness and stunning views of Earth from space. Upon landing, the astronauts are provided with a full video and photographic record of the journey and receive their Virgin Galactic astronaut wings.

- **Scientific research**

  Besides the market for human space travel, Virgin Galactic is also offering spaceflight opportunities for research missions. In fact, the company has already announced that 100 seats within the first 1,000 commercial seats sol will be reserved for research and scientific experiments. Virgin Galactic expects demand to come from government agencies as well as educational and commercial research institutions, spanning a wide range of technical disciplines.

  In most cases, researchers have to opt for expensive alternatives to create a few seconds of continuous microgravity, thus being subject to very limiting operational constraints. Virgin Galactic aims its spaceflight system to tackle these issues by providing the scientific research community affordable, repeatable access to several minutes of microgravity environment. Virgin Galactic operations include flying autonomous scientific payloads as well as the opportunity for one or more researchers to conduct in-flight experiments. In addition to its vehicles, Virgin Galactic suborbital platform provides hardware for researchers upon request and includes all the processes and facilities necessary for a successful mission.

- **Professional astronaut training**

  Additionally, Virgin Galactic missions include professional astronaut training. Historically, astronaut training and preparation has taken part in artificially created environments that simulate G-force and weightlessness situations, due to the obvious costs associated with transporting astronauts to the space environment. For this reason, the microgravity environment created by Virgin Galactic spaceflight system represents a unique opportunity for space companies and agencies in the development of astronaut training missions. An example is Axiom Space company, whose agreement with Virgin Galactic includes preparing an Axiom Space astronaut for an upcoming trip to orbit while conducting research in microgravity.

3.5.2 High-speed P2P commercial transport market

Over the last decades, the studies on high-speed commercial transportation have focused on the fundamental physics and technologies for developing aircraft capable of efficient and reliable performance. In recent years, multiple companies have embarked on the development of supersonic and hypersonic technologies for their concept vehicles, centering the research on the technical, economic and environmental requirements of potential commercial operation. In contrast, very little research has been undertaken on the risks and opportunities of the high-speed travel market. In this regard, in addition to its technical research, NASA recently commissioned independent studies focusing on the potential passenger demand as well as non-technical aspects of the market. One of these studies, published in April 2021 and conducted by the Science Applications International Corporation (SAIC) and BryceTech [40], provides valuable insights into the opportunities, challenges and requirements of the market by collecting data from numerous companies in the industry and more than 70 reports and studies on air travel and high-speed aircraft. Some of this information is very useful for the study of the Supersonic 2.0 business model opportunities carried out in this thesis, but it's

important to mention that all the values provided (including demand, operations, cost, revenues...) are result of modeled estimations of potential future scenarios, which might not be fulfilled.

Focusing on Virgin Galactic case, since in August 2020 announced its goal of offering high-speed commercial travel the company has reaffirmed its commitment to explore and evaluate this application, as well as to invest more resources on it. Virgin Galactic hopes to leverage its robust platform of advanced technologies, along with its experience in the aerospace industry and thousands of hours of flight testing, to manufacture an aircraft capable of sustainable, safe and reliable supersonic P2P transport. In this regard, the company is working together with international regulatory communities and industry leaders to ensure compliance with safety and environmental aspects while making customer experience a top priority.

Virgin Galactic's supersonic aircraft

On August 3, 2020, Virgin Galactic unveiled the concept for its preliminary design of a supersonic aircraft and announced the collaboration with Rolls-Royce in the designing and developing of the aircraft's engine propulsion technology. This followed the successful completion of an internal MCR and authorization from the Federal Aviation Administration's (FAA) Center for Emerging Concepts and Innovation to work with Virgin Galactic to begin to define a certification framework during the pre-project guidance phase [34]. The MCR included representatives from NASA, with whom Virgin Galactic previously signed a Space Act Agreement to collaborate on high speed technologies, and confirmed that the aircraft design concept can meet the high-level requirements and objectives of the mission. In addition, the MCR enabled Virgin Galactic to move to the next design phase, consisting of defining specific system architectures, configurations and materials, by evaluating key issues of routine supersonic commercial flights such as thermal management, maintenance, noise, emissions and economics.

As of today, Virgin Galactic has not yet announced detailed development schedule of the aircraft, making it very difficult to predict the year of the project's entry into service. Even though, the company already established some of the main parameters of its target product's preliminary design.

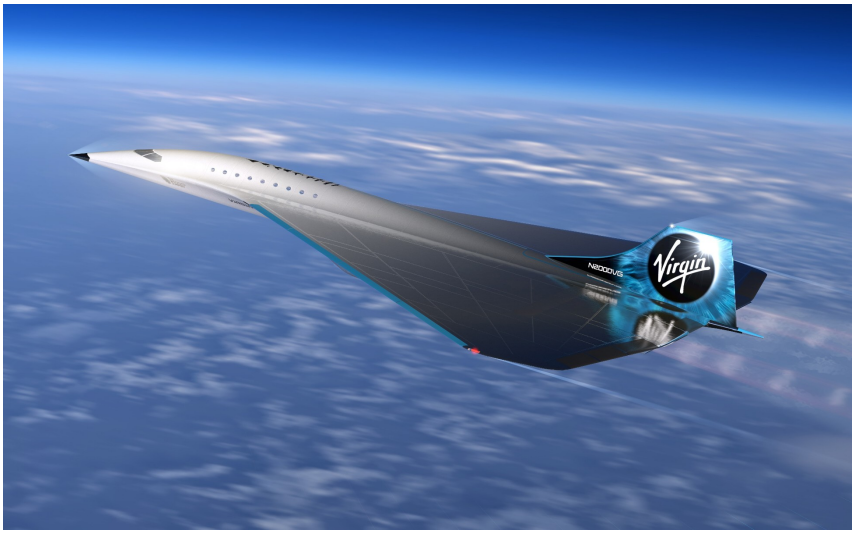

Figure 3.7: Initial design concept of Virgin Galactic's supersonic aircraft

The initial vehicle design consists on a Mach 3 certified delta-wing aircraft capable of flying at altitudes above 60,000 ft and is focused on environmental sustainability, aiming to use state-of-the-art sustainable aviation fuel. The concept aircraft would have capacity for 9 to 19 passengers and would also be expected to incorporate custom cabin layouts to address customer needs, including Business or First Class seating arrangements [34]. The aircraft would be designed for HTHL and would be expected to integrate into existing airport infrastructure and international airspace worldwide. Virgin Galactic intends its supersonic aircraft to perform in a variety of operational scenarios, which should include potential market segments presented below.

- **Long-distance commercial flights for passengers**

  Virgin Galactic would center its supersonic aircraft operations on scheduled passenger service on long-distance commercial aviation routes. This service would primarily target premium passengers, that is, those who purchase business or first-class seats, as they represent the group most willing to pay for these higher-priced flights in order to save time and participate in a more exclusive experience [40]. As Virgin Galactic expects to include a cabin layout specially tailored for this type of operation the needs of these customers would be easily covered, offering them a service totally suited to their requirements.

  The SAIC and BryceTech study assessed the potential opportunities in this market, forecasting passenger traffic for flights between 800 long-haul city pairs lasting 5 or more hours at current subsonic flight speeds [40]. However, several of the 800 city pairs analyzed resulted too expensive to operate, as the operating costs (mainly fuel) were higher than the revenue generated. The study concluded that the demand revenues would exceed operating expenses on more than 300 routes, making them viable operations for the company.

  Flying at speeds of Mach 3, the maximum speed targeted for Virgin Galactic's supersonic aircraft, would drastically reduce travel time on such trips, thereby creating an unparalleled service in the market. For example, travelling at Mach 3 would allow the aircraft to cover the London to New York route, which takes conventional airliners around 7 hours, in only about 90 minutes.

- **Charters and fractional flights**

  Virgin Galactic would also be intended to explore on-demand commercial operations, such as charter and fractional flights, targeting an addressable demand comprised primarily of private individuals, corporations and general aviation operators. These type of services typically involve lower marketing, administrative, and general costs compared to commercial operations [40]. Charter operations consist of a non-scheduled jet service generally priced by itinerary, in which customers have the possibility of renting the entire aircraft and crew for a private flight on an as-needed basis. On the other hand, the company would also expect to get revenue from fractional ownership sales, where customers are allocated a share of flight hours proportional to their share of the costs of owning/operating the aircraft, which include crew salaries, insurance, maintenance, and hangarage.

- **Cargo operations**

  While Virgin Galactic's supersonic aircraft design would not include much cargo space, the company could also consider meeting cargo demand. Cargo applications could span several service areas, including organ transplants, disaster relief, emergency repair parts, urgent documents and perishable luxury items. These type of operations would not incur appreciable revenue, as the time savings would not be expected to result in a significant price premium.

3.6 Stakeholder analysis

As can be concluded from the last three sections of this project, every business is made up of various interested parties. These interested parties are known as stakeholders, and can be defined as the people or organizations that share an interest in a business and that can be affected or influence a company's decision making. On the other hand, a quite common mistake is to confuse stakeholders with shareholders. As seen in Chapter 4.3, shareholders are only those who own shares in a company and therefore own part of it, which makes them just another interested party or stakeholder.

Identifying, understanding and managing stakeholders is crucial to the success of a business. The first part of the stakeholder analysis process consists on classifying the stakeholders on clearly identifiable groups with similar interests [41]. In this case, no differentiation is made between the stakeholders of the two businesses defined for Virgin Galactic (space travel and supersonic P2P transport), as it is considered that these will be very similar for both cases.

- Internal: board of directors, executive management and employees
- Connected: customers, partners, suppliers and shareholders (which include large investor groups and retail investors)
- External: governments and regulatory agencies

Once the various stakeholders have been differentiated, it is important to understand their role and prominence in the business [42]. In this regard, a very useful tool is the Stakeholder Map, also known as the Mendelow's matrix. The functioning of the Mendelow's matrix is based on considering the power and interest of the different stakeholder groups to determine their potential influence on the project. The four blocks that constitute the Mendelow's matrix, which divide the stakeholders according to their power and interest, are also very helpful in creating an optimal stakeholder management strategy.

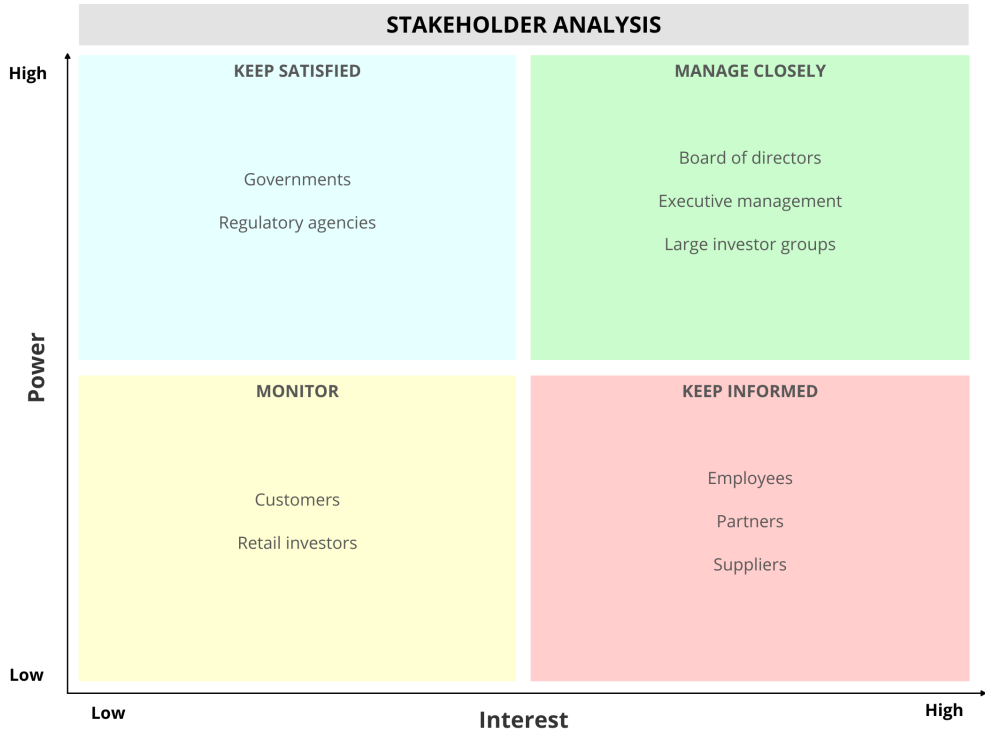

Figure 3.8: Mendelow matrix for Virgin Galactic's stakeholders

The figure 3.8 shows the Mendelow's matrix for Virgin Galactic's business. As can be seen, the position of each stakeholder in the table is directly related to the actions that the company should take in order to establish a good relationship and communication with them. Hence, an efficient stakeholder management strategy is divided in the four action plans corresponded with each block.

- **Manage closely (High power, high interest):** high power, highly interested stakeholders that play a key role in the business. They need close management and involvement, so they may need keeping daily communication. Is a priority for the company to keep them fully engaged in the business.
- **Keep satisfied (High power, low interest):** high power, less interested stakeholders with great influence in the business, but unlikely to have a direct role in it. The company should work to keep them satisfied and updated on the business progress.
- **Keep informed (Low power, high interest):** low power, highly interested stakeholders with heavy involvement in the business. The company should keep them adequately informed and check in with them regularly to ensure that no major issues are arising.
- **Monitor (Low power, low interest):** low power, less interested stakeholders unlikely to represent a priority on the company's action plan. The company should keep them informed periodically and monitor them to check if their levels of interest or power change.

3.7 Production system

Production system can be defined as the collection of methods and processes used to generate products, services or value from various resources. The resources that integrate the production system of a company can be grouped as tangible, intangible and human resources, and represent the assets that create the final value proposition. In the case of Virgin Galactic, the company possess highly specialized and extensive integrated resources and capabilities that enable it to manage and control almost every element of the design and manufacturing processes [27]. Virgin Galactic bases its production system philosophy on a unique approach and rapid prototyping capabilities that enable the company to design, build and test innovative ideas through agile, low-cost and rigorous processes.

Virgin Galactic's ability to produce its current and future vehicles and related systems depends on the sufficient availability of raw materials and supplied components, certain of which represent critical components in Virgin Galactic's operations. Virgin Galactic obtains raw materials and supplied components from a limited number of suppliers, which exposes the company to volatility in both prices and availability of these materials. In this regard, Virgin Galactic relies on the performance of these few suppliers to meet its manufacturing and operational needs, as failure to obtain raw materials and supplied components on favorable terms could result in delays or increased costs in manufacture processes.

Virgin Galactic conducts all its manufacturing operations at Mojave Air and Space Port, its proprietary facilities in Mojave, California. Mojave Air and Space Port consist on a 200,000 square feet of manufacturing and operations facilities that accommodates fabrication, assembly, hangar and both ground and test operations. This campus includes six main operational buildings and multiple storage buildings under independent lease agreements, which generally have initial terms of two to three years, accompanied by renewal options. The company also owns the Design and Engineering center located in Tustin, California, which comprises 61,000 square feet and houses research, design, development, marketing and other administrative functions. Moreover, Virgin Galactic plans to assemble its next generation spaceships in Mesa, Arizona. These manufacturing and operations facilities span approximately 151,000 square feet and were recently leased by the company in July 2022 [27].

The effectiveness of the production system also relies on the company's human and technological resources. Virgin Galactic has a highly talented and dedicated development and manufacturing team that supports the complete development of its high-performance vehicles. The engineers, technicians and professionals that comprise this team combine thousands of years of design, engineering, manufacturing and flight test experience from a broad range of the world's leading research, commercial and military aerospace organizations [27]. On the other hand, the company counts with its existing proprietary platform of advanced technologies. While these differentiated technologies are currently being used to develop highly specialized vehicles within commercial spaceflight operations, they are expected to be exploited in the Supersonic 2.0 high-speed transportation project and other additional applications. In this regard, Virgin Galactic remarks the importance of protecting these technologies as a key part of the company's success.

3.8 Value Chain Ecosystem

The value chain describes the set of consecutive activities required to bring a product from its initial design to the final consumers. The end goal of a value chain is to generate a competitive advantage for the company by adding some value to the finished product or service at each step of the process. A company's value chain is typically part of a larger value ecosystem that includes upstream and downstream activities or stages. The activities that compose a value chain are generally linked together and can be classified into primary and support activities. The former represent the essential and relevant activities for the creation and retention of value, while the support activities are intended to help make the primary activities more efficient [43].

Virgin Galactic defines itself as a vertically integrated aerospace company. The company has developed vertically integrated development capabilities that encompass not only the development, manufacturing and testing of aircraft and related propulsion systems, but also preliminary design and analysis of systems and vehicles and post-delivery support and maintenance.

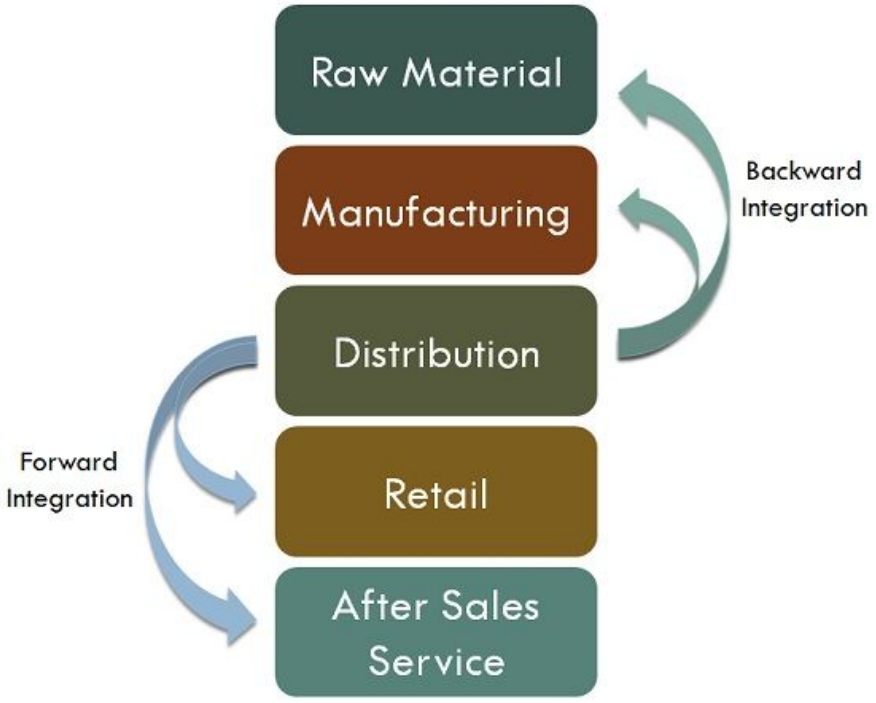

Figure 3.9: Vertical integration of the value chain

As a result, Virgin Galactic undertakes on its own all the primary activities of the value chain, which consist of five components that are defined below.

- **Inbound logistics**

  Inbound logistics consist on receiving, storing and managing inventory. Virgin Galactic's current stock is mainly based on key raw materials and components expected to be used for its human spaceflight operations, such as nitrous oxide, valves, tanks, special alloys, helium and carbon fiber, which the company obtains from a limited number of suppliers. At the end of each financial period, the company assesses if the value of its inventories has decreased due to damage, deterioration, obsolescence, changes

in price or other causes, and if so, a loss is recognized in that period [27]. Virgin Galactic uses the first-in, first-out or average cost methods to determine the costs of supply inventories, which along labor charges and overhead charges are charged to research and development (R&D) expense.

- **Operations**

  Operations include all the procedures for converting a raw material into a finished product, i.e., all the design and manufacturing processes involved in the production system of a company. Virgin Galactic locates all its manufacturing operations in Mojave, California, at the Air and Space Port campus. The vertical integration of Virgin Galactic allows the company to control almost all aspects of its business operations without third parties involved, creating greater efficiencies while reducing costs related to the profit margin of these third parties. Nevertheless, the vertical integration also exposes Virgin Galactic to larger impacts on its operations if disruptions or delays occur within the supply chain or manufacturing processes.

- **Outbound logistics**

  Outbound logistics encompass the various activities involved in distributing a final product or service to consumers, also including all planning and preparation activities to ensure the best possible delivery of this product or service. Regarding current human spaceflight outbound logistics activity, the company has dedicated more than a decade of diligent work in planning every aspect of the customer's journey to become an astronaut. Virgin Galactic's astronaut journey is conducted at the Virgin Galactic Gateway to Space terminal, where the customers undertake several days of pre-flight training in order to ensure a safe and comfortable trip to space, which include briefings, mock-up training, high-g centrifuge training and direct instruction with real flight hardware [27].

- **Marketing and sales**

  Marketing and sales activities include all strategies to make a product visible and reach target customers. Virgin Galactic's marketing and sales operations are currently focused on its spaceflight business, which in general requires a consultative and personalized sales approach. While Virgin Galactic's future astronauts have the possibility of undertaking their reservation process via the website of the company, Virgin Galactic is also exploiting the utilization of its direct sales organization, the London-based "Astronaut Office", as well as partnerships with third-party luxury travel agencies [27]. In transitioning to full commercialization, Virgin Galactic notes its limited experience in marketing and selling human spaceflights, but declares its intention to develop its marketing and sales strategy in anticipation of commercial operations as well as to take a more active role in these activities.

- **After-sales service**

  Virgin Galactic after-sales service is based on two distinct aspects. On one hand, the company has acquired development capabilities for products maintenance, which include post-flight support and maintenance of its spaceflight system vehicles. On the other hand, Virgin Galactic also leverages its high quality and personalized service to enhance customer experience. After the customers complete

the reservation for its spaceflight experience, they receive immediate membership of Virgin Galactic's Future Astronaut community and are welcomed via a call with Virgin Galactic's customer team. In addition to the culminating trip to space, Virgin Galactic is intended to provide a unique multi-day experience consisting on exclusive weeks at Spaceport America, which, among other items, include visits to Virgin Galactic's facilities and space readiness activities [27]. The company also offers a pre-flight training program customized by Virgin Galactic alongside training experts, behavioral health experts, experienced flight technicians and experienced government agencies, so that customers to focus their attention on getting the most enjoyment and the best experience possible.

3.9 Financial status

This section focuses on the analysis of Virgin Galactic's financial status. Based on financial statements released by the company, this analysis is intended to provide a general understanding of Virgin Galactic's overall health, as well as to assess its financial performance and business value.

Virgin Galactic went public in October 2019 thanks to its merge with the Special Purpose Acquisition Company (SPAC) closing at $11.75 per share in its debut. As of March 31, 2023, Virgin Galactic common stock shares (SPCE) were trading at $4.01 per share, in what represents a 65.87% retreat from its stock market debut and a 93.61% retreat from its all-time highs at $62.8.

Figure 3.10: SPCE share price fluctuation over the last 3 years [44]

As the figure 3.10 shows, Virgin Galactic's share price dropped significantly on July 12, 2021, just one day after Sir Richard Branson's successful flight into space, when the company announced that it was selling up to $500 million in stock "for general corporate purposes, including capital expenditures for the manufacture and development of its spaceflight fleet" [45].

On the other hand, Virgin Galactic has also been incurring losses related to its operations. The revenues generated, primarily from fees related to Virgin Galactic's future spaceflight bookings, continue to represent a very small portion compared to all of the costs associated with the R&D activities to support the spaceflight experience or the costs related to the administrative, marketing and sales activities. As a result, in transition

to full commercialization of its human spaceflight experience, the company is not only not being able to retrieve all of its expenses and investments, but is incurring larger and larger net losses each year.

This financial information from Virgin Galactic can be found in its publicly available Annual Reports, where the company provides a variety of information related to its financial condition, such as consolidated balance sheets, statements of operations and cash flow statements, used to manage its business operations and provide transparency to its stakeholders. In its 2022 Annual Report [27], Virgin Galactic publishes the financial results of its operations for the years 2020, 2021 and 2022, where, in addition to the final results for each of these years, a breakdown of the main operating costs is presented:

Results of operations (in thousands) [27]			
	2022	**2021**	**2020**
Revenue	$2,312	$3,292	$238
Operating expenses:			
Customer experience	$1,906	$272	$173
Selling, general and administrative	$175,118	$166,814	$111,203
Research and development (R&D)	$314,174	$144,223	$154,365
Depreciation and amortization	$11,098	$11,518	$9,781
Total operating expenses	$502,296	$322,827	$275,522
Operating loss	**$499,984**	**$319,535**	**$275,284**

Table 3.3: Results of Virgin Galactic's operations for the years 2020, 2021 and 2022

The financial results presented in the table 3.3 show increasing operating losses resulting in a $500M operating loss in the year 2022, and a total cumulative loss of almost $1B between the years 2020, 2021 and 2022. Nevertheless, the company notes that comparisons of financial results between periods are not necessarily indicative of future results. Logically, Virgin Galactic expects the start of commercial human spaceflight operations, expected in the second quarter of 2023, to be a turning point for the company's results, as in addition to a significant increase in revenues, the costs related to R&D could be greatly reduced. In this regard, as demand for the spaceflight experience is expected to increase in the coming years, Virgin Galactic is currently working on the development of its newest spaceship, VSS Imagine, to increase the annual flight rate and reduce the capacity constraints associated with having a single spaceflight system. Expanding Virgin Galactic's current fleet by manufacturing the VSS Imagine and additional spacecraft, as well as operating and maintaining these vehicles, would result in a substantial increase in Virgin Galactic's operating costs. Even so, the company is confident that the market for commercial human spaceflight, which is currently considered significant and untapped, will prove to be a viable business.

Chapter 4

Supersonic 2.0 Business Model

In the previous chapter, the main aspects of the Virgin Galactic company were studied in-depth, providing indispensable information for understanding how it operates. As explained, the commercial human spaceflight business concentrates most of Virgin Galactic's economic and human resources. With the goal of taking more and more humans to space, Virgin Galactic has been working for more than a decade on the development the platform of high-advanced technologies that conform its spaceflight system, which has already successfully completed various flights into space. The company is currently conducting more crewed test flights in order to prepare for commercial operations, which are scheduled to commence on the second quarter of 2023.

However, this thesis focuses on the other application that Virgin Galactic is intended to explore for its technologies: commercial supersonic P2P travel. Three years ago, the company officially declared its intention to enter the commercial supersonic transport market, unveiling the preliminary design of its supersonic vehicle and announcing a partnership with Rolls-Royce for the venture. Previously, the company already reached an important program milestone with the successful completion of an internal MCR. In addition, Virgin Galactic entered into agreements with regulators and industry leaders such as the FAA, Boeing and NASA, to collaborate on the development of high-speed technologies.

At present, Virgin Galactic has not yet defined a clear business plan or strategy for entering the market for commercial supersonic transportation, and the schedule for the development of the supersonic aircraft is still difficult to predict. Nevertheless, the company claims that a significant market opportunity exists for this type of vehicles. Moreover, while the company is expected to face intense competition in this emerging market, Virgin Galactic expects to leverage its powerful alliances in addition to its proprietary high-speed technologies to generate a competitive advantage. For this reason, this project aims to develop a comprehensive study of Virgin Galactic's Supersonic 2.0 business model, addressing key aspects such as the assessment of the company's strengths and weaknesses, the definition of the value proposition and the ways to generate it, and the identification of customers and competitors, as well as their values and behavior.

4.1 Business Model Canvas building blocks

In this chapter, Virgin Galactic's business model for the commercial supersonic travel market is evaluated. In this regard, the Supersonic 2.0 business model is assessed through the use of a Business Model Canvas (BMC), a strategic management template that provides a comprehensive description of how the company creates, delivers, and captures value in order to get profit. The BMC is typically composed of nine fundamental building blocks intended to outline the essential strategic details to successfully bring a product or service to market. The nine BMC building blocks are studied in detail below, before being presented together in the resultant BMC document.

4.1.1 Customer segment

Customer segments can be defined as the different groups of people or businesses that share common needs, characteristics or behaviours. The correct identification and analysis of these segments enables the company to effectively reach its target customers. In the case of the Supersonic 2.0 business model, two main segments of potential customers have been identified, and are discussed below.

- **First and business class passengers**

  Virgin Galactic, like several other companies seeking to enter the market, expects to center its commercial supersonic operations on passenger service, which would basically cover long-haul routes (5+ hours). In this regard, Virgin Galactic already affirmed that was designing its supersonic aircraft "for a range of operational scenarios", focusing on "service for passengers on long-distance commercial aviation routes" [34]. Virgin Galactic's supersonic vehicle design is tailored to suit this type of service, with customer comfort and experience as a top priority. The aircraft is expected to have capacity for 9 to 19 passengers and can incorporate customized cabin layouts to address customer needs, such as first class or business class seating arrangements.

  Addressable passenger demand primarily refers to premium passengers, i.e., customers who purchase first or business class seats and would potentially choose to pay higher prices for faster and more comfortable intercontinental travel. The total passenger demand can be estimated by analyzing the first and business class capacity of aircraft currently flying subsonic long-haul routes, which results in 2% of current passengers on long-haul subsonic routes flying first class, while 12% fly business class [40]. In the SAIC and BryceTech study, total passenger demand was calculated by applying existing passenger forecasts through 2050, adapting them to the relevant time frame and relevant viable routes above mentioned. The methodology initially considered that passenger demand will recover from COVID-19 impact in 2024, when it would reach 2019 levels. Then, regional and route growth rates were used from 2024 to 2050. Finally, for the period from 2050 to 2070, demand was extrapolated by applying an overall growth rate based on the compound annual growth rate of the previous 25 years. The results obtained by this method are shown in the following graph:

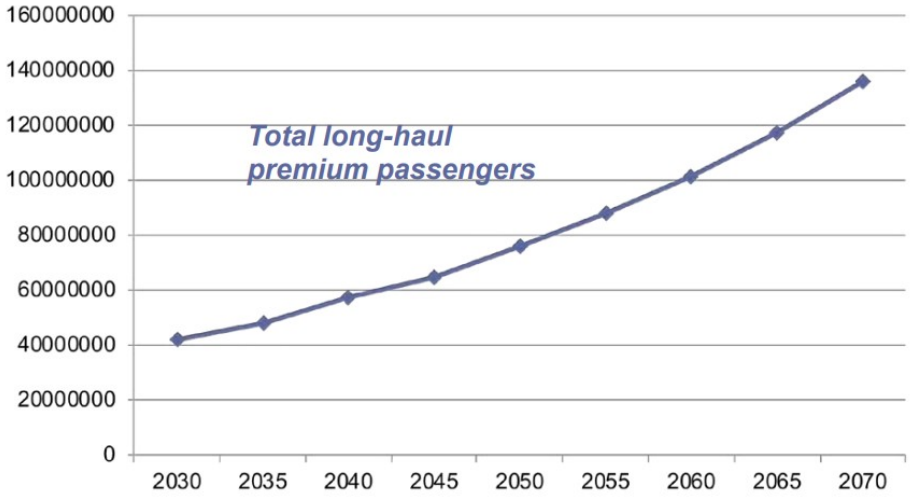

Figure 4.1: Total passenger demand for long-haul routes [40]

Figure 4.1 shows how the total number of premium long-haul passengers reaches almost 80 million by the year 2050 and about 140 million by 2070. Obviously, this total demand would be distributed among all the various companies in the market, depending, among other factors, on the characteristics of each company's vehicle and the fares they impose for their service. The study of these aspects is carried in more detail in the revenue stream building block.

- **Cargo transportation**

  The additional segment considered as a potential alternative to premium passenger demand is cargo transportation. Supersonic cargo transportation would primarily be intended to meet the demand from time-urgent applications that could include, amongst others, organ transplants, disaster aid, perishable luxury goods, emergency repair parts, and urgent documents.

  With regard to the current demand for air cargo transportation, since 2009 has been increasing by about 4% per year on average. However, air cargo still makes a marginal contribution within the total freight transport worldwide. For example, in 2015, only 0.25% of the 108 trillion tonne-km of freight transported went by air [40].

  On this basis, the market for high-speed cargo transportation is expected to be very limited. Most of the markets associated with the mentioned urgent applications do not appear to be sensitive to changes of hours, and some of them seem to be small in size. On the other hand, high-speed aircraft projected to enter the market in the near future are generally designed with very limited cargo capacity and would have little capability to adapt to this type of service.

Having examined the customer segments initially considered, it is important to identify which of them is the most attractive for the business model under study. On one hand, with an aircraft design specially suited to meet passenger needs while providing fast and comfortable travel, Virgin Galactic would be able to compete for a significant portion of the projected demand for long-haul premium passengers, which is expected to

grow significantly in the coming decades. On the other hand, no appreciable demand is found for cargo transportation, as the time savings offered by supersonic transport would not be appealing to most of the markets and would not incur a significant price premium.

For all the above reasons, it is concluded that premium passengers represent the most attractive segment, and are chosen as the target customer segment for Supersonic 2.0 business model.

In order to get a better understanding of a certain group of customers, it is important to understand their behavior and empathise with them. For this reason, is very important the use of an empathy map, an efficient tool to organize in a condensed format all known data about a consumer's motivations, frustrations and actions. An empathy map uses a primary buyer persona, which must be representative of the customer segment, and helps the company to create a sense of empathy with it [46]. Next, the empathy map developed for the target customer segment of Supersonic 2.0 business model is presented.

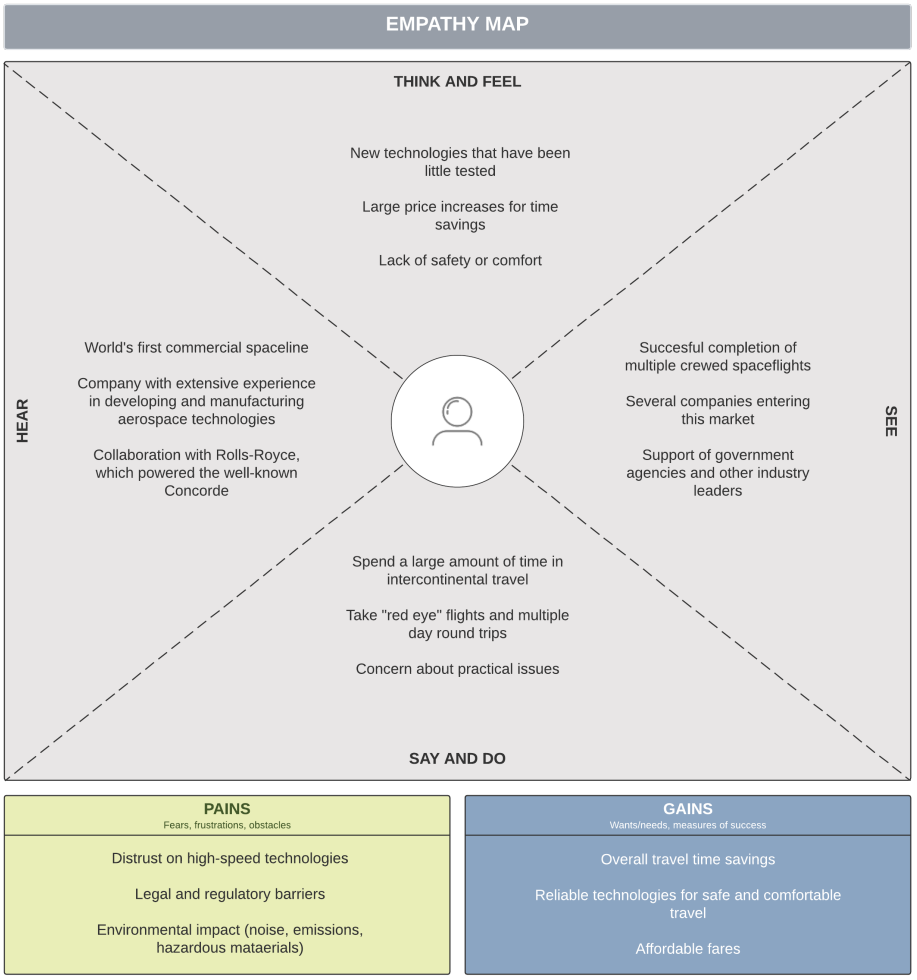

Figure 4.2: Empathy map for first and business class passengers

4.1.2 Value Proposition

A value proposition is a clear, concise and simple statement of the benefits that the company's product or service will provide to a target customer or market segment [47]. Essentially, a value proposition is aimed to specify what makes the company's product or service attractive and how it is differentiated from similar offerings, in order to persuade a customer to purchase the product or service from this particular business:

> *Virgin Galactic's supersonic aircraft helps first and business class passengers who want to take a long distance trip by drastically reducing flight time and allowing them to enjoy a unique and unrivalled experience.*

The above statement refers to the Supersonic 2.0 value proposition, the main aspects of which are discussed in further detail below.

- **Drastic reduction in international travel times**

  Through its Mach 3 aircraft, Virgin Galactic aims to significantly reduce flight time on international long-haul routes. More than 300 long-haul (5+ hours) city pairs are expected to be viable for commercial supersonic passenger transport [40]. For example, at speeds of Mach 3, Virgin Galactic's supersonic aircraft would be able to cut about 5 hours off the flight time for North America to Europe routes, such as New York - London or New York - Paris, which currently require a 7-hour flight for conventional subsonic airliners. Many passengers would be attracted by the drastic time savings on these trips, which at the same time would also enable to increase the number of daily takeoffs and landings, thus creating more potential demand.

- **Top priority on customer experience**

  Virgin Galactic's supersonic aircraft is designed to take customer experience as a top priority. With this approach, the company would offer its customers not only comfortable and enjoyable supersonic travel, but also the opportunity to participate in a more exclusive experience. In this respect, Virgin Galactic would have certain advantage over its competitors, as the Virgin brand counts with an exceptional reputation worldwide associated with unique customer experiences, adventure and luxury [27].

- **Focus on environmental sustainability**

  In addition to customer experience, the design of Virgin Galactic's supersonic aircraft has a focus on environmental sustainability. In order to achieve this, Virgin Galactic will be working along Rolls-Royce, a leader in cutting-edge technologies capable of delivering clean, safe and competitive solutions to the planet's vital needs [34]. The aircraft design is also intended to lead the way toward the use of next-generation sustainable aviation fuel. It is hoped that the incorporation of sustainable technologies and techniques into the aircraft design will also serve as a catalyst for adoption by the rest of the aerospace industry.

Following, the value proposition of Virgin Galactic's Supersonic 2.0 business model is presented using the Value Proposition Canvas (VPC) tool. VPC is a tool that helps the company to assure that its product

or service is positioned around customers' values and needs [48]. Thus, the main objective is to generate a fit between the product or service offered and the market requirements, understanding the customer's expectations and developing a product in accordance with them.

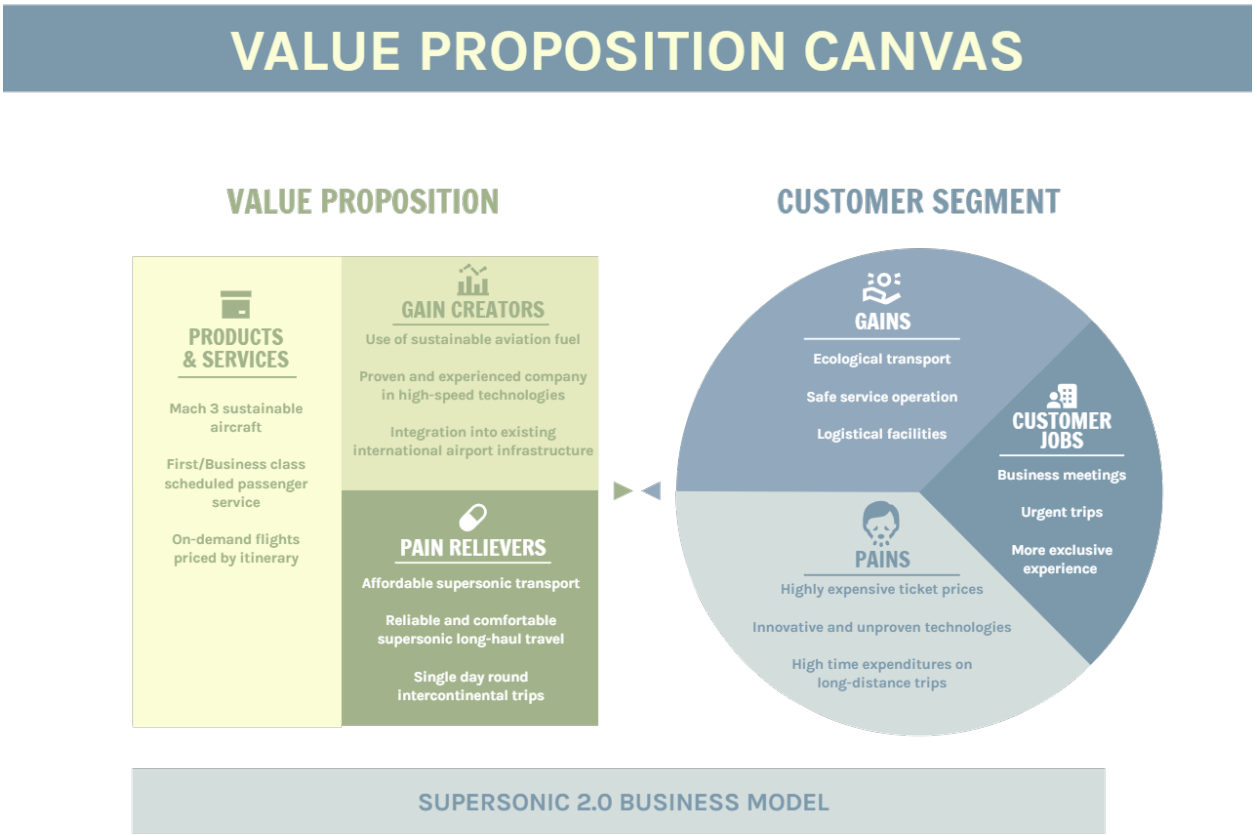

Figure 4.3: Value Proposition Canvas for Supersonic 2.0 business model

4.1.3 Channels

Channels can be defined as the mechanisms that the company uses to communicate with and reach the customers to deliver its value proposition. Channels play a key role in the customer experience as they are responsible of several functions, which include raising awareness among customers of the existence of the product, persuading customers of the attractiveness of the product, allowing customers to purchase a specific product or service, and provide after-sale customer support [49]. The channels of a company can be divided in direct and indirect (intermediaries) channels, and are comprised by the communication, distribution, and sales interfaces.

In the case of of Supersonic 2.0 business model channels, it is supposed that they would use similar approaches to those that the company is employing for its commercial human spaceflight business. On this basis, the description of the channels is focused on what channels Virgin Galactic is currently using for this business and how they could be adapted to the commercial supersonic passenger transport business.

- **Virgin Galactic website**

  Virgin Galactic currently uses its official website, *virgingalactic.com*, to provide a wealth of information about the company and its operations. This information includes governance documents, information about the executive management and board of directors, quarterly financial results, news and updates, and detailed descriptions of all phases of its multi-day astronaut experience, as well as unique audiovisual archives of its successfully completed crewed spaceflights. All this publicly available information helps Virgin Galactic to be highly transparent to its customers, who also have access to the company's annual reports and proxy statements.

  In terms of the supersonic passenger transport business, Virgin Galactic would require using *virgingalactic.com* for multiple functions. In addition to a channel to provide users with key information aout the service, such as available routes, schedules and fares, the company would probably need to use its website also as a sales channel, as most airlines currently do.

- **Direct sales offices**

  To date, Virgin Galactic has primarily sold its reservations for its astronaut experience through its direct sales organization. Virgin Galactic's direct sales organization, known as the "Astronaut Office", is based in London, England, and has been responsible of most of the 800 bookings that the company already has for its future spaceflights. In this regard, Virgin Galactic claims the importance of its direct sales organization for this business, as spaceflight sales are consultative and often require a one-on-one sales approach [27].

  For its supersonic P2P travel business, the company could explore the possibility of using independent direct sales offices. Even so, since sales for supersonic passenger transport would involve much more demand, the company could not rely exclusively on the selling capacity of these offices, and would have to explore additional ways to sell its service. However, this channel could also serve to provide a more personalized service to those customers who require it, as well as to act as an information point to get a more direct approach from the Virgin Galactic team.

- **Sir Richard Branson's network**

  Richard Branson, founder of the Virgin brand and all its derivative businesses (which obviously include Virgin Galactic), counts with an extensive network of key contacts and partners around the world, from which the company could benefit to generate new demand and additional sales, as well as referrals from existing clients that would help the company's reputation.

- **Third-party luxury travel agencies**

  Virgin Galactic would also intend to go to the market utilizing partnerships with third-party luxury travel agencies. Virgin Galactic already established a partnership for its human spaceflight operations with Virtuoso, a company with a network of more than 20,000 luxury travel advisors and upscale clientele. With similar alliances, Virgin Galactic could significantly expand its demand for supersonic passenger travel, as well as consider acting as an exclusive operator for these agencies.

4.1.4 Customer relationship

The type of relationship a company establishes with its customers plays a key role in their overall experience and level of satisfaction. Customer relationships are defined by the approach the company uses to attract and retain customers, as well as to boost sales [50]. For its human spacelfight sales, Virgin Galactic currently uses personalized and consultative processes, but backed by a digital customer relationship management. These processes are designed to deliver a high-touch user experience, but efficient and scalable at the same time. Once the reservation transaction is completed, the customer receives immediate membership of the Future Astronaut community and is welcomed via a call with Virgin Galactic's customer team in the Astronaut Office. This welcome is further enhanced by a personalized, high quality welcome pack sent to each customer, containing a personal letter from Sir Richard Branson [27].

Obviously, given that demand for the supersonic passenger transport business is expected to be much broader, the company would have to redesign this personalized approach in customer relations. In this sense, Virgin Galactic could proceed to digitalize customer relationship management in a more global way, thus allowing a more generalized service for the majority of customers. However, the more individual or targeted approach could be maintained for the most sensitive customers, such as businesses or high-net-worth individuals looking for on-demand flights or to purchase fractional ownership of the aircraft.

4.1.5 Revenue streams

While customers are often considered the heart of the business model, revenues are analogous to arteries. Revenue streams are defined as the earnings the company obtains from the revenue generated by each customer segment [51]. In some cases, an accurate assessment of the value provided to a customer segment may result in multiple revenue streams being derived from this specific customer segment. This is the case for Virgin Galactic's Supersonic 2.0 business model, which although it would exclusively focus on service targeting premium passenger demand (excluding cargo demand), could derive revenue from several types of operations. These operations would be divided into two main modules, depending on how the company would price its service: scheduled commercial flights (priced per seat) and commercially operated on-demand flights (priced per itinerary).

- **Passenger ticket sales**

  This type of service could be equated to the current subsonic commercial aviation service, which is mainly based on scheduled commercial passenger flights. At present, premium fares for the viable routes considered in this study, i.e., long-haul flights of 5 or more hours, reach an average price of about $5,000 [40]. The revenues generated by premium fares account for about 75% of total profits, a very substantial percentage considering that passengers purchasing these fares represent less than 20% of all passengers. In [40], the willingness of customers to pay for time savings was assessed. This evaluation, which considered a range of 1.5x to 10x current premium fares, was aimed to find the most optimal fares for this service, as while willingness to pay increases with time saved the comparatively large operating costs of the aircraft reduce overall revenue. The calculated revenues for each fare pricing are

presented in the table below, which only considers the results for a Mach 3 aircraft (Virgin Galactic's supersonic aircraft case).

Revenue on Viable Routes ($B) [40]						
	2030	**2035**	**2040**	**2045**	**2050**	**2055**
1.5X Fare	$37.9	$45.6	$54.4	$65.1	$78.0	$93.4
2.5X Fare	$3.2	$4.2	$5.9	$7.6	$10.0	$13.3
5X Fare	$2.0	$2.4	$3.4	$4.3	$5.5	$7.1
10X Fare	$0.2	$0.5	$0.8	$1.1	$2.0	$3.8

Table 4.1: Revenue from scheduled commercial passenger flights in a Mach 3 case

As seen in the table 4.1, the best case clearly results from fares at 150% of current first and business class prices. Above 1.5x subsonic fares, the results show a significant drop in the revenues obtained, as fewer passengers would be willing to pay the higher fares.

Although it does not appear in the table presented above, the study showed that best business case results from a Mach 3 aircraft, as cases above these speeds are constrained by fewer viable routes due to increased operating costs [40]. If these results are proven to be true, Virgin Galactic could benefit from this competitive advantage over other competitors in the sector, since it is currently the only company with an aircraft designed to fly at these speeds.

- **Charter operations and fractional ownership sales**

  This type of operation would refer to the current subsonic general aviation service, which includes commercially operated on-demand flights, such as charter and fractional flights. Charter service refers to non-scheduled flights whose price depends on the itinerary requested by the clients, and in which customers rent the entire aircraft and crew for a private flight at their convenience. In contrast, fractional operations are based on fractional ownership of the aircraft, where customers own a share of the airplane and enjoy the benefits of sharing both the costs and responsibilities of aircraft ownership. The revenue assessment for this case considers a range of 1.5x to 10x long-haul private jet fares, which are currently around $15,000.

Revenue on Viable Routes ($B) [40]						
	2030	**2035**	**2040**	**2045**	**2050**	**2055**
1.5X Fare	$7.1	$8.5	$10.3	$12.5	$15.1	$18.2
2.5X Fare	$14.6	$16.5	$18.7	$21.3	$24.2	$27.4
5X Fare	$0.0	$0.0	$0.0	$0.1	$0.1	$0.1
10X Fare	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0

Table 4.2: Revenue from commercially operated on-demand flights in a Mach 3 case

As the table 4.2 shows, the best case for general aviation is for prices at 250% of current long-haul private jet prices. Results in table 4.2 also show no appreciable revenue for 5x and 10x fares. The high prices associated with this type of operation may imply a greater targeting of high net worth individuals, which have a higher purchasing power and would show more willingness to pay. Additionally, the company could also consider targeting corporations and general aviation operators.

4.1.6 Key resources

Key resources represent the assets that the company needs to create and deliver the value proposition, and differ substantially depending on the type of business model. In the case of the businesses in the aerospace industry, they mainly rely on the physical, technological and human resources dedicated to the manufacturing of the vehicles and related systems. However, Virgin Galactic and several other companies also depend on their ability to create and protect their intellectual property resources.

- **Virgin Brand**

  The Virgin brand is recognized worldwide as an iconic brand associated with unique customer experiences based on innovation, adventure and luxury. This exceptional reputation represents a key asset to Virgin Galactic's ability to attract an retain customers. In fact, the company already attributes a large number of its reservations for the human spaceflight experience to the strength and prominence of the brand, which have driven many of Virgin Galactic's future astronauts to approach the company directly with inbound applications [27].

- **Virgin Galactic facilities**

  Virgin Galactic owns dedicated facilities that support the full development of its high-performance vehicles. Mojave Air and Space Port facilities, located in Mojave, California, are house of all the manufacturing processes of Virgin Galactic. The 200,000 square feet manufacturing and operations facilities are composed of six main operational buildings and multiple storage buildings that collectively accommodate fabrication, assembly, warehouse, office and both ground and test operations [27]. The company already counts with its Design and Engineering center located in Tustin, California. This facility spans about 61,000 square feet and hosts Virgin Galactic's management, research, design, development, marketing, finance and other administrative functions [27]. Additionally, the company recently leased approximately 151,000 square feet of manufacturing and operations facilities in Mesa, Arizona. While these facilities are intended to house the assembly of Virgin Galactic's next generation spaceships, they could also be used for some future manufacturing operations dedicated to high-speed vehicles and systems.

- **Raw materials and supplied components**

  Virgin Galactic's capacity to produce its current spaceflight systems, as well as aircraft or related systems for future supersonic transport operations, is highly dependent on the sufficient and continued availability of supplied raw materials and components. Some of these materials and components, which the company obtains from a limited number of suppliers, are critical to the manufacture and operation

of Virgin Galactic's vehicles. In this regard, failure to obtain these resources on favorable terms or at all could impair the delivery of Virgin Galactic's value proposition, causing delays or interruptions in the service provided.

- **Technologies and expertise**

  Virgin Galactic's developing and manufacturing operations are highly dependent on the technological and human resources of the company. Since Virgin Galactic's formation in 2004, the company has been working on the development of a robust and broad platform of advanced proprietary technologies, which today are dedicated exclusively to operations for spaceflight. In addition, Virgin Galactic has developed extensive, vertically integrated aerospace development capabilities, as well as a significant amount of know-how and expertise, that enable the company to implement innovative and efficient development and manufacturing processes. These processes are performed by Virgin Galactic's development and manufacturing team, comprised of talented and dedicated engineers, technicians and professionals with thousands of years of combined experience in the aerospace industry.

  Virgin Galactic expects to leverage its existing proprietary technologies, along with significant design, engineering and manufacturing expertise, and thousands of hours of flight training, to develop additional aerospace applications [27], such as the manufacture of aircraft dedicated to supersonic P2P travel. Exploiting these resources for supersonic passenger transport could enable Virgin Galactic to face competition from companies with greater knowledge and economic resources.

- **Intellectual property**

  As explained above, Virgin Galactic's design, developing and manufacturing processes are based on proprietary methodologies, technologies and technical expertise. For this reason, the success of the company depends on the ability to protect all of these intellectual property rights. In this regard, Virgin Galactic employs various measures to adequately protect its intellectual property, such as trade secrets, non-disclosure agreements with employees and consultants, and patent protection.

4.1.7 Key activities

Like key resources, key activities are aimed to create and deliver value to the customer. Key activities are defined as the ability of the company to effectively transform its resources into a product or service. Virgin Galactic's key activities were already assessed in Chapter 4.8 within the value chain ecosystem, but they are redefined in this building block by focusing on the activities for the supersonic passenger transport business.

- **Developing**

  Development activities are aimed to enable the company to stay ahead of its competition through the research, development and introduction of new products or services, as well as the improvement of existing offerings [52]. They usually correspond to the first phase of the development process, which includes the preliminary design and analysis and detailed design phases. As for the Supersonic 2.0 business model, Virgin Galactic would focus its development activities on the design and development

of high-speed technologies, with a particular emphasis on engine propulsion technology for supersonic aircraft for which the company would work alongside Rolls-Royce.

- **Manufacturing**

  Manufacturing is composed of all fabrication and assembly processes aimed at converting raw materials and components into finished products [53]. Manufacturing activities dominate the business models of companies in aerospace industry, as they are primarily responsible for adding value to the product. Efficiency is a crucial factor in manufacturing procedures, as it leads to increased productivity and cost savings. In this respect, Virgin Galactic is focused on developing and implementing manufacturing efficiencies that would reduce costs of future commercial operations. The company conducts all of its manufacturing operations, which include, among others, fabrication, assembly, warehousing and ground operations, at the Air and Space Port in Mojave, California [27].

- **Testing**

  The implementation and growth of the commercial supersonic transportation business is highly dependent on the successful development of advanced high-speed technologies. In most cases, these technologies are new and largely unproven, making testing a crucial process in this industry. In the coming years, all companies planning to start commercial operations will have to subject their developed technologies to numerous phases of testing in order to ensure their safety and reliability for regular commercial operation.

- **Marketing**

  Virgin Galactic anticipates that the success of its business will depend largely on the company's ability to effectively market and sell its products and services. At present, Virgin Galactic bases its marketing strategy in digital marketing, and expects to increase the reach of digital content by publicity distribution using online marketing services. At the same time, in transition to full commercialization of human spaceflight operations, the company is continuing to evaluate and develop its marketing strategies in order to take a more active role in future marketing campaigns and to be able to engage customers in the most cost-effective manner [27].

4.1.8 Key partners

Companies usually create alliances with external partners, the purpose of which is to help the company optimize its business model, reduce risks or getting access to key resources. These alliances can be classified into four different types of partnerships, which are strategic alliances between non-competitors, coopetition (strategic partnerships between competitors), joint ventures to develop new or complementary products, and buyer-supplier relationships.

- **Boeing**

  Boeing and Virgin Galactic announced in October 2019 entering into a strategic partnership to work together on transforming global travel technologies. The agreement between the two companies consists

of a $20 million investment by Boeing that is to be returned through new Virgin Galactic shares. This collaboration brings together two companies with extensive experience in the aerospace industry, and is aimed to "help unlock the future of space travel and high-speed mobility" [32]. Virgin Galactic hopes working with Boeing, the world's largest aerospace company with more than 150,000 employees, will support its mission to develop and implement high-speed travel technologies.

- **NASA**

  The alliance between Virgin Galactic and NASA was stated in May 2020 through the signing of a Space Act Agreement. The collaboration between Virgin Galactic and the U.S. agency is focused on the development of high-speed technologies, centering the efforts in sustainability. In this sense, the agreement offers Virgin Galactic the possibility to use the data collected from NASA's experimental quiet supersonic aircraft, the X-59 QueSST, in the development of advanced technologies capable of offering silent, as well as efficient and sustainable, high-speed travel.

- **Rolls-Royce**

  Virgin Galactic will work jointly with Rolls-Royce on the design and development of engine propulsion technology for its commercial supersonic aircraft. The agreement between the two companies, which was reached through the signing of a non-binding MOU in August 2020, represented an exciting step forward in Virgin Galactic's venture within the market for commercial supersonic transport. Virgin Galactic expects to benefit from Rolls-Royce's expertise in providing clean and safe cutting-edge technologies to develop an aircraft capable of making supersonic travel practical, sustainable, safe, and reliable, while making customer experience a top priority [34].

- **Federal Aviation Administration (FAA)**

  The FAA is responsible for the certification that ensures that commercial and general aviation aircraft meet the highest safety standards, from initial design to retirement [54]. Since the regulations and guidance issued by the FAA will apply to the use and operation of Virgin Galactic's supersonic aircraft, the company looks forward to working together with the FAA to ensure that its designs can make a practical impact from the start. In this regard, in 2020 the FAA's Center for Emerging Concepts and Innovation already reviewed Virgin Galactic's supersonic aircraft design, and authorized FAA resources to work with Virgin Galactic team to begin outlining a certification framework [34].

- **Raw materials and components suppliers**

  Virgin Galactic's production system significantly depends on the sufficient availability of certain raw materials and supplied components, which the company obtains from a limited number of suppliers. Once commercial operations commence, any disruption in the supply of these key raw materials or components would result in cancellations or delays of scheduled flights and negatively affect operating results. For this reason, Virgin Galactic's ability to meet manufacturing and operational needs in a cost-effective and timely manner will depend on the performance of these external suppliers and contractors.

4.1.9 Cost structure

The cost structure refers to all fix or variable costs incurred to operate the business model. These costs can be calculated relatively easily after defining Key resources, Key activities, and Key partnerships [55]. Virgin Galactic's possesses a value-driven type of cost structure, as the company is less concerned with the cost implications and instead focuses on value creation for customers.

- **Research and Development (R&D)**

  Research and development costs represent expenditures incurred to support activities that advance Virgin Galactic's vehicles and related systems toward commercialization, including basic and applied research, concept formulation studies, design, development, and related testing activities [27]. Given that the design of Virgin Galactic's supersonic aircraft is still in its preliminary stages, R&D expenses would initially account for majority of the total costs associated with the Supersonic 2.0 business model. However, Virgin Galactic would expect R&D costs to decrease once technological feasibility for its supersonic aircraft is achieved, as the costs incurred to manufacture additional vehicles or systems would no longer be considered R&D activities.

- **Manufacturing and operating**

  Manufacturing expenses comprise the costs dedicated to develop the structure and propulsion system for Virgin Galactic's supersonic aircraft, including equipment, materials, and labor hours (including from third-parties), as well as third-party fees to manufacture key subassemblies for the aircraft [27].

  Operating costs, on the other hand, represent all costs related to the flight operations of the aircraft, including fuel, maintenance, air crew and insurance costs [40]. Operating costs also include ground costs related to the servicing of passengers and aircraft at airport stations, including aircraft landing taxes and reservation/sales fees. To be considered viable flight operations, operating costs must be lower than the revenues for a given route.

- **Marketing and branding**

  Marketing and branding costs refer to the expenses dedicated to advertising and promoting the company's products or services. These costs include expenses such as public relations, sales promotions and marketing campaigns, and are intended to attract and retain customers, as well as increase brand awareness and generate sales. Virgin Galactic anticipates its marketing and brand content advertising campaigns could involve significant expese.

- **General and administrative**

  General and administrative expenses refer to expenses related to the human capital of employees involved in general corporate functions. These human capital expenses primarily include salaries, cash bonuses, stock-based compensation and benefits [27]. General and administrative costs also include facilities rent, professional fees and other general corporate expenses. Virgin Galactic predicts that general and administrative costs will increase as the company continues to grow.

4.2 Business Model Canvas document

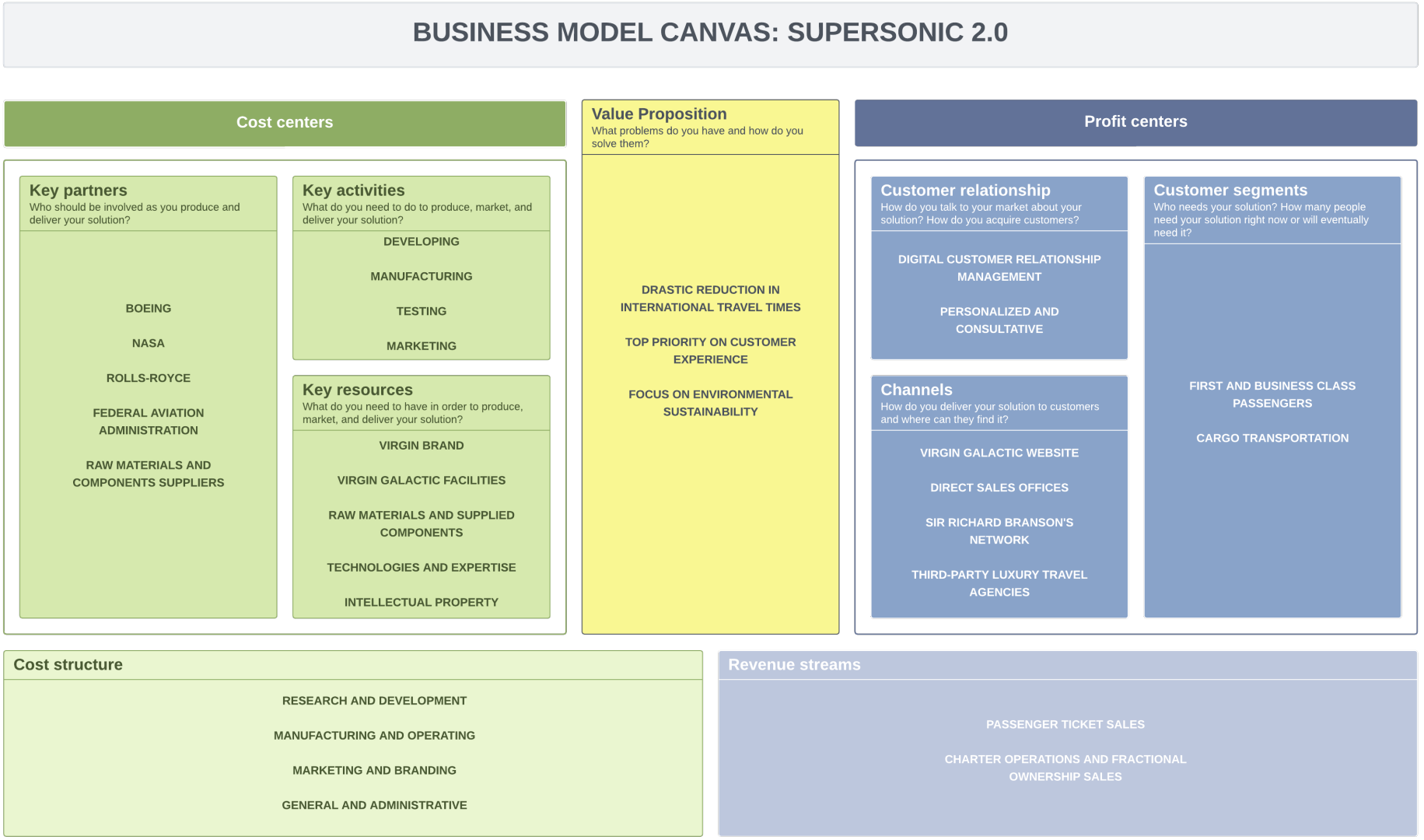

Figure 4.4: Business Model Canvas of the Supersonic 2.0 business model

Chapter 5

Risk analysis

Risk is defined as an uncertain event or condition that, if materializes, has a positive (opportunity) or negative (threat) effect on the business model operations. The risk analysis process consists of four main phases: risk identification, risk assessment, risk response and risk re-assessment. The four phases of the risk analysis process are described and addressed below in order to obtain a comprehensive risk management approach for the Supersonic 2.0 business model.

5.1 Risk identification

The first phase of the risk analysis consists of identifying all the risks to which the business model is subject. Next, the risks to the Supersonic 2.0 business model are defined and classified, also describing the positive (not in all cases) and negative impacts they could have on the business model. To facilitate the subsequent risk assessment process, the risks are presented in a numbered format.

5.1.1 Internal risks

1. The Virgin brand is not under Virgin Galactic's control, and any adverse publicity related to the Virgin Brand name or in relation to another Virgin-branded company could negatively affect Virgin Galactic's reputation, as well as its business and results of operations.

   On the other hand, Virgin Galactic expects to integrate as part of its internal corporate culture and external marketing strategy the identity values that represent the Virgin brand, such as quality, innovation, creativity, fun, a sense of competitive challenge and employee-friendliness [27].

2. Virgin Galactic relies on a limited number of external suppliers and contractors to successfully develop its vehicles. This could expose the company to price volatility of certain raw materials and supplied components, prolonged interruptions or delays in the supply of these materials, and difficulties in finding new sources of supply [27], which could result in cancellations or delays of scheduled flights and consequently affect results of operations.

In contrast, Virgin Galactic's vertical integration allows the company to conduct all of its operations with very few third-party contractors involved, creating greater flexibility and efficiency while reducing the profit margin costs related to these third parties.

3. Business success depends largely on the continued services of its senior management team and highly skilled personnel. Consequently, the company's ability to attract, motivate and retain a sufficient number of talented personnel, including engineering, design, finance, marketing, sales and support personnel [27], will have a key impact on Virgin Galactic's capacity of implementing its business strategy.

4. Virgin Galactic has already developed and expects to continue developing intellectual property rights, which include specific methodologies, practices, technologies and know-how used in the design, development, implementation and maintenance of applications and processes [27]. In this regard, the company relies on the adequate protection of its intellectual property rights to maintain its competitive position and to prevent copying of its proprietary technologies that may compete with its own.

5.1.2 Financial risks

5. If the business and demand for supersonic passenger transport grows as expected, Virgin Galactic may require significant expenditures for additional future operating facilities, as well as for the maintenance, renovation and improvement of existing facilities. In this regard, Virgin Galactic anticipates that in the future, particularly once commercial operations commence, the company may need to raise capital through public or private financing.

   If such financing is not available on acceptable terms or at all when needed, Virgin Galactic may be required to sell a portion of its equity or debt securities. However, given that the company operates within the Virgin Group, also founded and managed by Richard Branson, Virgin Galactic would be expected to leverage its position within the Virgin Group's investment portfolio in order to receive the needed additional funding.

6. Certain shareholders, including institutional investors, investor advocacy groups, investment funds, creditors and other influential financial market participants, are increasingly focusing on the environmental, social and governance (ESG) practices of companies when evaluating their investments and business relationships. In this scenario, failure to meet future shareholder expectations about Virgin Galactic's ESG strategy or performance could result in adverse investor sentiment towards the company, resulting in a negative impact on Virgin Galactic's share price and access to capital [27].

7. Virgin Galactic expects to face intense competition in the commercial supersonic transportation market. Many of these potential competitors would be larger and have substantially greater resources than Virgin Galactic has and expects to have in the future, thus being able to dedicate greater resources to the development of supersonic aircraft and related technologies or offer lower prices.

   In order to offset this situation, Virgin Galactic could exploit its existing proprietary technologies and extensive experience, as well as the Virgin brand and its exceptional global reputation, to gain a competitive advantage over these more financially strong companies.

5.1.3 Technological risks

8. The ability to generate and grow the business will depend on the successful development of state-of-the-art high-speed technologies, which are new and currently remain largely unproven. Any delays on the timing for completing the design, manufacturing and testing of these technologies will directly affect Virgin Galactic's schedule for the commencement for commercial operations. If such technologies fail to perform as expected or competitors are able to develop such technologies before Virgin Galactic it could materially and adversely impact Virgin Galactic's operations results [27].

   Conversely, if the company is able to develop and manufacture the high-speed technologies necessary to power commercially available supersonic travel in a cost-efficient and timely manner, it could gain competitive advantages over its competitors.

9. Virgin Galactic will manufacture and operate highly sophisticated aircraft that rely on innovative and complex technology. Although the company has created operational processes to ensure that rigorous performance goals are met, these could result in unsatisfactory safety performance or safety incidents at Virgin Galactic's facilities.

10. Business success will depend in part on the continued operation of the Virgin Galactic's supersonic vehicle/s. While the vehicle is designed for a certain number of cycles, know as the design life, the operational or useful life of the aircraft could not be consistent with its design life [27].

5.1.4 Operational risks

11. The market for commercial supersonic passenger transport is still in its infancy and has not been precisely established. Therefore, at present, total addressable demand can only be calculated from third-party forecasts. Although these estimates are considered reasonable and reliable, they could prove to be incorrect, and the total addressable market may not reach (or exceed) the anticipated growth potential or growth rate.

12. If Virgin Galactic's operations within commercial supersonic travel grow as planned, the company will need to expand all of its key activities, as well as its products and services. If not managed efficiently, continued growth could increase pressure on Virgin Galactic's resources, and the company could experience operational difficulties [27].

    In contrast, if Virgin Galactic is able to scale the business and aircraft manufacturing efficiently, the company should be able to manage, maintain and operate a sufficient number of aircraft to accommodate customer demand and provide customer service that meets or exceeds their expectations [27].

13. Virgin Galactic will most likely start commercial operations with a single supersonic aircraft. This aircraft will be composed of cutting-edge, highly sophisticated technologies that will be required to meet rigorous performance targets that, occasionally, may necessitate the replacement of critical components [27]. This could lead to the inability to operate the aircraft at the planned flight rate, resulting in the cancellation or delay of some flights.

14. Supersonic passenger transport carries intrinsic risks, as a single human error or any other incident could lead to a catastrophe affecting human lives. While it is impossible to completely eliminate the possibility of human error, Virgin Galactic will need to implement rigorous protocols and procedures for safety-critical crew actions, as any accident resulting in loss of human life could entail reputational damage and legal liability [27].

15. The supersonic passenger transport business will be subject to a wide variety of international laws and regulations relating to business operations, including employment and labor, taxes, health and safety, and environmental issues [27]. Changes in international legislation and regulatory requirements or the imposition of new regulations could require Virgin Galactic to change the way it operates, resulting in additional costs associated with compliance with these laws.

5.1.5 Environmental risks

16. There is great concern about the environmental impact that high-speed aircraft could cause. In addition to the acoustic impact created by the sonic boom when transitioning from subsonic to supersonic flight, supersonic and hypersonic aircraft are expected to consume more than subsonic aircraft, resulting in increased emissions of carbon dioxide and other particulates [40]. However, it is assumed that commercial high-speed aircraft will have to operate at similar noise levels as subsonic aircraft, and under strict environmental regulations related to emissions that could be difficult to comply with.

    On this basis, Virgin Galactic will be working with Rolls-Royce, a leader on developing and providing competitive solutions to the planet's vital power needs, to design and develop sustainable engine propulsion technology for its supersonic commercial aircraft, which would be expected to use state-of-the-art SAF. The two companies aim the aircraft design to lead the way toward the use of sustainable fuel and act as a catalyst for the adoption of sustainable technologies in the rest of the aviation community [34].

17. The occurrence of natural disasters such as tornadoes, hurricanes, fires, floods ans earthquakes or unusual weather conditions where Virgin Galactic's or third-party facilities are located could have a material adverse effect on the company's operations. Furthermore, severe weather conditions such as rainfall, snowfall or extreme temperatures could impact the ability to operate the aircraft under normal conditions, resulting in additional expense to reschedule the operation and customers' travel plans [27].

5.2 Risk assessment

After identifying and classifying the risks of the Supersonic 2.0 business model, the assessment process can be carried out. The risk assessment process consists of defining the probability and impact of each risk in order to determine the potential effect they could have on the business model. A very valuable tool for assessing and managing risks is the risk matrix, in which each risk is positioned according to its probability and impact. Given that threats and opportunities are evaluated using the same procedures, they are presented in a joint risk matrix.

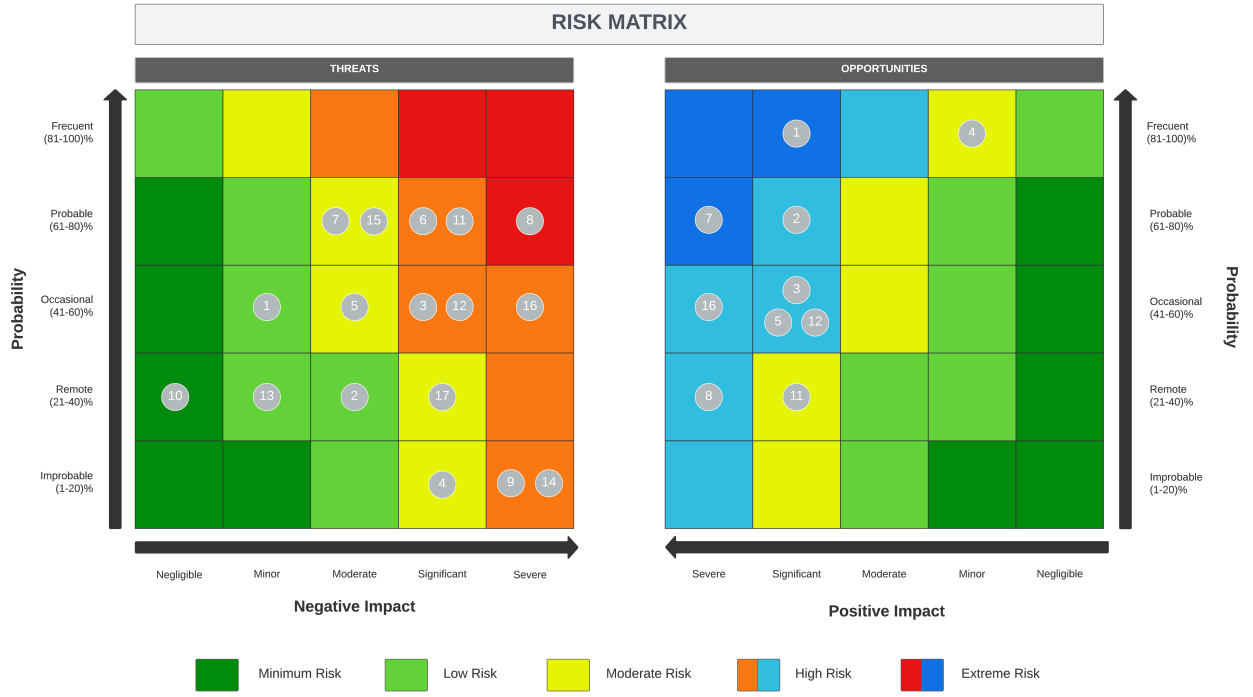

Figure 5.1: Risk matrix for Virgin Galactic's Supersonic 2.0 business model

Figure 5.1 shows the threats/opportunities matrix for the Supersonic 2.0 business model. Once risks have been assigned a probability and impact, they can be categorized into different levels of risk: minimum, low, moderate, high and extreme. The correct identification of these levels is crucial, as they enable to evaluate the response priority for each risk.

5.3 Risk response

The risk response plan of a company is aimed to reduce or eliminate any threats to the project, as well as increase the opportunity offered by a positive risk [56]. Risk response strategies focus on addressing the risks that require more immediate attention, which are typically limited to the 5 to 8 largest risks in order not to lose efficiency in the responses. These risks are those typically located at the high and extreme risk levels, and are referred to as high priority risks. In this sense, the risk response plan concentrates on determining the most appropriate response strategy for each of these high-priority risks. Following, the response strategies for both threats and opportunities are presented in a table.

Type of response	Target risk	Description
Avoid	Threat	Eliminate the risk by developing an alternative strategy, changing the design, or modifying a requirement.
Mitigate	Threat	Risks the company just can not avoid. Reduce probability and/or impact of the negative risk through active measures.
Transfer	Threat	Reduce probability and/or impact by transferring all or part of the work on resolving the risk to another party, such as a highly specialized company or an insurance company.
Accept	Threat and opportunity	Adopt a wait-and-see attitude and take action when triggers are met. Budget, schedule, and other resources must be held in reserve in case the risk occurs.
Share	Opportunity	Share the risk response with another party that can increase the probability and/or impact of opportunities.
Enhance	Opportunity	Increase probability and/or impact of opportunity.
Exploit	Opportunity	Add more tasks or change the management plan to take advantage of opportunities.

Table 5.1: Identification and description of risk response strategies

The table 5.1 shows the identification and description of the various risk response strategies, and allows to proceed to the next step of the risk response plan, consisting of determining the response strategy to be implemented for each defined risk:

Threats

- Avoidance: 3, 6, 14
- Mitigation: 12
- Transfer: 9, 16
- Acceptance: 8, 11

Opportunities

- Share: 16
- Enhancement: 3, 8, 12
- Exploitation: 1, 2, 5, 7

5.4 Risk re-assessment

The last phase of the risk analysis process corresponds to risk re-assessment. The risk re-assessment phase focuses on evaluating the change that high priority risks have experienced in their probability and impact after being subjected to the risk response plan. This changes can be clearly identified through the development of the re-assessed risk matrix, which is presented below.

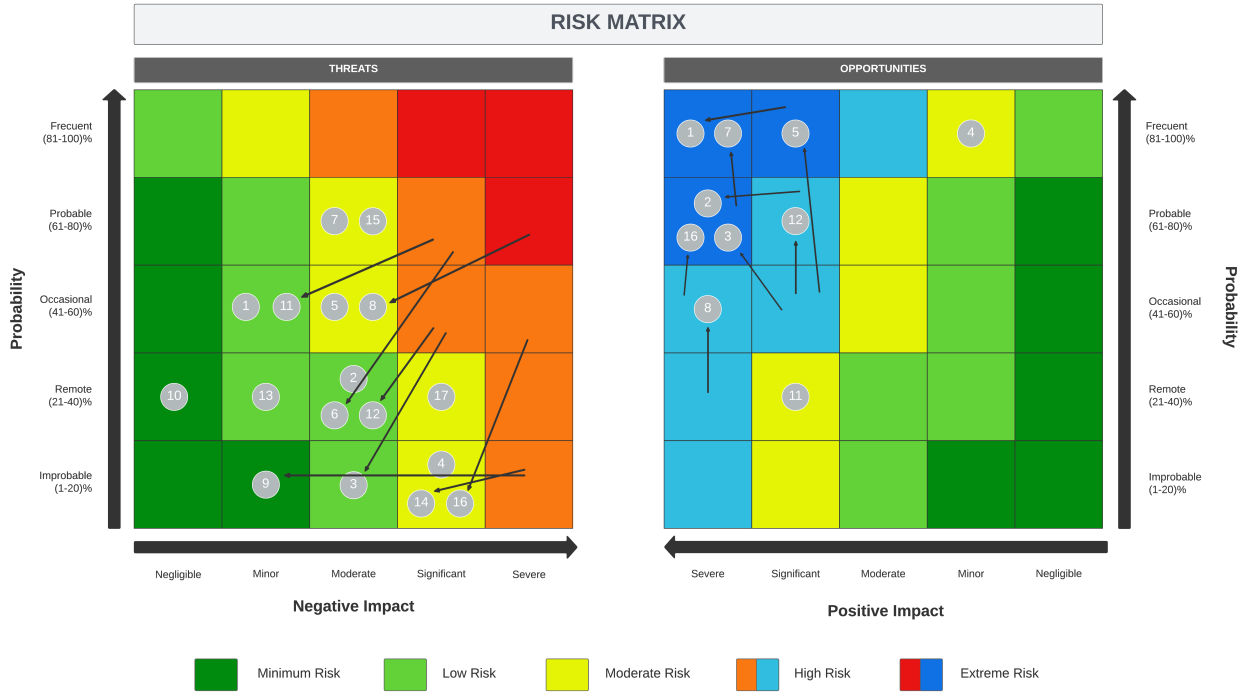

Figure 5.2: Re-assessed risk matrix for Virgin Galactic's Supersonic 2.0 business model

Figure 5.2 shows how the correct implementation of the risk response plan helps the company to significantly improve its risk matrix. On the one hand, threats previously situated in the high and extreme levels of the risk matrix are reallocated to the moderate risk level cells. As for opportunities, their probability and/or impact is increased following the action of the risk response plan, enabling them to move to the upper left positions of the risk matrix. Although these risks have not been completely eliminated, the risk re-assessment demonstrate that they no longer represent a danger or impediment to the correct functioning of the Supersonic 2.0 business model.

Chapter 6

Environmental impact

This section is intended to provide an overall assessment of the impact that the study carried out may have on environmental aspects. In the case of this project, it has focused on the study of the Virgin Galactic company and its business model for commercial supersonic passenger transport, the Supersonic 2.0 business model. Taking into account the various environmental risks that this business implicitly entails, and especially considering the current environmental situation of the planet, it is essential to evaluate the impact that the implementation of the Supersonic 2.0 business model, as well as that of its possible competitors, would have on the global health of the planet.

Virgin Galactic is committed to complying with all the rules and regulations to which the supersonic passenger business will be subject. In this regard, the company has established environmental sustainability at the core of the design of its supersonic aircraft, and has announced a collaboration with Rolls-Royce, a leader in cutting-edge technologies that provide clean and safe solutions to the planet's vital power needs, for the development of sustainable engine propulsion technology for the aircraft [27]. In addition, both companies aim for the aircraft to be capable of using state-of-the-art sustainable aviation fuel, thereby significantly reducing particulate emissions.

Emissions of particulate pollutants such as carbon dioxide and nitrogen oxide are at the center of the debate on the sustainability of the commercial supersonic transport business, as supersonic aircraft that continue to use hydrocarbon fuels are expected to consume more than current subsonic aircraft [40]. For this reason, and given that environmental standards and regulations are expected to be very stringent, it is imperative that companies seeking to enter the market are able to develop sustainable propulsion technologies for their high-speed aircraft. Moreover, the development and improvement of state-of-the-art sustainable fuels will be key to enabling these aircraft to operate in an environmentally friendly manner and in compliance with international regulatory agencies.

The other major environmental impact associated with commercial operations of supersonic and hypersonic aircraft is the sonic boom they create when transitioning from subsonic to supersonic flight [40]. These aircraft are expected to generate significant noise during acceleration and deceleration phases of the engines,

especially at takeoff. For this reason, the designs of such aircraft will have to be based on quiet propulsion technologies or be able to incorporate noise reduction systems. In this regard, Virgin Galactic and NASA are working together on the development of such technologies, which will benefit from the data collected by the U.S. agency's experimental supersonic supersonic silent aircraft, the X-59 QueSST. Since it is assumed that high-speed aircraft will have to operate at the same noise levels as subsonic aircraft, companies will have to work with the FAA and other regulatory agencies to ensure that their vehicles can meet acceptable levels of noise and sonic boom. Otherwise, these aircraft will face prohibitions on flying over continental areas, significantly reducing the number of viable routes that can be operated.

On the other hand, it is also important to consider the indirect impact that commercial supersonic transport operations may have. At present, most existing airport infrastructures would not be able to accommodate the technical and logistical needs of potential supersonic and hypersonic aircraft. For example, the runway lengths of most airports on the routes considered feasible would not be sufficient for the high speeds at which these aircraft would land. This could mean that, in order to be able to handle this type of operations, many of these airports would have to undergo major changes and extensions that could have a significant environmental impact on the area. In this regard, Virgin Galactic assures that its aircraft would be designed to perform horizontal takeoffs and landings like any other conventional aircraft, as well as to be able to integrate into existing airport infrastructures and international airspace, thus minimizing the indirect impact of its operations.

Chapter 7

Conclusions

Just 20 years ago the last supersonic aircraft to perform commercial operations, the Concorde, made its last flight. The extremely high operating and maintenance costs combined with a tragic accident in July 2000 left the supersonic travel market abandoned. Now, after a long period of time with no intention of recovering this service, numerous companies have decided to get back into the supersonic passenger transport business, with state-of-the-art designs that aim to provide safe, comfortable and clean supersonic travel. With their innovative proposals, all these companies hope to be able to lead the commercial supersonic transport market, which, while it is still re-emerging, is expected to experience significant growth in the next few decades. One of the companies that has decided to enter this market, Virgin Galactic, has been the subject of the comprehensive study carried out in this project, which has allowed to understand its operation and internal structure. This study, focused on Virgin Galactic's Supersonic 2.0 business model, has reviewed the main key aspects for the success of this business model, as well as the value propositions it can offer to make Virgin Galactic become a leader in the industry.

After reviewing the only two supersonic aircraft that came into commercial operation, as well as the technical and economic issues that forced them to withdraw from the market, an overview of the companies that are already at relatively advanced stages of their designs for high-speed aircraft has been given. With their designs, based on cutting-edge high-speed technologies, these companies expect to be able to solve many of the challenges experienced by their predecessors, as well as provide a great improvement in the customer experience and a reduction in the environmental impact. The main characteristics of these designs have been presented in a summary table, offering a general comparison that allows to observe the wide variety of solutions that the market will be able to count on. Even so, these companies and their respective designs will depend heavily on the successful development and implementation of technologies that, for the moment, are largely unproven.

Having presented and compared Virgin Galactic's main competitors in the market, the project has then focused on an in-depth case study of the company. A first overview of the company's history has allowed to see the most important milestones achieved by Virgin Galactic so far, which have been concentrated on the

space travel business and culminated in July 2021 when it became the world's first commercial spaceline. Subsequent chapters, focused on understanding the internal functioning of Virgin Galactic, clearly showed how the company's technological, human and financial resources are currently focused on the business of human space travel. In this sense, Virgin Galactic's ability to compete in the supersonic passenger transportation market will largely depend on the company's ability to leverage its existing high-speed technologies, as well as to adapt all its development, production and marketing activities. Thus, if the company is able to take advantage of its extensive set of integrated aerospace development capabilities, as well as its position in the Virgin group's portfolio, it could gain numerous advantages over its potential competitors in the market.

In order to obtain a better understanding of the Supersonic 2. 0 business model, it has been conducted a detailed study of the business model using the Canvas format, a very useful tool within business management that divides the business model into nine fundamental building blocks. The correct analysis of these building blocks has led to the composition of the Businesss Model Canvas, which allows to clearly identify the main strengths on which the company expects to base the operation of its business model, permitting at the same time the extraction of the main value propositions that Virgin Galactic is intended to offer to its clients. The study has also led to the identification of a defined segment of customers, based on first and business class passengers for whom the demand is predicted to continue growing at a great rate during the coming years. In addition, it has been noted the crucial role of Virgin Galactic's partners in delivering the value proposition, as all of them will be essential in the proper development and implementation of supersonic technologies capable of powering, in a safe and sustainable manner, high-speed commercial travel.

Finally, an analysis of the risks to which the business model could be exposed has been carried out. As it has been noted, although a correct response plan can mitigate most of the risks, the supersonic passenger transport business and the advanced technologies it requires carry many inherent risks that cannot be ignored. These new, highly sophisticated and complex technologies will require numerous and rigorous tests to prove their reliability and demonstrate they can comply with the multiple regulations to which the business is subject, since a single mistake, whether technological or human, could lead to the loss of many human lives. Especially for this reason, most companies are still far from being able to commercially implement their designs, and they will still require a lot of time and resources to demonstrate to regulatory agencies and their future consumers the safety, reliability and sustainability of their vehicles.

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