Department of Economics and Finance

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The evolution of the space sector: an insight into the new trends and business opportunities

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INTRODUCTION

The space sector has been subject to major changes during the last 20 years. Comprehending all the activities and resources related to space, that create a value to human beings, and their impacts on economy and society, the so called "space economy" is influenced by different geopolitics and market forces, which are typical of such an ever-evolving environment. Reaching also other industrial sectors, it is subsequently subject to general macro-trends, that lead to considerably wider economic and societal impacts and justify the noteworthy government spending on it. In fact, the space is evolving from a strategic and pioneering environment, whose aspects are mainly scientific and technological, to an industry with an increasing economic value. As this sector becomes a business worth more than $300 billion, the features of this environment shift towards a decentralization known as the "new space".

The purpose of this thesis is to analyze the evolution of the space sector, focusing firstly on the legacy space business and the ways in which it evolves into the new space, and afterwards, on the subsequent changes affecting the investors and the typologies of investments comprising space.

In the first chapter, an in-depth analysis has been conducted regarding the global space economy and how it is structured. Dividing it into two main categories, the non-satellite industry and the satellite industry, it can be shown how the space sector impacts not only space-related products, belonging to the "core" space industry, but also a wide range of products and services not strictly connected to it, such as contents of telecommunication. Regarding the actors playing a major role in this environment, the supply of the space sector is considered fragmented as the eight main players in the field absorb more or less 30% of the overall demand. US players represent the majority among the Top 10 because of the dimension of their institutional captive market, which is almost four times bigger than Europe's. Nevertheless, the scenario is changing. The entrance of private actors, such as SpaceX and tens of start-ups, is eroding both the public monopoly and the well-established oligopoly of traditional space companies. It can be seen, at the end of the chapter, how the space industry is consequently moving towards new business strategies, digital transformation and miniaturization of satellites, along with re-usability, with the ultimate goal of reducing the cost to access to space.

In the second chapter, the focus is on the magnitude of investments directed towards the space sector, and the various typologies of investors contributing to the development of this industry. As new investors continue to enter the market, a total of five typologies have been identified, each one corresponding to a specific role as a funding source, preferred funding instrument and the purposes of such investment. The five categories are the following: angel investors, who are wealthy individuals and families that invest large amounts of money in ventures during their early stages, with aim of obtaining high returns; venture capital firms, which consist of various investors who focus their investments on companies at their early stage, start-ups or growth companies; private equity firms, which focus their investments on already established

companies; corporations, which usually invest capital internally, focusing on the research and development department, manufacturing, operations and all the remaining areas of a company, that can contribute to the exploitation of an existing strength or the creation of a new one; and banks, not the most typical investors in start-ups, however they have financed and supported the programs of large-size and well-established firms in the space sector in the last 20 years. In the same timeframe, the start-up space has attracted $27.8 billion in investments, which can be divided into six main categories: seed funding, venture capital, private equity, acquisition, public offering and debt financing.

The third chapter is entirely dedicated to SpaceX, the space company founded in 2002 by Elon Musk, which designs, manufactures and launches rockets and spacecrafts, with the aim of reducing the cost to access to space, and is now valued at $36 billion. What can be deducted from its achievements is that SpaceX is looking at the bigger picture, focusing on the re-usability of its space vehicles to make humanity multiplanetary, by building a totally independent city on Mars. In fact, in the last period of time, SpaceX has revolutionized the supply chain of the space industry by internalizing several operations that were traditionally outsourced. Moreover, what Elon Musk has done, through SpaceX, is to revolutionize the mindset of the space sector, based on the belief that hardware should be expensive and robust, by showing to the legacy companies that commercial products are nowadays more advanced with respect to the military and traditional space equivalents.

Chapter One

The space industry: an overview

1.1 Global space economy and market segments

"The Space Economy is the full range of activities and the use of resources that creates and provides value and benefits to human beings in the course of exploring, understanding, managing and utilizing space… It follows that the Space Economy goes well beyond the space sector itself, since it also comprises the increasingly pervasive and continually changing impacts (both quantitative and qualitative) of space-derived products, services and knowledge on economy and society"[1].

Therefore, the Space Economy is characterized by various aspects and driven by many different but related geopolitics and market forces that go beyond simple market dynamics. The following are the main domains of the space sector, which are influenced by a diverse range of trends and located in a policy and regulatory environment in constant evolution:

- Access to space
- Satellite services
- In-orbit economy
- Exploitation and science
- Space situational awareness

As mentioned above, the Space Economy reaches also other industrial sectors. A consequence of such linkage is the subsequent influence of general macro-trends, which leads to considerably wider economic and societal impacts and justify the noteworthy government spending on it.

In fact, the Space is evolving from a strategic and pioneering environment, whose aspects are mainly scientific and technological, to an industry with an increasing economic value.

The Global Space Economy was worth around $360 billion as far as 2018, a value which can be divided into two main categories. On one hand, a portion intended to the non-satellite industry, which amounts to $82.5 billion and is dedicated to government space budgets and commercial human spaceflight. On the other hand, $277.4 billion invested in the satellite industry, which constitute 77% of the Space Economy. The Satellite industry can be further divided into the following sections (Figure 1):

- Satellite Ground Equipment, $125.2 billion:
    - Network Equipment (gateways, network operations centers, satellite news gathering equipment, etc.)
    - Consumer Equipment (Sat TV, Radio, Broadband and Mobile Equipment)

[1] OECD Handbook on Measuring the Space Economy 2012

    - GNSS Chipsets and Navigation Devices
- Launch Industry, $4.6 billion
- Satellite Manufacturing, $15.5 billion
- Commercial Remote Sensing, $2.1 billion
- Broadband, $2.4 billion
- MSS, $4.1 billion
- Satellite Radio, $5.8 billion
- FSS, $17.9 billion
- Television, $94.2 billion

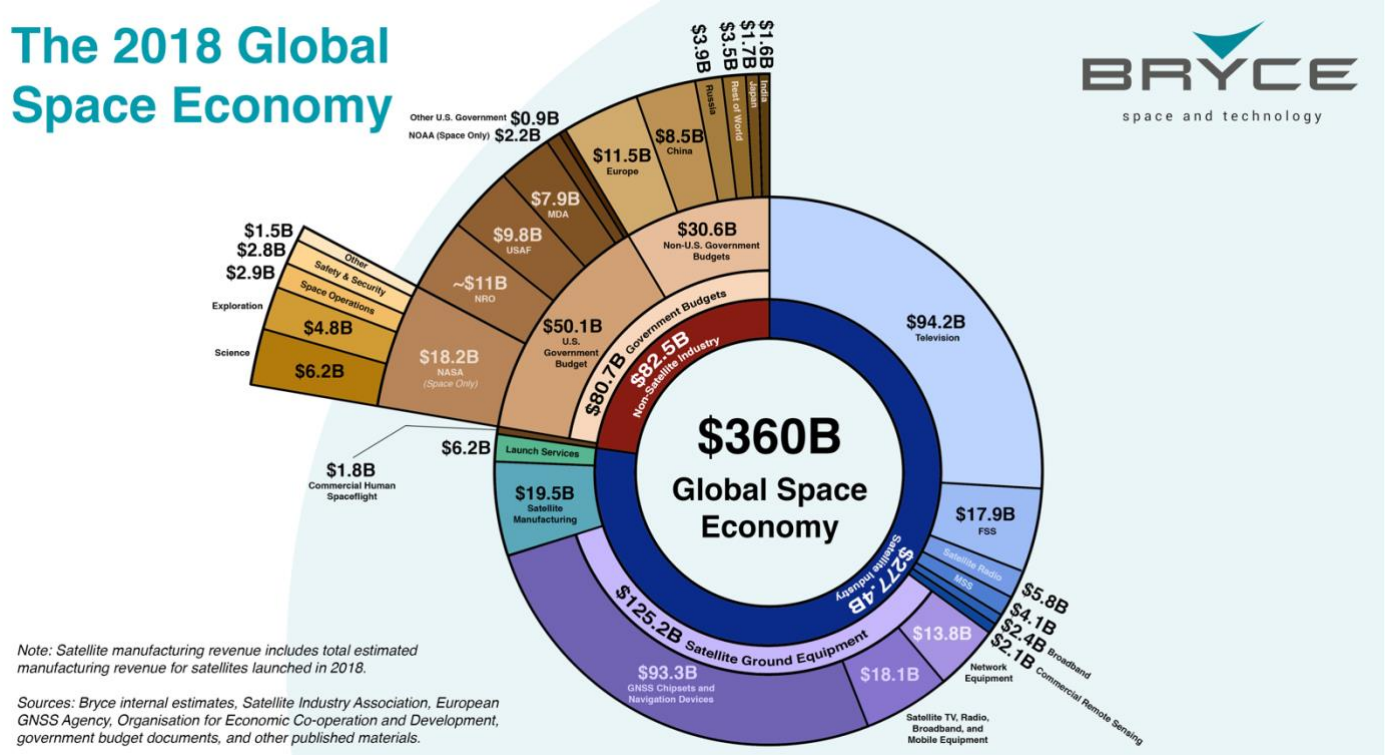

Figure 1. The Global Space Economy according to the 2018 Bryce Start-Up Space Report.

Taking into account the previous definition of Global Space Economy, it can be stated that it includes all activities, products and services not strictly related to the core space sector: equipment for activities related to telecommunications, contents of telecommunication, etc. Indeed, the "core" space industry (refer to the value chain shown in the Value Chain table, Paragraph 2) is worth around $95-100 billion, based on 2017 estimates, and it is structured as follows:

- Commercial
    - Services 25%
    - Manufacturing 5%
- Institutional Military
    - Services 7%
    - Manufacturing 19%

- Institutional Civil
    - Services 8%
    - Manufacturing 36%

To summarize, 70% of the "core" space industry is dedicated to institutional services and manufacturing, while an overall 60% is focused on manufacturing.

The United States of America represent the major producers and consumers of the space sector since the US Government invested $50 billion in 2018, of which $18 billion were spent by NASA. The US are followed by Europe, the second largest space consumer ($11.5 billion), China and Russia.

The previously mentioned US leadership in the space sector is confirmed when analyzing the "core" industry in geographic terms. North America leads the market with 43% (although it is low compared to 75% in the early 2000's), having an institutional investment equal to $35 billion that supports a strong domestic manufacturing market. Moreover, the US Department of Defense represents the 66% of the world's military space expenditures, being the single largest investor worldwide in space technology. Japan and Russia are together the second largest military spenders. Brazil and Russia are both undertaking strong programs to restore their space leadership, while new players are emerging with a lower entry level, such as South Korea, Turkey, Israeli, Thailand, South Africa and Vietnam. Regarding Europe, the national priorities are confirmed in parallel with the growing European Space Agency and the European Commission.

1.2 Space industry – The value chain

Figure 2. The value chain of the "core" space industry players. Source: estimates gathered for thesis purpose.

With regard to the value chain of the "core" space industry players, it includes all the activities which provide services while generating value and it can be divided into three main categories.

Systems/Infrastructures Development, which is the upstream, comprehends manufacturing, the engineering aspect of the earth segment, the construction of the station, the antenna and the control rooms. This sector of the value chain can be further divided into three sub-categories:

- The definition of the mission consists in determining the entire process and is considered a fundamental step of the value chain as it shows the overall structure of each operation.
- Satellites (development and realization) includes all the manufacturing activities of the space segment.

- Earth segment (development and realization) focuses on constantly monitoring satellites to ensure the right implementation of the mission.

Operations is the mid-stream and includes launch services, which are considered a business per se, and the TT&C (Telemetry, Tracking and Command), which controls the functionality of the satellite.
The Downstream is about applications and services and is divided as follows:

- Networks and platforms, which allow players to gather information and provide services.
- Applications and services / SatCom, Geoinformation and Navigation

Players can operate in one of the above-mentioned categories, while big players are usually vertically integrated, comprehending the entire value chain expect for the launch segment.
Nowadays, the Space is experiencing both a revenue and mindshare growth, as well as increasing implications in multiple downstream industries.

1.3 Space players

The supply of the space sector is considered fragmented as the eight main players in the field absorb more or less 30% of the overall demand.
US players represent the majority among the Top 10 because of the dimension of their institutional captive market, almost four times bigger than Europe's. The US space sector is considered a captive market due to a low level of competition combined with a high level of prices. In this type of market, the suppliers can autonomously set a price that maximizes profits, while consumers can only decide whether to buy products at this price or not.
Regarding Europe, Airbus D&S is a vertically integrated player which comprehends the main space activities operating in Germany, UK, Spain and part of France, while Space Alliance covers the entire value chain thanks to two joint ventures with industrial assets and operative activities in Italy, France, Germany, Spain, Belgium, UK, Brazil, Argentine and Romania.
As for the launch business, it is dominated by eleven players, mainly from US and Russia, and is highly differentiated on the basis of their level of integration.

The main space players are the following:

- Lockheed Martin is an American company organized on four business segments:
    - Aeronautics
    - Rotary and mission systems
    - Space
    - Missile and fire control

  Space is a business unit that provided to the company more or less 20% of 2018 revenues and has a workforce of nearly 20,000 employees. It is organized in different business lines:

    - Commercial satellites
    - Government satellites
    - Space transportation systems
    - Strategic missile and missile defense systems
    - AWE Management Limited

It owns six satellite buses, six manned aircrafts and three launchers.

- Airbus is a global leader in aeronautics, space and related services. The Company is organized in three program lines:
    - Airbus Commercial Aircraft
    - Airbus Helicopters
    - Airbus Defense and Space (ADS), which includes all Space related activities and Unmanned Aerial Systems, covering more or less 20% of 2018 revenues.

The Company has a workforce dedicated to Defense and Space of nearly 30,000 employees, along with 20 satellites, 7 teleports and 20 facilities.

- Northrop Grumman is an American company structured as follows:
    - Aerospace systems
    - Mission systems
    - Technology services
    - Innovation systems

The Aerospace Systems can be divided into three main business areas: Autonomous Systems, Manned Aircraft and Space.

Focusing on the Space sector, it includes spacecraft systems, subsystems, sensors and communications payloads, that generated $4 billion in revenues in 2018. It comprehends Civil Systems, such as NASA, Military Systems and National Systems, along with numerous assets, such as 7 satellite buses, 13 manned aircrafts and 29 defense systems.

- Boeing is an American company organized on four reportable segments:
    - Commercial airplanes
    - Defense, Space and Security
    - Global services
    - Boeing Capital

It has a workforce dedicated to Defense, Space and Security of nearly 40,000 employees, generating 20% of 2018 revenues. This Business Unit is organized in eight divisions:

    - Autonomous Systems
    - Commercial Derivative Aircraft
    - Global Operations
    - Missiles and weapons systems

    - Phantom works
    - Space and launch
    - Strike, surveillance and mobility
    - Vertical lift

It owns as assets four satellites, nine manned aircrafts and three launchers.

- Space Alliance is a European company formed through a joint venture between two leaders, Thales Alenia Space and Telespazio, which generated revenues as high as $3 billion in 2018. It is organized based on six distinct product fields and a full vertical market integration:
    - Telecommunications both for civil and military use
    - Earth observation
    - Navigation
    - Science and exploration
    - Orbital infrastructure/transportation
    - Satellite operations and control
- Maxar Technologies is an American provider of solutions in Earth intelligence and space infrastructure, which can be divided into three segments:
    - Space Systems
    - Imagery
    - Services

It owns five satellites and 29 facilities, generating around $2 billion in revenues in 2018.

- Thales Group, which is part of the Space Alliance, is organized on six global business units:
    - Avionics
    - Defense Mission systems
    - Digital identity and security
    - Ground transportation systems
    - Land and air systems
    - Secure communications and information systems
    - Space

The Aerospace business, which includes the Space business unit, generated 40% of total sales in 2018.

- Leonardo is an Italian company which owns 33% of Thales Alenia Space and is organized on five main business units:
    - Helicopters
    - Aeronautics
    - Electronics, defense and security systems
    - Space
    - Others

Leonardo Space Line of Business has been a leading player in the space market for over forty years and is involved in the most important European and Italian space programs, while supplying equipment and payloads to the European space agency, the Italian space agency and NASA.

- OHB is a German company which can be divided into two business units:
    - Space systems (80% of 2018 revenues)
        - Small satellites
        - Manned space flight
        - Exploration segment
        - Reconnaissance satellites and broadband radio transmission of image data
    - Aerospace and industrial products
        - Ariane rocket program
        - Aviation and defense products
        - Mechatronic systems for antennas and telescopes

The company owns eight satellite buses and 20 facilities, generating $1 billion in revenues in 2018.

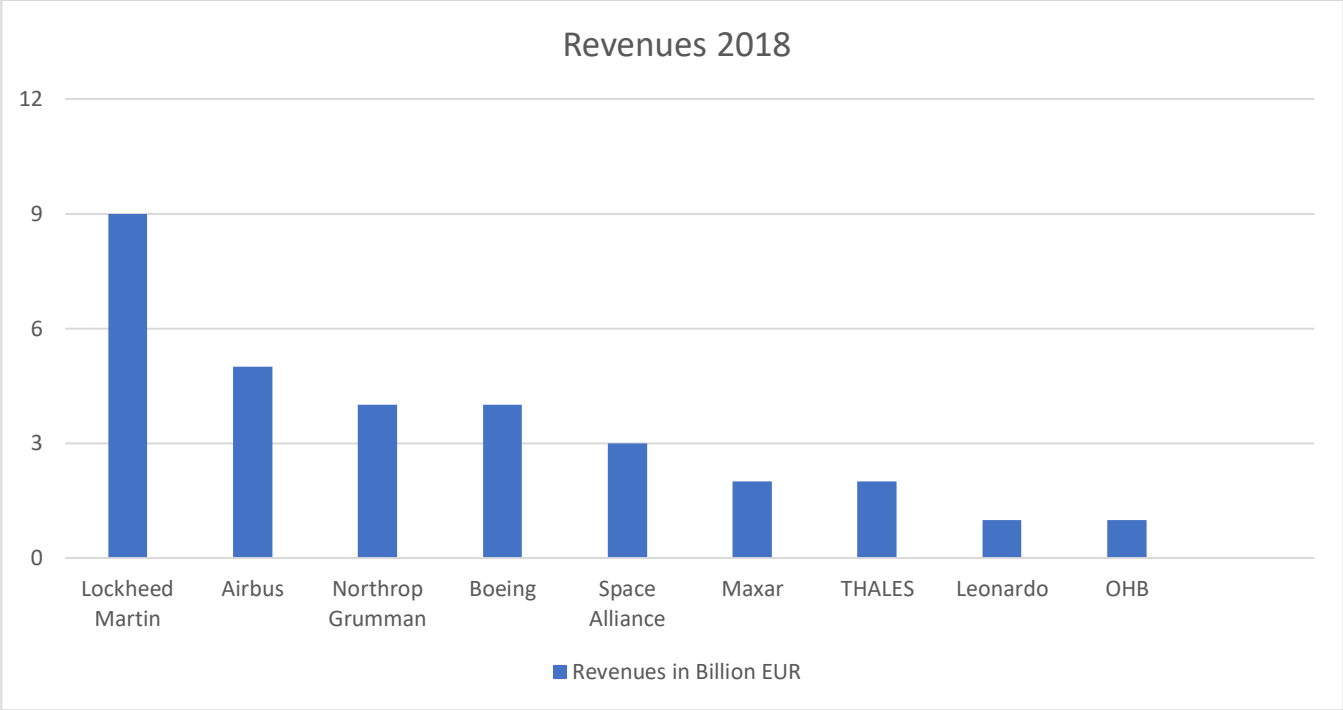

Figure 3. Revenues in Billion EUR of the nine most relevant players in the field. Source: Estimates gathered for thesis purpose.

1.4 Main space programs

- The International Space Station represents the greatest international project ever, which consists in a partnership among ESA (Europe), NASA (United States), Roscosmos (Russia), JAXA (Japan) and CSA (Canada). The ISS is considered the largest artificial object in space being a modular space station, which means a habitable artificial satellite, located in the Low Earth orbit. It is used for scientific

experiments in several fields, such as meteorology, physics and astronomy, although it is suited also for long-duration missions to the Moon and Mars.

- Copernicus is a program managed by the European Commission in partnership with the Member States, ESA and EU agencies with the aim of improving Europe's life quality. It provides information services through satellite Earth Observation and non-space data. This information is also used to deal, among other things, with climate change and civil security issues and is available for free to all its users and the public.
- Galileo was created in 2016 by the European Union as a Global Satellite Navigation System (GNSS) with the aim of providing a high-precision positioning system, along with horizontal and vertical position measurements, within one-meter precision. The basic services of the project are available free of charge to the public, while the other more sophisticated services are used by paying commercial users. The reason why Galileo was created is the need for Europe to gain independence from the U.S. GPS or the Russian GLONASS systems.

1.5 From the "legacy" space business to the "new space"

Over the years, the space sector has been mainly based on government or institutional budgets and the number of relevant players has been relatively low. Among the countries operating in the space sector, the United States have been the most powerful players followed by Europe, although the second one is characterized by fragmented budgets and players. The main goal of traditional space programs has always had an intrinsic value of public utility, such as environmental monitoring, response to natural disasters and so on, justifying the amount of institutional investment dedicated to them.
In the meantime, the space has become a significant business now worth more than $300 billion, which is a significant increase from its value in 2005 (less than $200 billion). Furthermore, the entrance of innovative aerospace companies, such as SpaceX ($21 billion in revenues), Orbital ATK ($7.8 billion) and tens of startups ($2.8 billion of overall financing in 2016), has led to this decentralization called "new space".
It consists in the emergence of private actors eroding both the public monopoly and the well-established oligopoly of traditional space companies. It is considered not only a new generation of companies or a steady increase in revenues, but also a new approach in which private firms share both the high risks and the potential returns on investment in space. For example, regarding the access to space and the launch services, the key innovation has been to make NASA a client and a partner of its private contractors, rather than a supervisor. In this scenario, investors are accustomed to take risks, and firms are given the freedom and responsibility to design and produce their systems in the most appropriate way, meeting the requirements of both NASA and the market while keeping the intellectual property of the products to themselves. The subsequent advantage of NASA and the Pentagon is to obtain the required services at a lower cost: in fact, putting into orbit a kilogram of cargo for the International Space Station now costs only $89,000 with

SpaceX, rather than $272,000 using the Space Shuttle (a low Earth orbital spacecraft operated by NASA). Another consequence of the entrance of private companies in the launch sector is the reuse of launchers achieved by Elon Musk, the founder of SpaceX, which leads to a further commercialization of space.

To summarize, in the last twenty years the space industry has witnessed a series of relevant changes, which are the following:

- Traditional systems have become more flexible as new business models and functions appear over time, such as the increasing number of new LEO systems and constellations.
- New missions and initiatives have emerged with the aim of providing new infrastructures and services.
- Private investment has increased substantially up to around $1.7 billion per year in the time period 2012-2017.
- Space infrastructure has partially commoditized as the new business models become sustainable and competition increases.
- Global consumer players (GAFA), such as Facebook, have developed innovative global connectivity concepts based on different technologies, including space.

The key trends driving the New Space sectorial dynamic are the following:

- The increasing vertical integration towards the upstream sector (platforms and services) and the rapid expansion of emerging markets.
- New policies based on market creation, such as the space tourism.
- New business strategies based on innovative approaches with the aim of disrupting existing markets, addressing new mass markets and creating new production and development methods of space systems.
- The optimization of industrial organization through risk sharing with private players and new procurement schemes that seek cost effectiveness, by moving from long-term returns on large investments to rapid renewal.
- New entrants, such as entrepreneurs and non-space companies, who challenge the traditional space players. The focus shifts to the commercial value of the sector, as space is considered an instrument to provide services and information.

Thus, the New Space brings along the establishment of new players and ventures, different from the ones mentioned in the previous sections and mostly US-backed:

- Communications : SpaceX, OneWeb, LeoSat, Sirion, Astroscale, Hiber, etc…
- Earth observation: Perseus, Skybox Imaging, Planets Labs, Hera Systems, etc…
- Suborbital \ technological test and tourism: ZeroGravity, Up Aerospace, Virgin Galactic, etc…
- Access to space: SpaceX, Blue Origin, Generation Orbit, Swiss Space Systems, etc…

These new players are only a small part of the impressive number of new ventures established in these fields, along with other areas such as In-space operation, Human spaceflight, Science and others.
Indeed, commercial players are already playing an important role in space exploration and exploitation, attracting capital. Private ventures are leveraging technology spillovers towards low-earth orbit economy, while government agencies and banks are focusing on innovative ways to finance risky, long-term return endeavors.

Digital Transformation is another relevant factor which is heavily impacting the space sector. Nowadays, the latter can be thought of as a single digital "ecosystem" including space and non-space-based systems, networks and platforms. As a consequence of these blurred boundaries, the space sector is no longer a closed market and all its data are stored on cloud, always available to the users.
Therefore, as Space increasingly becomes of interest to other sectors, new players enter the market crowding orbits. In fact, it can be shown that over 1,000 smallsats were launched during the period 2012-2018, of which launches in 2018 were six times higher than at the beginning of the period.

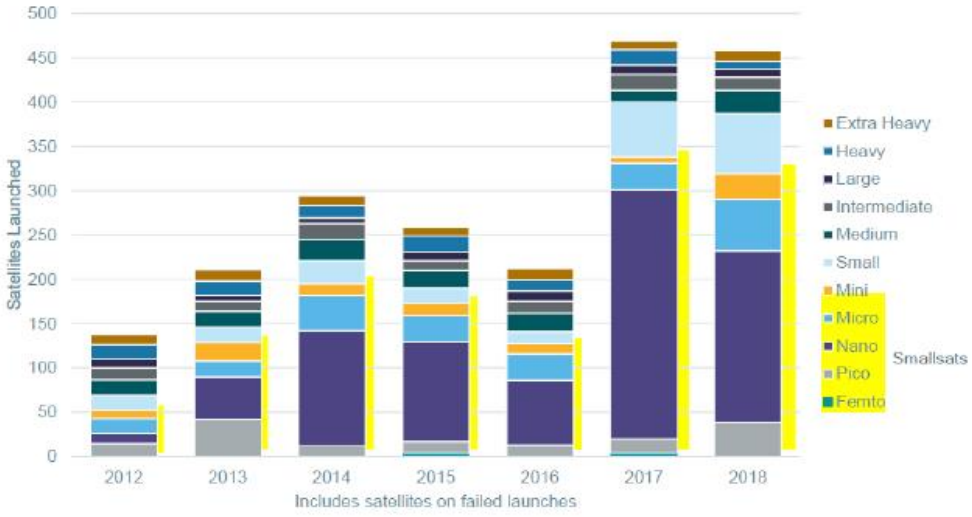

Figure 4. Satellites launched over a time period of seven years, based on their size. Source: Data gathered for thesis purpose.

In fact, the miniaturization of satellites plays an important role in the Space crowding. The CubeSats are cube-shaped satellite buses weighting 1-2 kilograms, which can be piled to meet the needs of a mission. The basic nano satellite costs $10,000, meaning one unit will cost $100,000 per year including payload development, allowing different types of entrants to own one. There exist several trends around the development of new ways to reduce the cost to access to space, and companies react to an increasing competition by lowering the development, manufacturing and operation costs to reach a competitive price. This goal can be achieved also by developing fully reusable launchers or modular launch systems, which acquire economies of scale by using each component on different launcher families.

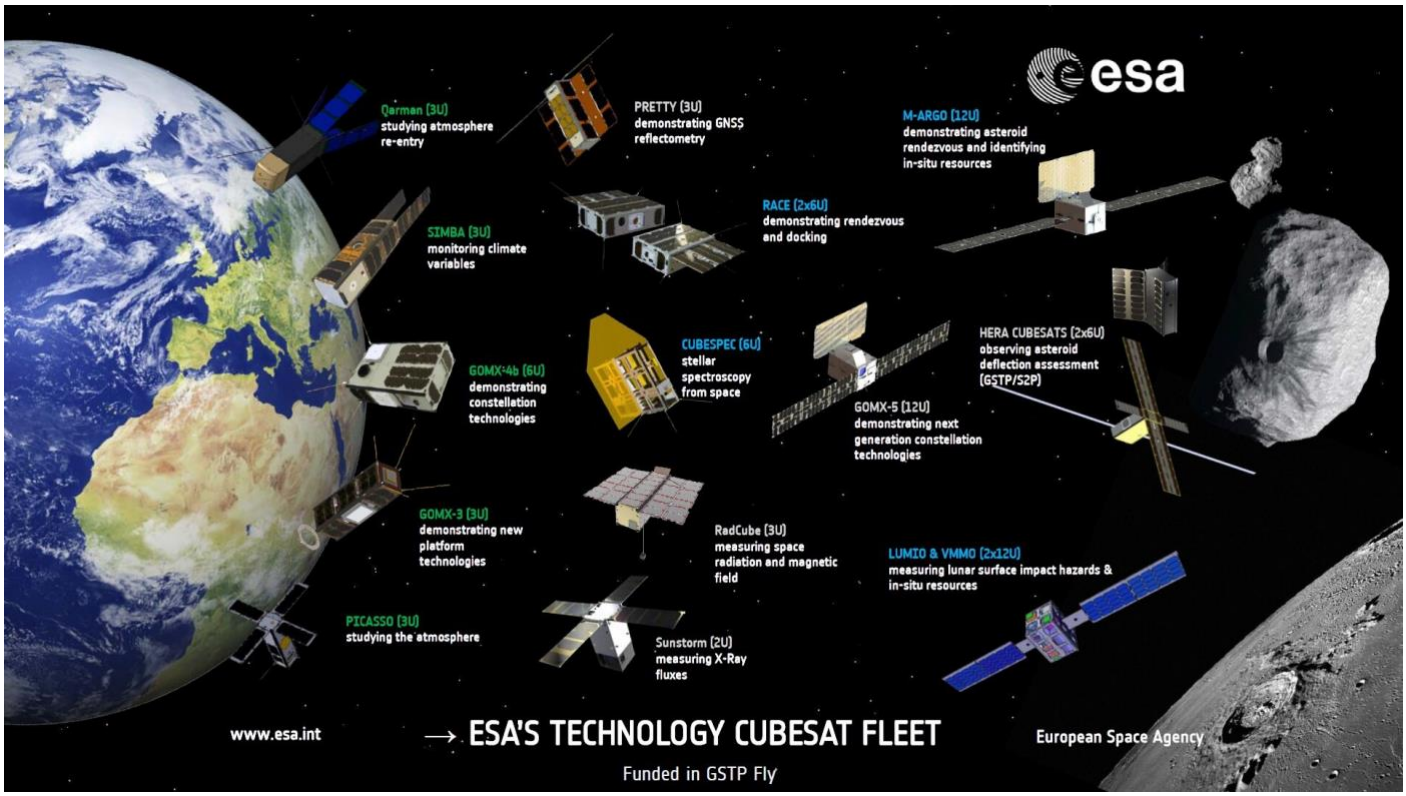

Figure 5. ESA's Technology CubeSats. Source: ESA

Chapter Two

The Start-Up Space: Space investment in the 21st century and Investment Trends

2.1 Introduction

Over the last twenty years, the Start-up space has experienced a steady growth driven by the increasing number of investors, putting large amounts of money in more ventures, and the growing presence of non-US start-ups, obtaining funds. In fact, the year 2019 saw a record-breaking $5.7 billion financing in start-up ventures, which was by far higher than the $3.5 billion record of 2018.
The number of funded start-up space ventures in 2019 (135) has increased by 34% from 2018, investors by 46% up to 328 and deals by 36% up to 150, leading to overall investment of $1.8 billion in 2019, without considering giants such as SpaceX, OneWeb, Virgin Galactic and Blue Origin. Another noteworthy trend of this environment has been the increasingly relevant role of government stakeholders in the success of venture-funded start-ups, as firms has started to consider the government as a potential customer. Although this period reached a record-breaking level of investments in space start-ups, many of them have not yet demonstrated profitability and sustainability.

Over 310 new angel- and venture-backed space companies have been founded and funded in the period from 2000 to 2019. In the early 2000s, an average of four funded space companies were started per year; today the figure is nearly eight times higher. (In the last five years, the number of funded new companies has averaged 29 per year.) That average excludes new firms that have not yet secured investment.

New investors continue to enter the ecosystem: 127 venture capital firms, 38 angel investors, and 29 corporations invested in start-up space ventures for the first time in 2019. Notable entities like Boeing, C5 Capital, Echostar, Lockheed Martin, Goldman Sachs, Planet, and Softbank invested in or acquired start-up space companies in 2019. The profile of investment in start-up space companies has diversified substantially over the last 20 years. From 2000 to 2004, the number of investors per year averaged only 8, but by the end of 2009, the average number had increased to 16. The average number of investors then more than tripled to 53 in 2010–2014. Since 2014, this figure has quadrupled, reaching an average of 212 investors in 2015-2019. This represents a nearly twenty-six-fold increase from the first period to the fourth.

Analyzing the 20-year divided into sub-periods consisting of five years:

- 2000-2004 recorded an annual average of four venture capital firms, two corporations, only one angel investor and two private equity firms financing the start-up space;
- 2005-2009 an annual average of eight venture capital firms, three angels, one bank and two corporations;

- 2010-2014 an annual average of twenty-three venture capital firms, seventeen angels, five corporations and three private equity firms;
- 2015-2019 an annual average of 122 venture capital firms, thirty-three angels, six banks, ten private equity firms and forty corporations.

Focusing on the last five years, the annual average of 40 corporations is the result of an initial decrease from 46 in 2017 to 42 in 2018 followed by an increase in 2019 to 50 corporations investing in start-up space companies (of which only 19 are U.S.-based). Regarding banks, they emerged significantly in 2010-2011 due to deals for O3b and Ligado Networks. However, in 2019 their presence was relevant as a record-breaking total of 14 banks invested in the space sector. Analyzing the geographic trend of investors during the last 20 years, 52% of the total are non-U.S. based as the number of international investors increase. Regarding the United States, they host 461 investors.

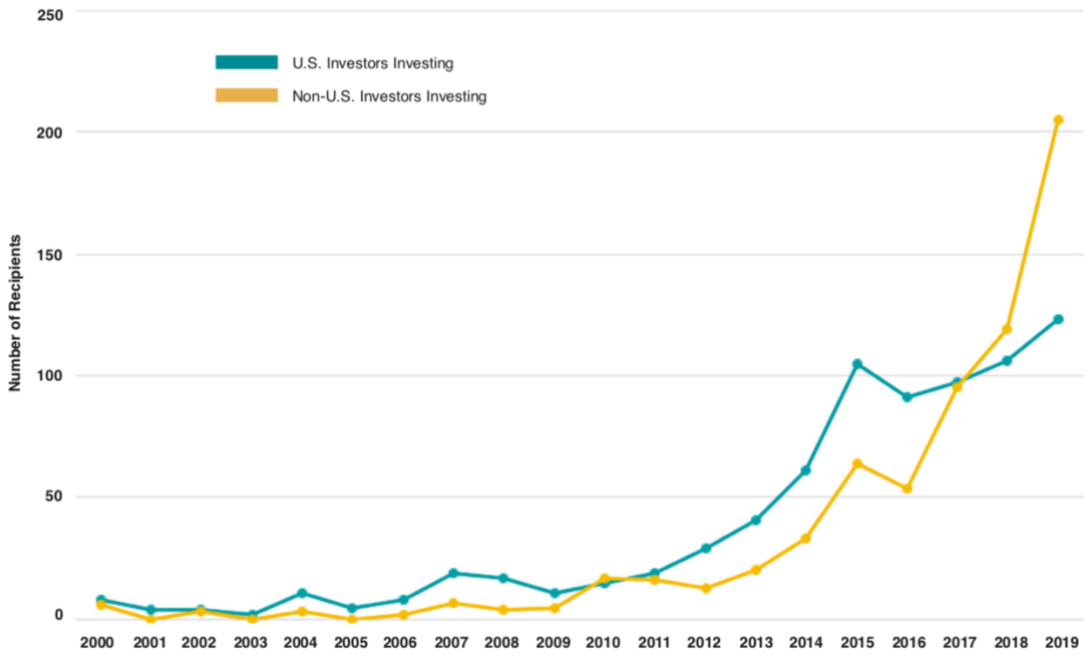

Figure 6. Number of U.S. versus non-U.S. investors (Source: Bryce Report "Start-Up Space", 2020).

2.2 Space Investors' Typologies

Space companies can be defined as business entities that provide products and services related to space, such as the manufacturing of a satellite or a service based on data gathered from space and terrestrial systems. If a space company receives and reports seed funding or venture capital, then it is considered a start-up venture.

The majority of start-up space firms are located in the United States and amount to 180 companies, which means they account for 55% of the currently existing 330. Only California by itself hosts 71 companies, representing 39% of the U.S. total and 22% of the global total. During the last three years, U.S. start-ups has prevailed in start-up space, including 80% of total investment in that period.

Regarding non-U.S. start-up space companies, there exist 150 firms located in the rest of the globe, of which 31 are headquartered in China, more or less 21% of the non-U.S. total. The United Kingdom comes after China, hosting 24 space start-ups, and is followed by Canada (10), Japan (8), India (8), Singapore (7) and Israel (7). In 2019, the number of non-U.S. space companies receiving investment increased from 47 in the previous year to 79, exceeding for the first time the number of U.S. companies and making up nearly 60% of the total number. In addition, also the number of non-U.S. investors increased to 63% of all investors from 53% in the previous year. China also hosts 21% of the total 506 investors based outside of the United States, followed by Japan, the United Kingdom, India, Canada, Israel, Spain and Australia.

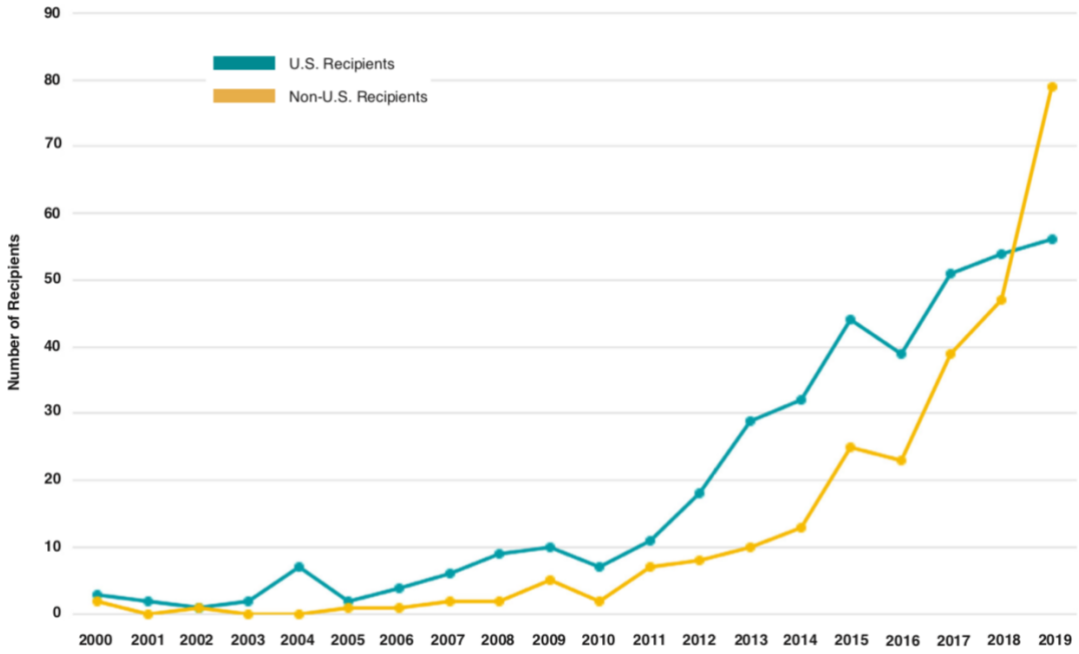

Figure 7. Number of U.S. versus non-U.S. investment recipients (Source: Bryce Report "Start-Up Space", 2020).

In 2019, there has been identified a total of 967 investors in start-up space, a 38% increase from 2018, even though the number is expected to be much higher taking into account undisclosed investors. These investors can be divided into five main categories based on their role as a funding source, their preferred funding instrument and the purposes of their investment. Considering these factors, in the last 20 years venture capital firms have represented the largest number of investors, followed by angel investors, making up together nearly 73% of the total investors in start-up space. The remaining 28% includes corporations, private equity, firms and banks.

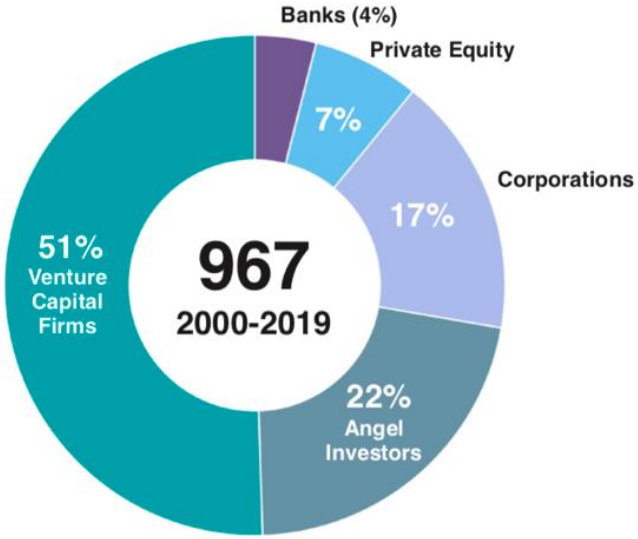

Figure 8. By number of investors, venture capital firms are the largest investor group for space start-ups (Source: Bryce Report "Start-Up Space", 2020).

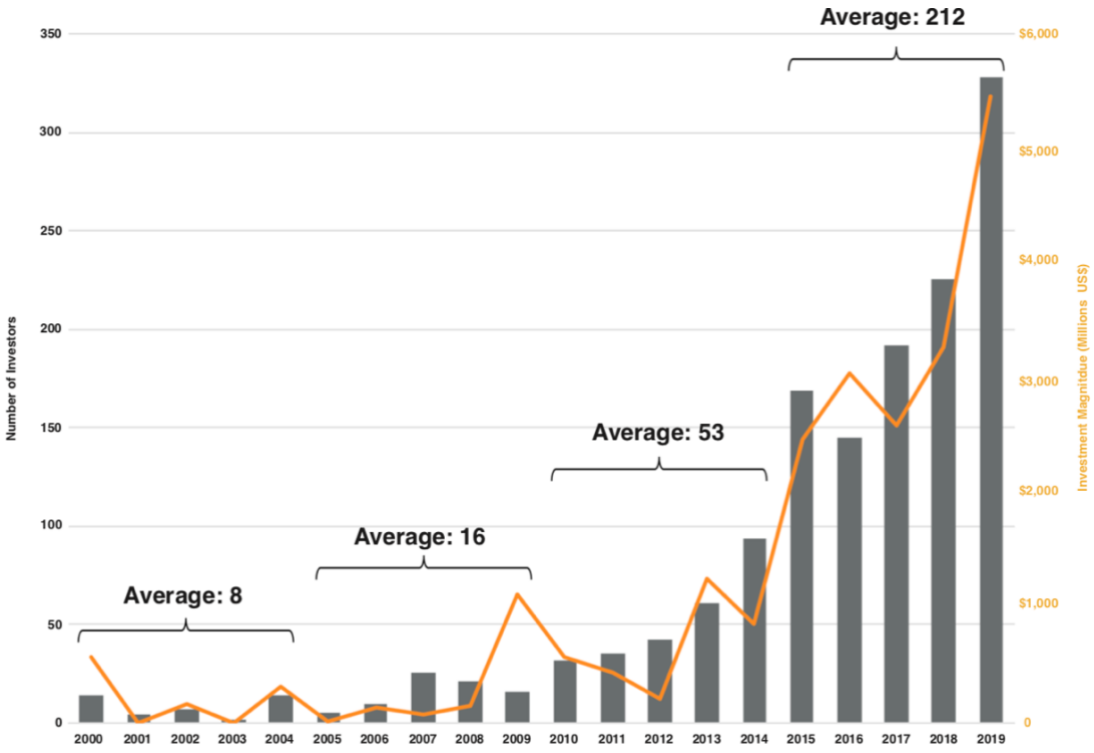

Figure 9. The average number of space investors per year has grown from 8 to 212, looking at five-year periods (Source: Bryce Report "Start-Up Space", 2020).

2.2.1 Angel Investors

Angel investors are wealthy individuals and families that invest large amounts of money in ventures during their early stages with aim of obtaining high returns. The reason why angel investors focus their investments on the stage of development of a venture's product or service is the consequent potential return. In fact, by investing at the beginning of the process, this kind of investor establishes himself in the company and can expect in the future an equity stake as high as 30-40% in return for his early investment. In this scenario,

angel investors can exit the company, realizing their return, in about 5-7 years from the date of their initial investment. The latter usually comprises straight equity into the company, ranging from $50,000 to more than $1 million.

Moreover, angel investors can share the risk of financing different start-ups by combining their resources with those of other angels and venture capital firms. In this way, they can fund more ventures and invest more money without facing the corresponding high risks. The most active group of angels is called Space Angels and is located in New York City. It comprises 250 accredited angel investors from around the world and finances a large number of space start-ups at their early stage through an online investment platform. However, it is not possible to determine the exact number of angel investors worldwide, as a great amount of investments are not publicly declared.

A relevant sub-category of angel investors is the one including billionaires and individuals with a much higher level of wealth, who seek potential high returns along with the technological and scientific progress by investing in new space start-up ventures. Because of their high status in the society achieved from their success in other businesses, space billionaires can provide a financing as high as $100+ million. An example of a super-angel investor is Jeff Bezos, founder of Amazon, who entered the space sector by founding also the space company Blue Origin. As Bezos, also Elon Musk of PayPal founded SpaceX, while Mark Zuckerberg, Bill Gates and Richard Branson are among those considered super-angel investors.

Moving back to typical angel investors, this category also comprises accelerators and incubators which invest in the start-up space while providing services, such as mentoring, at the early stage of a venture.

Regarding the activity of this kind of investors, it has experienced an increase in the number of reported angel investments from an average of one in early 2000s to a record 47 in 2019.
The majority of these reported angel investors is located in the United States, which host 60% of the global total, confirming again the predominance of California (30%). About the remaining non-U.S. angel investors, 20% are based in India, another 20% in the United Kingdom and a further 20% in Japan, while the remainder across 16 other countries.

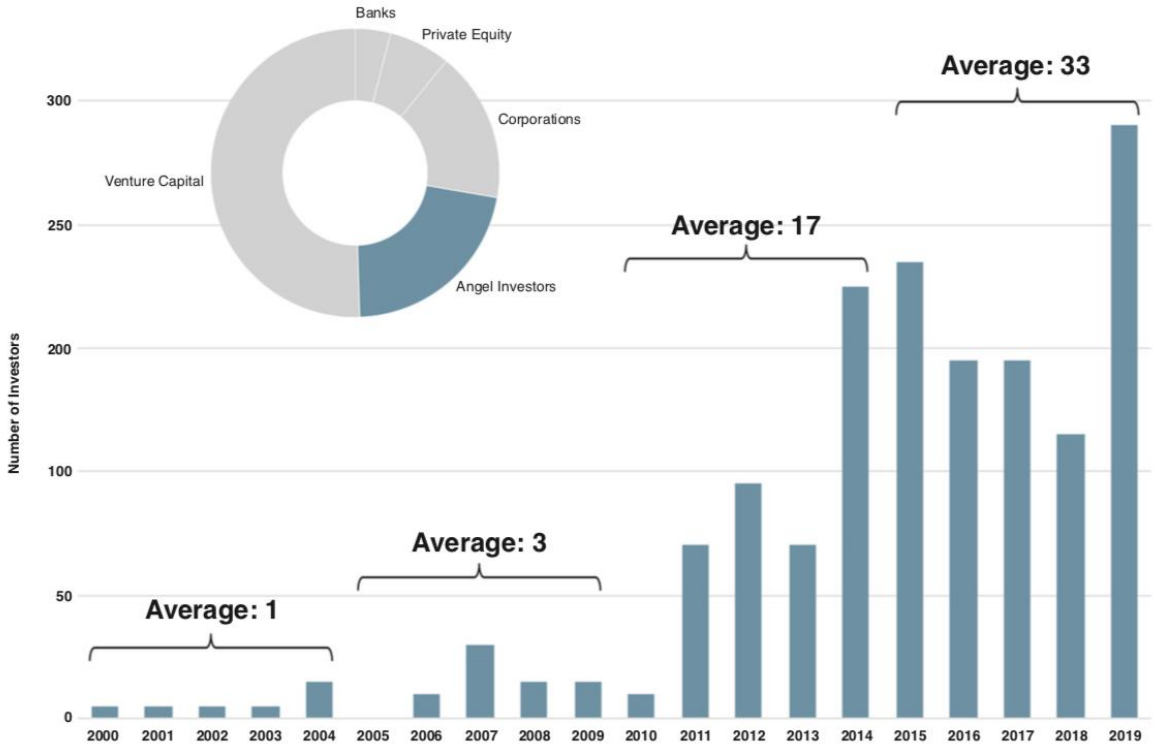

Figure 10. Considering multi-year periods, angel investor activity has increased (Source: Bryce Report "Start-Up Space", 2020).

2.2.2 Venture Capital Firms

Venture capital firms consist of various investors who focus their investments on companies at their early stage, start-ups or growth companies. Even though they choose their recipients on the basis of 'how much they will grow in the future', the high level of risk associated with this kind of investment mostly leads to failure. VC firms operate their financing in the form of equity through different stages denominated as Series A, Series B, etc. Usually a Series A investment is around $2 million up to $10 million, while a Series B ranges from $10 million to $50 million. However, this kind of funding is evolving towards a single continuous investment trend by a group of investors rather than rounds. Because of their use of preferred stock, these firms can expect an equity ownership stake at a higher priority with respect to other investors, such as angels. However, they still have a lower preference compared to any holders of company debt. In the case of exit due to an initial public offering (IPO) or the sale of a company, then these preferred shares can be transformed into common stock.

Over the last 20-year period, 500 venture capital firms focused their investments on the start-up space. Among them, 127 new ones were reported from 2018 to 2019 investing in start-up space companies for the first time. In fact, in the period from 2015 to 2019 the average number of venture capital firms per year increased by a factor of more than five. They usually invest in syndicates, where their resources are pulled together with those of other VCs, angels, private equity firms and banks. An example of venture capital firms that directed part of its funds to the space sector is Seraphim Capital. The latter created the Seraphim Space Fund in 2016, which is entirely focused on the development of space technology and comprises more

than $100 million. Its large group of investors includes Telespazio, Airbus, the British Business Bank, the ESA and SES. Moreover, along with this category of investors, also governments and sovereign wealth funds have started to invest in the start-up space.

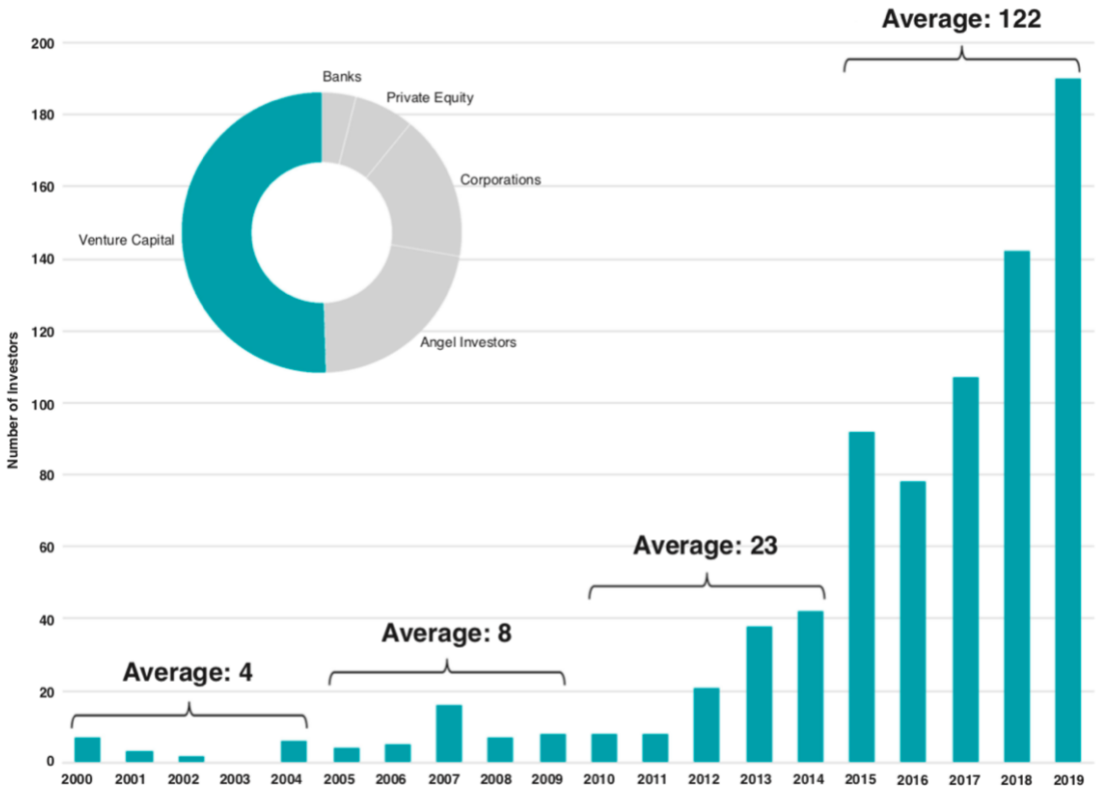

Figure 11. More venture capital firms have invested in start-up space in recent years (Source: Bryce Report "Start-Up Space", 2020).

Regarding the positioning of VC firms around the world, there exist 247 in the United States, of which a half is located in California. Non-U.S. venture capital firms total 242, being almost equal to the U.S.-based ones, and are spread over 34 different countries.

2.2.3 Private Equity Firms

Private equity firms do not focus their investments on start-ups but rather on already established companies. The funding is operated by this kind of investors even though the money actually comes from a limited partnership with other investors. They usually invest large amounts of money directly into the companies, acquiring either one or a group of them that can merge. The financing involved comprises capital commitments made by these investors, that can be pension funds, wealth funds or family offices. The latter can represent the resources of an individual or a group of individuals considered wealthy.

Over the last 15 years, large-size private equity firms have directed their investments towards the space sector, investing $100 million and more in companies used for debt reconstructing and leveraged buyouts, such as large commercial satellite operators. In fact, around this period, 67 private equity firms have focused

their investments on the start-up space. By the way, in the past years, this kind of investor distinguished himself by investing in ventures at their early- and mid-stage, which is far from the typical type of financing of private equity firms. This trend can be explained as the boundaries dividing private equity and venture capital financing are blurring over time. This happens in part because of the constant technological progress that characterizes the space sector.

Only last year, the number of PE firms operating no private equity rounds doubled to 25 from 2018. While less than 30% of these PE firms in the space sector are based in the United States, especially in New York and California, the remainder is distributed across 15 countries, prevalently in China and the United Kingdom.

2.2.4 Corporations

Corporations usually invest capital internally, focusing on the research and development department, manufacturing, operations and all the remaining areas of a company that can contribute to the exploitation of an existing strength or the creation of a new one. Moreover, this kind of investors can fund ventures with the aim of supporting their space-based programs. In this scenario, corporations' investments come often in the form of straight equity or debt, which can be later on transformed into equity of the recipients' company. Another way of investing is through a corporate venture fund, which is equivalent to company-owned venture capital, such as Lockheed Martin Ventures.

Over the last twenty years, 113 start-up space companies have received financing from corporations interested in contributing to the development of innovations in the space sector. For instance, in 2015 Google invested $900 million in the space company SpaceX. The average number of investors per year was as low as two back in 2004, slowly rising to five at the end of 2014. However, in the last three years the average was forty, showing an increasing attractiveness of the space sector. In fact, there has been 184 deals since early the 2000s, of which 16% regarded acquisitions of established companies and ventures. Only during last year, these investors acquired six start-up ventures for approximately $106 million. Among the corporations financing space start-ups, only 30% are space companies while the remaining 70% (114) are non-space companies.

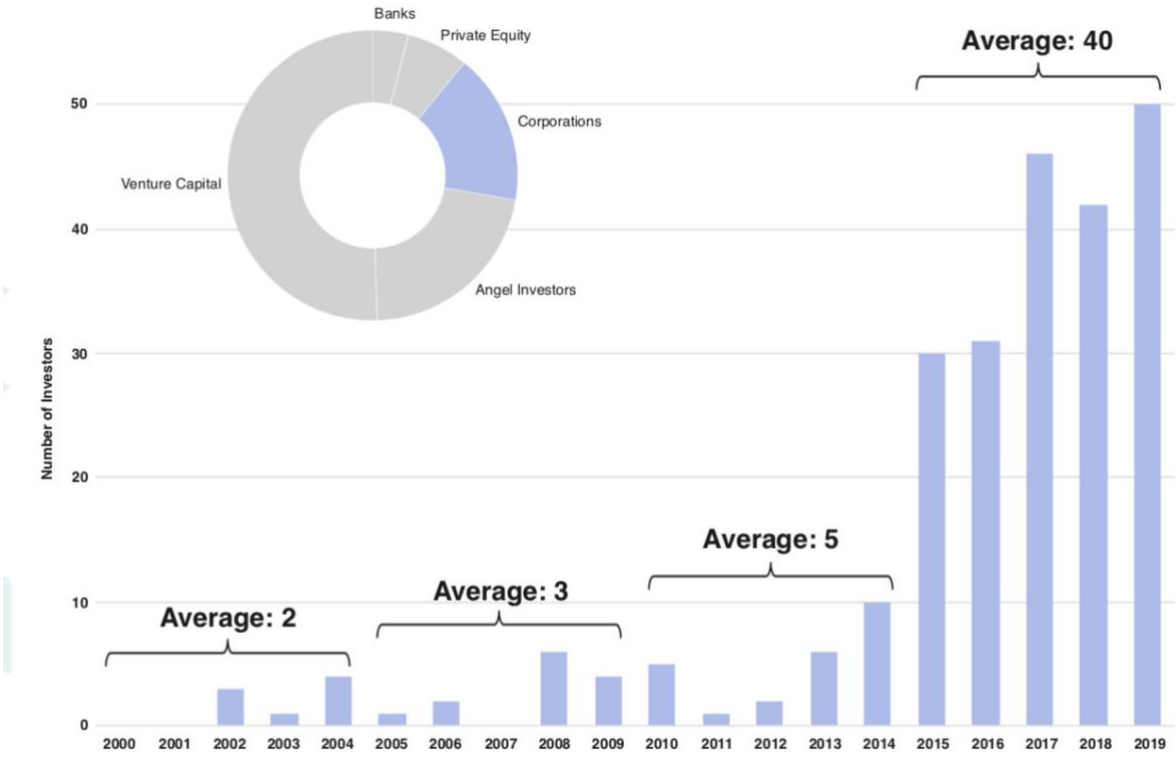

Figure 12. The number of corporations investing in start-up space ventures has surged since 2014 (Source: Bryce Report "Start-Up Space", 2020).

Regarding their location, 38% of the corporations funding the start-up space are based in the United States as California alone hosts 12% of the global total. About the remainder, they are spread over 22 different countries. For example, japan is home to 33% of non-U.S. investors, followed by China and the United Kingdom both hosting 10%, Spain and Canada.

2.2.5 Banks

Even though banks are not the most typical investors in start-ups, in the last 20 years they have financed and supported the programs of large-size and well-established firms in the space sector. In fact, last year the number of banks financing the start-up space reached its highest value as 14 banks provided funds. Their investments consist in financing a part of the total expenditure expected for a specific program, which usually equals 30% of the total or the required CapEx. The remaining capital is then obtained in the form of debt that can be also partially or totally transformed into an equity stake of the investee company if necessary.

In the previously mentioned period, commercial banks from around the world have provided debt financing ranging from $100 million to more than $1 billion per program to companies requiring large satellite CapEx. These banks, such as Citibank, Wells Fargo and Deutsche Bank, support companies as Intelsat and Inmarsat, which need different GEO satellites for their programs, each one costing more or less $275 million to be

build and launched. Moreover, there exist companies like GlobalStar, which involves around $2.5 billion CapEx requirements for LEO satellite constellations.

Furthermore, government-backed banks, such as U.S. Export-Import Bank, support through debt financing space companies with the aim of benefiting national businesses.

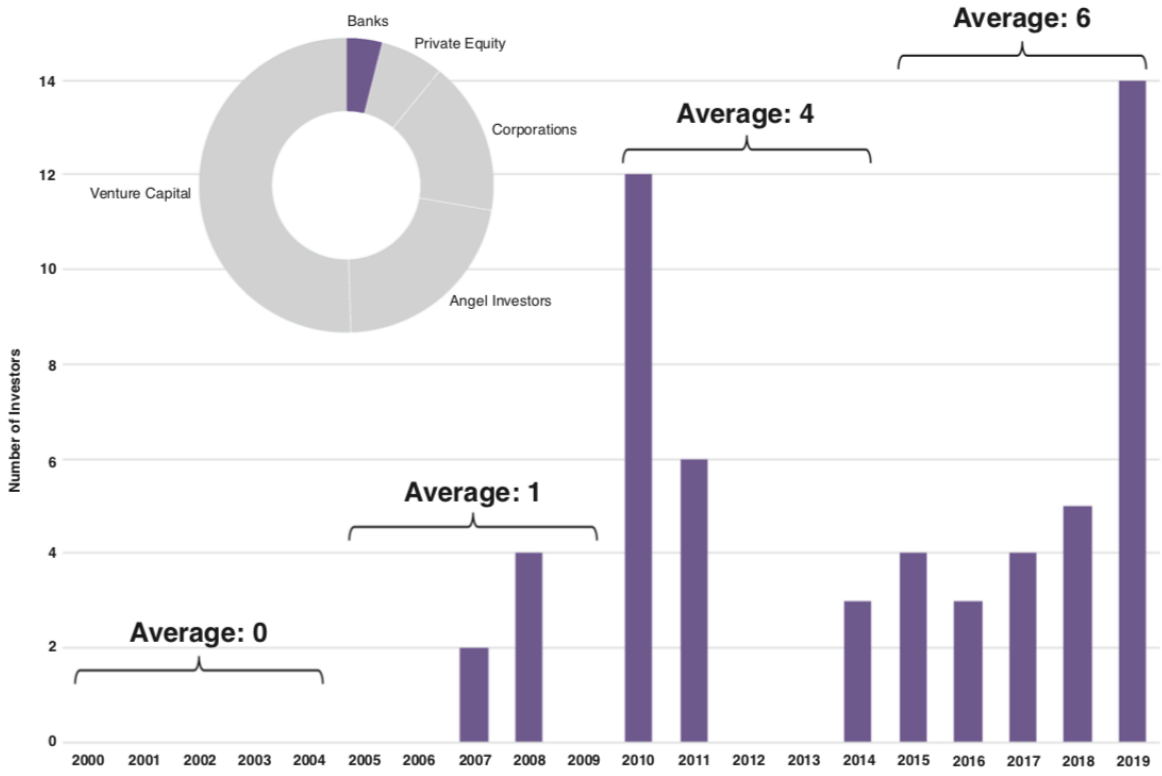

Figure 13. Banks financing start-up space ventures peaked in 2010 and 2011, coinciding with the peak in debt financing during the study period (Source: Bryce Report "Start-Up Space", 2020).

2.2.6 Public Markets

Over the years, there exists the possibility for a space company to sell its equity to the public or the chance for an initial public offering. Even though IPOs are not typical of this kind of sector, they are useful in raising capital to support previous series of financing or to enable investors to sell their equity shares in the public marketplace as an exit for their early investments.

The volume of space-related initial public offerings ranges from $100 million, such as GlobalStar, to nearly $800 million, such as Intelsat. Regarding secondary IPOs, they are also used to collect more capital to finance expenditures related, for example, to operations. Boeing and Lockheed Martin are perfect examples of established space companies trading publicly following their initial public offerings. Another instance is Virgin Galactic, which merged with a special purpose acquisition company called Social Capital Hedosophia in 2019, collecting $500 million in venture capital.

2.3 Typologies of investments

Over the last twenty years, the start-up space has attracted $27.8 billion in investments. However, more than a half of the overall financing has been recorded in the last five years, of which around $18 billion (80%) were seed and venture capital. Moving back to the previously mentioned total investments, they can be classified as follows:

- $12.5 billion directed to early and late stage venture capital;
- $5.1 billion in debt financing;
- $4.6 billion of seed financing;
- $3.8 billion invested in mergers, acquisitions and public offerings;
- $1.8 billion in the form of private equity.

Investment Type	2000-2004 (millions)	2005-2009 (millions)	2010-2014 (millions)	2015-2019 (millions)	Total 2000-2019 (millions)
Seed/Prize/Grant	$640.1	$111.6	$307.4	$3,590.0	$4,649.4
Venture Capital	$189.2	$253.5	$689.1	$11,356.1	$12,487.9
Private Equity	$232.8	$542.7	$777.3	$228.0	$1,780.9
Acquisition	$0.0	$584.0	$1,566.5	$1,637.7	$3,788.2
Public Offering	$0.0	$10.0	$9.3	$25.0	$44.3
Total Investment	$1,062.2	$1,501.9	$3,349.9	$16,836.8	$22,750.9
Debt Financing	$0.0	$1,530.1	$2,680.5	$887.9	$5,098.5
Total with Debt	$1,062.2	$3,032.0	$6,030.4	$17,724.8	$27,849.5

Figure 14. The magnitude of investments varies based on investment type and time period (Source: Bryce Report "Start-Up Space", 2020).

Focusing only on 2019, the year experienced a record-breaking overall amount of investments in start-up space ventures equal to $5.7 billion, nearly $2 billion more with respect to 2018. In fact, last year recorded eleven deals out of the overall 150, exceeding $100 million, as the number of deals increased by 36% in a year. The major investment of the year was made into OneWeb and was equal to $1.25 billion. It was followed by a $1 billion investment by Jeff Bezos in Blue Origin and three late-stage financing in SpaceX, amounting to $200 million each. Last but not least, also the space company Virgin Galactic collected $682 million as seed and venture capital.

Investment Type	2017 (millions)	Change	2018 (millions)	Change	2019 (millions)
Seed/Prize/Grant	$563.17	77%	$998.66	31%	$1,308.83
Venture Capital	$1,674.17	24%	$2,073.07	95%	$4,043.68
Private Equity	$0.0	--	$85	-100%	$0.0
Acquisition	$360	-72%	$100	6%	$106
Public Offering	$0.0	--	$11	-100%	$0.0
Total Investment	$2,597.34	26%	$3,267.73	67%	$5,458.51
Debt Financing	$4.97	5,273%	$267.07	-9%	$242.31
Total with Debt	$2,602.31	36%	$3,534.81	61%	$5,700.82

Figure 15. Total 2019 start-up space investment increased about 61% (Source: Bryce Report "Start-Up Space", 2020).

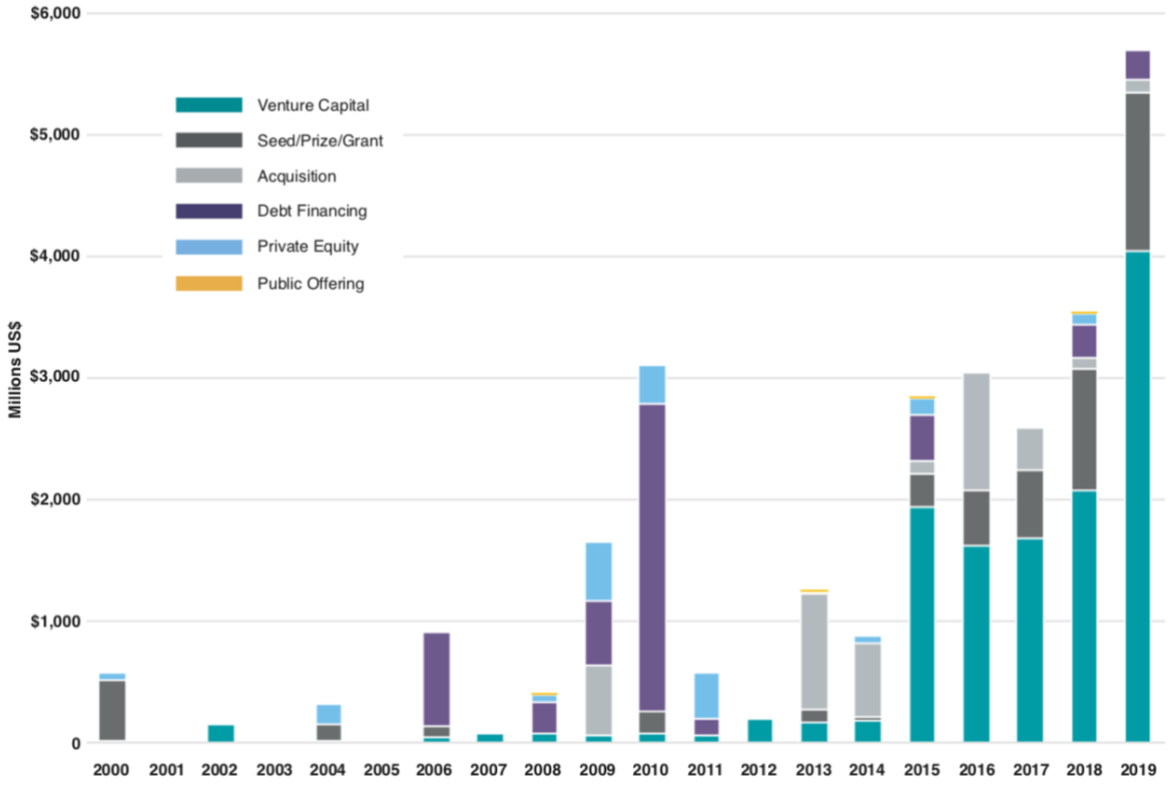

Figure 16. The mix of types of investment in space companies varies from 2000 to 2019 (Source: Bryce Report "Start-Up Space", 2020).

Regarding the number of investors participating in 2019, it grew by 46% to 328 from the 225 investors present in 2018, while the number of space start-ups funded in 2019 reached 135 from the 101 recorded in the previous year.

Since early 2000s, the types of investment mostly used per year changed over time. Seed funding is a category of investment which can be identified throughout the 20-year period, even though it always remained at a lower level with respect to others. Its highest peak was reached when the billionaire Jeff Bezos

invested in Blue Origin. Focusing on the middle years, debt financing emerged prominently along with private equity, while venture capital increased only recently.

In the same period of time, four space companies received investments higher than $1 billion. Reconsidering seed funding by Jeff Bezos in Blue Origin, it is estimated to be higher than $3.4 billion. Moreover, SpaceX received more than $3.4 billion from investors such as Google; OneWeb attracted $3 billion from SoftBank and others; Virgin Galactic received $1.5 billion in the form of seed funding, private equity and venture capital series; lastly, $1 billion were invested in SpaceX.

Taking into account only start-up space venture based outside the United States, in the last year $901 million were invested altogether, showing a 27% higher value with respect to 2018. Of this total, $691 million were seed and venture funding and more than a half was aimed at China and Singapore.

2.3.1 Seed Funding

In the considered timeframe, seed funding totals $4.6 billion. In the last year, this type of investment grew by 31% from $999 million to $1.3 billion, mainly due to super-angel investors providing seed financing to space companies. In fact, the largest amounts of seed funding of this period comprise the overall $3.4 billion invested by Jeff Bezos in Blue Origin. Along with the billionaire founder of Amazon, also Elon Musk contributed with an early investment of $100 million in SpaceX (in 2006), while Virgin Galactic received seed funding equal to $157 million from Richard Branson and Robert Bigelow invested $250 million in Bigelow Aerospace (both in 2019).

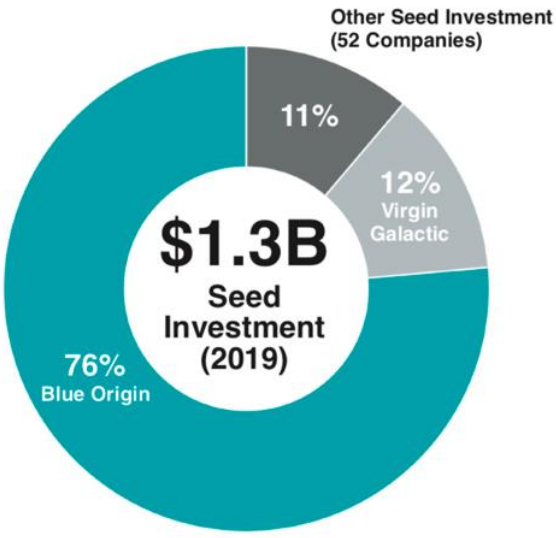

Figure 17. Blue Origin and Virgin Galactic comprise 88% of seed investment in 2019 (Source: Bryce Report "Start-Up Space", 2020).

Taking into consideration investments different from those of super-angels, overall investments in 2019 totaled $146.4 million, experiencing an increase equal to 615% from $20.4 million in 2015. Focusing on the

average investment per seed deal, it has increased by 324% from the $600,000 in 2015, however it later slightly decreased in 2019, being equal to $2.7 million compared to the $3.4 million of 2018. Regarding deals, they doubled from 2018 to last year, reaching a total of 55 seed deals, while their average size lowered by 32% from $34 million in 2018 to $23 million in 2019.

The trend of regular seed funding can be summarized as follows:

- $8 million in the period 2000-2004;
- $2.3 million in the period 2005-2009;
- $25.5 million in the period 2010-2014;
- $79 million in the period 2015-2019.

This upward trend is accompanied by an increasing average number of angels, which quadrupled in the first half of the period, before increasing furthermore in the second half as it tripled.

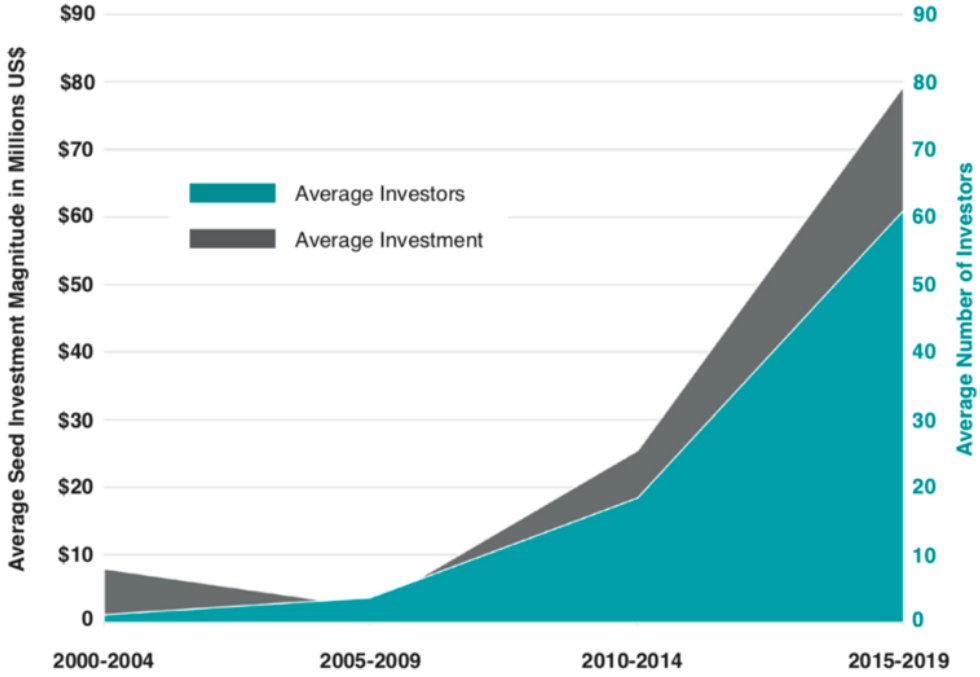

Figure 18. The yearly average magnitude of seed investment and average number of seed investors are trending up (Source: Bryce Report "Start-Up Space", 2020).

2.3.2 Venture Capital

Over la last twenty years, there has been a total of $12.5 billion of venture capital invested in 184 start-up space ventures. As for other types of investments, also venture capital was mainly concentrated in the last five years, a timeframe in which 91% of total investment happened. Regarding the number of venture capital firms investing in start-up space ventures, it grew by 34% from 142 in 2018 to 190 in 2019. Among these 190, only 63 were firms that have already financed the start-up space, while the remaining 127 appeared for

the first time in this scenario last year. In fact, even though the global total of venture capital investments registered a fall equal to 9% from 2018 to $108 billion in 2019, this type of financing in the start-up space experienced an increase equal to nearly $2 billion in the same year. This upward trend can be also noticed in the number of start-ups attracting venture capital investments, as it grew from 66 in 2018 to a record 75 in 2019.

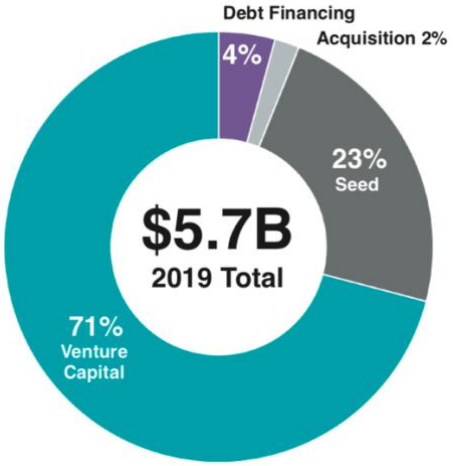

Figure 19. Venture capital accounted for 71% of investment in 2019 (Source: Bryce Report "Start-Up Space", 2020).

In addition, also the number of venture deals increased steadily, growing by 15% from 2018 and reaching a record-breaking total of 78 deals last year, of which 66 were early-stage financing. The average deal in 2019 amounted to $14 million, lower with respect to an average of $17 million in previous year. However, not taking into consideration deals comprising more than $100 million, it has been recorded a fall equal to $50 million from 2018 to 2019, bringing total venture capital investment to $950 million. Regarding venture capital mega-deals, last year experienced a record global total of 213 deals exceeding $100 million, compared to the 194 identified in 2018. Focusing on the space sector, eight venture mega-deals were identified, bringing the total average up to $51.8 million in 2019 and showing a relevant increase from the average of $30.5 million in 2018. However, since 2015 more than a half of the total venture capital investments were directed to two space companies: SpaceX and OneWeb. Indeed, the largest venture financing of the last 20 years comprised $900 million Series E in 2015, and $1.2 billion undisclosed round and $1.25 billion Series D in OneWeb respectively in 2015 and 2019.

2.3.3 Private Equity

Since early 2000s, private equity investments have reached a total value of $1.8 billion. However, in the last five years this type of investment in start-up space was disclosed to the public only in 2018, while the year after did not record publicly disclosed private equity financing.

Therefore, the largest private equity funding of the 20-year period were Virgin Galactic's 2009 investment by Aabar Investments equal to $380 million, along with another $110 million financing in 2011, and O3b's $230 million investment in 2010 from numerous investors, such as Google and HSBC Holdings.

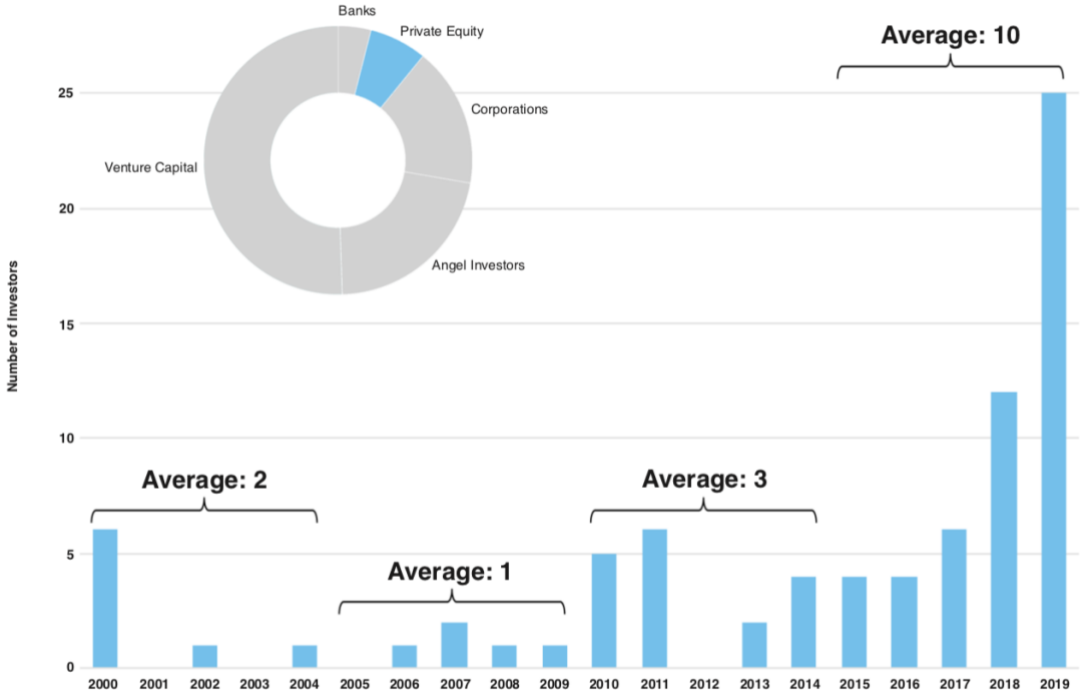

Figure 20. Private equity investment activity is variable over the study period, looking at multi-year periods (Source: Bryce Report "Start-Up Space", 2020).

2.3.4 Acquisition

Over the last 20 years, it has been recorded a total of 300 space companies attracting venture capital investments or financing from angel investors, of which 30 have been acquired. The total value of acquisitions in this period equals $3.8 billion, even though 40% of the overall acquisitions of start-up space ventures have happened in the last four years, being as high as $1.5 billion.

Examples of acquisitions occurred in the past 20 years are the following:

- Apple acquired Mapsense in 2015 for $25 million;
- Uber acquired deCarta in 2015 for an undisclosed amount;
- SES acquired O3b in 2016 for $730 million;
- Spaceflight Industries acquired OpenWhere in 2016 for an undisclosed amount;
- Social Capital Hedosophia acquired Virgin Galactic in 2019 while funding from the merger ($500 million).

2.3.5 Public Offering

Being considered a rare event, only a few start-up space companies are traded publicly on the marketplace, which are the following:

- UrtheCast;
- exactEarth;
- Satrec Initiave;
- Kleos Space;
- Virgin Galactic.

However, this does not mean that all of them have been subject to a typical initial public offering to become traded on the public markets. In fact, as previously mentioned, Virgin Galactic came to the market after it merged in 2019 with special purpose acquisition company Social Capital Hedosophia. After that event, Richard Branson's space start-up started trading its shares on the marketplace. Only in a limited period of time, their price rose from $7 per share at the end of 2019 to an impressive $37.35 per share at the beginning of 2020. In addition, the start-up reported to SEC that its revenue totaled $3.8 million and a net loss of $211 million for the year 2019.

Furthermore, regarding UrtheCast, it became publicly traded following a reverse IPO. However, excluding space start-ups, the last significant public offering in the space sector occurred in 2013 as Intelsat attracted as much as $349 million through an initial public offering.

2.3.6 Debt Financing

In the last 20-year period, a total of $5.1 billion has been recorded as debt financing in the start-up space. The highest number of debt financing transactions of the analyzed timeframe is concentrated around the period from 2007 to 2012: Protostar in 2006 and later in 2008, WildBlue in 2006, O3b in 2009 and 2010 and Ligado Networks in 2010. Among the various start-ups receiving funds, noteworthy investments were made in 2015 to O3b, Planet and UrtheCast. Later on, in 2016 and 2017 also Ecometrica, Kepler Communications, Space Tango, Vector and Ursa Space Systems received this type of funding. The following year, debt financing was obtained only by SpaceX and Audacy.

The year 2019 experienced the largest transaction as the Asian Development Bank, along with other investors, provided $160 million in debt financing to Kacific Broadband Satellites. In the same year, other nine companies reported this type of transactions, such as a $50 million investment of Intelsat in Blacksky's Earth observation satellite constellation, and a $5.1 million investment in Axelspace from the Japan Finance Corporation.

2.4 Start-up Space: WHAT'S NEXT?

The year 2019 was a record-setting one for start-up space, with more than $5.7 billion in investment reported. Several companies are planning important technical demonstrations for 2020, and others are promising an expansion of operations. Services and products that have long attracted investment are scheduled to deploy in 2020, particularly those related to commercial human spaceflight (SpaceX, Virgin Galactic, and Blue Origin). The revenue dynamics and operational performance of maturing start-up space firms are important trends to watch in start-up space.

2.4.1 Large LEO Constellations

One of the main topics of the future of the space sector is the low Earth orbit telecommunications. The main players in this field are SpaceX and OneWeb, which have already positioned part of their LEO constellations in 2019 and are planning to expand them in the next years. In fact, only in 2020 SpaceX has positioned 180 satellites that add up to the 120 already deployed, while OneWeb 40. The plan for 2020 is to launch a significant number of satellites, having the goal to reach a total as high as tens of thousands of smallsats in the near future.

Another relevant subject of the past year was Earth observation. Numerous Earth observation satellite start-ups attracted study contracts from the National Reconnaissance Office and contracts about commercial imagery from NASA. Besides the growing number of contracts emerged due to an increasing interest in this matter, it has been identified an upward trend in investments, which reflects the multiple deals emerged and confirms the constant growth experienced by Earth observation smallsats. As a consequence, space start-up ventures dealing with either Earth observation or telecommunications small satellites will face strong competition as the former try to attract new types of users belonging to new markets, and the latter have to compete against providers not related to the space sector.

In fact, this market significantly attracts additional non-space companies and further increases the focus on smallsat launch ventures, which will have a more important impact on the space start-up.

2.4.2 Smallsat Launch Ventures

Recently, numerous smallsat launch ventures are obtaining large amounts of investments to develop and put in operation a significant quantity of small satellites. For example, Relativity Space attracted $140 million in Series C last year. On the other hand, Rocket Lab, the only U.S.-based start-up provider in operation, which launched six mission in the last year and focused on reusable Electron rockets, announced its business' maturity stating that it needed no more financing.

In addition, this type of ventures is attracting different actors, such as national security customers and governments. The former includes the National Reconnaissance Office, which is collaborating with Rocket Lab on smallsat launches, and the U.S. Air Force, also interested in contracts about the launch of small satellites. Regarding governments, their interest on the matter is increasing over time, even though the competition between smallsats and big vehicles is still strong. However, this specific sector is very dynamic and will experience significant changes in the near future as ventures evolve. An example can be considered the case of Vector, which obtained a contract with the U.S. Air Force to launch a mission, but later that week put on hold operations because of financial issues. This volatility is mostly caused by the great amount of small launch vehicles that are being developed and the lack of financing received, which characterize this industry based on innovative technologies and business models.

2.4.3 Space Tourism

Space tourism is a major topic in the current space sector, as commercial suborbital human spaceflights are expected in the near future.

The space company Blue Origin already developed and tested three times its vehicle called New Shepard during last year, however they planned to launch it with a crew onboard by the end of that year without success. Regarding the other space company focused on this matter, publicly traded Virgin Galactic achieved major results in the past, including test flights and expecting to sell tickets in 2020, even though commercial flights are postponed to 2021.

2.4.4 Commercial Crew

The most successful start-up in this field has been SpaceX, which in 2019 conducted with success the Demo-1 mission by launching the Crew Dragon spacecraft autonomously and without crew members to reach the International Space Station. Later on, at the beginning of 2020 it successfully passed an in-flight abort test, leading to the first flight with crew of the Dragon to the ISS and the first human spaceflight of NASA from the United States since 2011.

2.4.5 Exploration

Regarding exploration, governments are the main customers to demand activities related to the matter through their programs. In fact, a major actor in this field is NASA, which proposes to the start-up space the opportunity to participate in various programs. For example, its Artemis program has set the goal to bring humans back to the moon by the end of the next four years, giving start-ups the opportunity to be part of it as its final goal is to achieve reached a sustainable presence on the moon. Moreover, its program called Commercial Lunar Payload Services gives them the chance to compete against each other for task orders with the aim of flying research payloads to the moon. In 2019, a selection of the fourteen companies

participating in the program, such as Astrobotic and Orbit Beyond, was given $253 million to bring the first science and technology payloads. Lastly, start-ups can accelerate the development of their technologies by taking advantage of the lunar-focused Small Business Innovation Research initiatives and awards.

2.4.6 National Security

As mentioned above, the relevance of governments is increasing as they play the role of a potential customer in the start-up space. In 2019, the creation of the U.S. Space Force and new space-oriented organizations, along with an increasing number of study contracts issued by intelligence agencies lead the way to government into the start-up space environment, accelerating the development of some of their commercial markets. in this scenario, governments can take advantage of start-up space ventures by doing more and spending less, while simultaneously facing the risks associated with the uncertainty related to this type of business. As a consequence, in the future they will be essential for the development of venture-backed start-up in the space sector.

Chapter Three
New Initiatives: The SpaceX Case

3.1 The Founder: Elon Musk

Elon Musk, born in 1971 in South Africa, is one of the most famous entrepreneurs in the world. He started his career back in 1995 when he founded, along with his brother, the company Zip2. Four years later, they sold it for $307 million. The money earned from the sale were further reinvested in X.com, a company providing financial services and online payments through the email, later on known as PayPal. In fact, in 2002 eBay bought the company for $1.5 billion, the capital used by Elon Musk to build his empire in the renewable energy and space sectors.
Musk is currently seventh on the Forbes 400 2020 list and thirty-first on the Billionaires 2020 list, having an estimated net worth of $93.4 billion. However, the most note-worthy position reached during his career can be considered the first place on the Innovative Leaders 2019 Forbes list.

3.1.1 Tesla

Elon Musk is the co-founder and CEO of the American company Tesla, headquartered in Palo Alto. His role in the company consists in the design, planning and global production of electric vehicles, along with batteries and products aimed at providing solar energy to the company. The latter was founded in 2003 with the objective of accelerating the transition towards a more sustainable world. Tesla debuted in 2008 with its first electric sport car, the Roadster, quickly followed in 2012 by the sedan Model S and, in 2015, the SUV Model X. The success arrived immediately, as the Model S was identified as the best car of the year by Motor Trend and Consumer Reports, while Model X passed successfully the security tests of the National Traffic Safety Administration. The company continued to evolve in the following years, introducing the electric car Model 3 in 2017, and the Tesla Semi, an engine able to reduce the use of fuel by $200,000. Furthermore, in the last two years, Tesla brought to the market two new vehicles: the Cybertruck, which is the mix of a traditional pick-up and a sport car, and the SUV Model Y. In 2016, it became the first company of solar energy being vertically integrated, thanks to its acquisition of SolarCity, which is the main supplier of solar panels in the United States, and the following years, it developed the Solar Roof, a product generating energy at a reasonable price. In addition, three energy storages are produced by Tesla: the domestic battery Powerwall, the industrial-oriented battery Powerpack and the Megapack, meant for distributors of electric energy.

3.1.2 Neuralink

In addition, Musk is also the CEO of Neuralink, which is a start-up he founded in 2016 with the aim of providing interfaces connecting the brain and the computer. The final goal of the company is to help patients suffering paralysis by operating, for example, on cells that have experienced traumas.

3.1.3 The Boring Company

Elon Musk founded The Boring Company in 2016. It provides a technology to build tunnels easily, combined with an electronic system of public transport, all aimed at reducing the pollution caused by traffic, and allowing drivers to travel by car for long distances at a high speed.
The company has already built a tunnel in Hawthorne, and is currently working on the Vegas Loop, which is a public transport system located in the Las Vegas Convention Center.

3.2 SpaceX

Regarding the space sector, SpaceX, founded in 2002 by Elon Musk, designs, manufactures and launches rockets and spacecrafts, with the aim of reducing the cost of access to space, and now is a company valued at $36 billion. The entrepreneur, besides being the founder, CEO and CTO of the start-up, is also the lead designer, which means he is in charge of supervising the development of rockets and other space vehicles that will be used for missions also on other planets. The key to success for the company is re-usability: its rockets are able to fly to space and return to Earth untouched, ready to fly again. These rockets, called Falcon, can land either on SpaceX autonomous spaceport drone ships, located in the middle of the ocean, or on a landing zone near the area of launch (Figure 1).

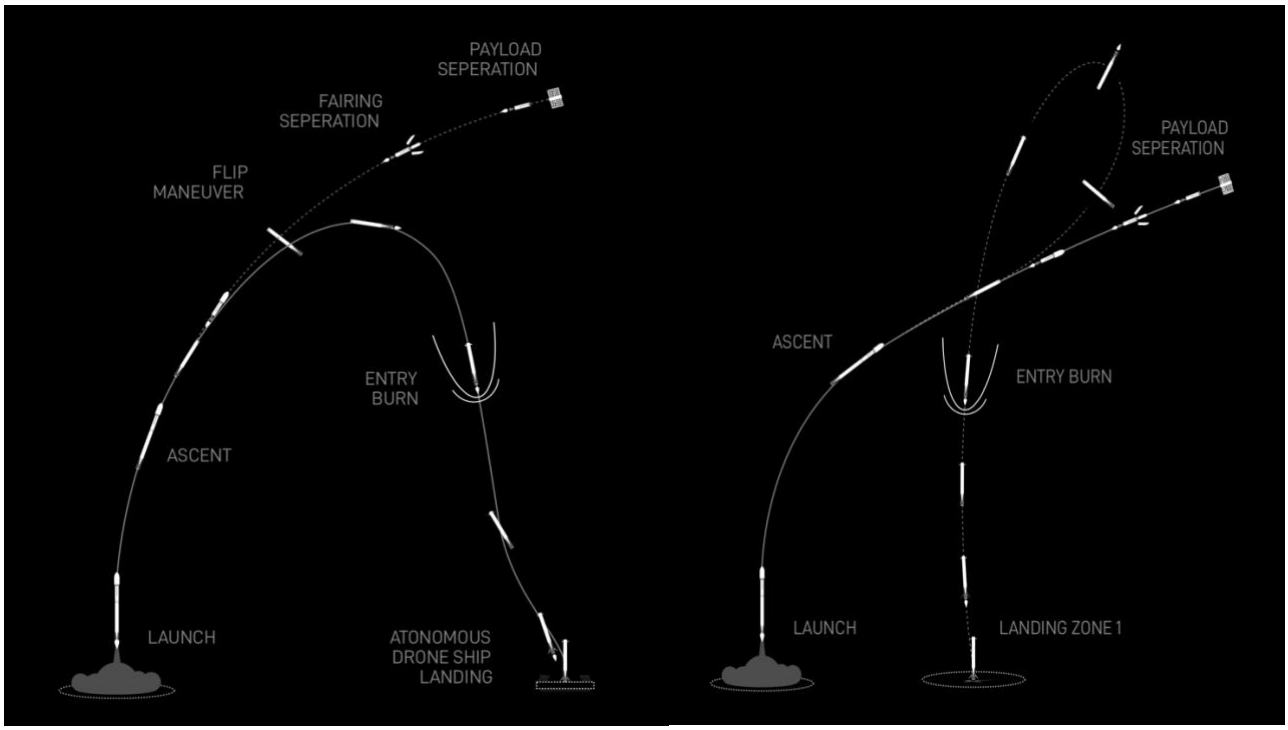

Figure 21. On the left, the Falcon lands on a SpaceX's autonomous spaceport droneship, located out in the ocean. On the right, the Falcon lands on a landing zone, located near a SpaceX's launch pad (Source: SpaceX).

The first recorded success of SpaceX can be considered Falcon 1, which in 2008 was the first rocket using liquid fuel and being developed by private actors that has ever reached the Earth orbit. Nine years later, the company achieved another major success, reusing for the first time ever the rocket Falcon 9, which in 2015 flew eleven communications satellites to orbit and returned, and the space vehicle Dragon, which in 2012 visited the space station as the first private spacecraft ever. In 2018, also the Falcon Heavy completed its first flight, being the most powerful operating rocket ever existed, while the following year the Dragon completed its first demonstrative mission, being able to transport a crew. This latest achievement will permit in 2020 SpaceX to bring the NASA astronauts to the ISS for the first time.
Regarding the next steps of SpaceX, there are currently two main projects in development. The first one is Starship, a transport system which is totally reusable and designed to fly equipment and crew to the Moon and Mars (Figure 2), and the second one, Starlink, which is a project aimed at providing internet at a high speed in areas where it is currently unavailable or too expensive.

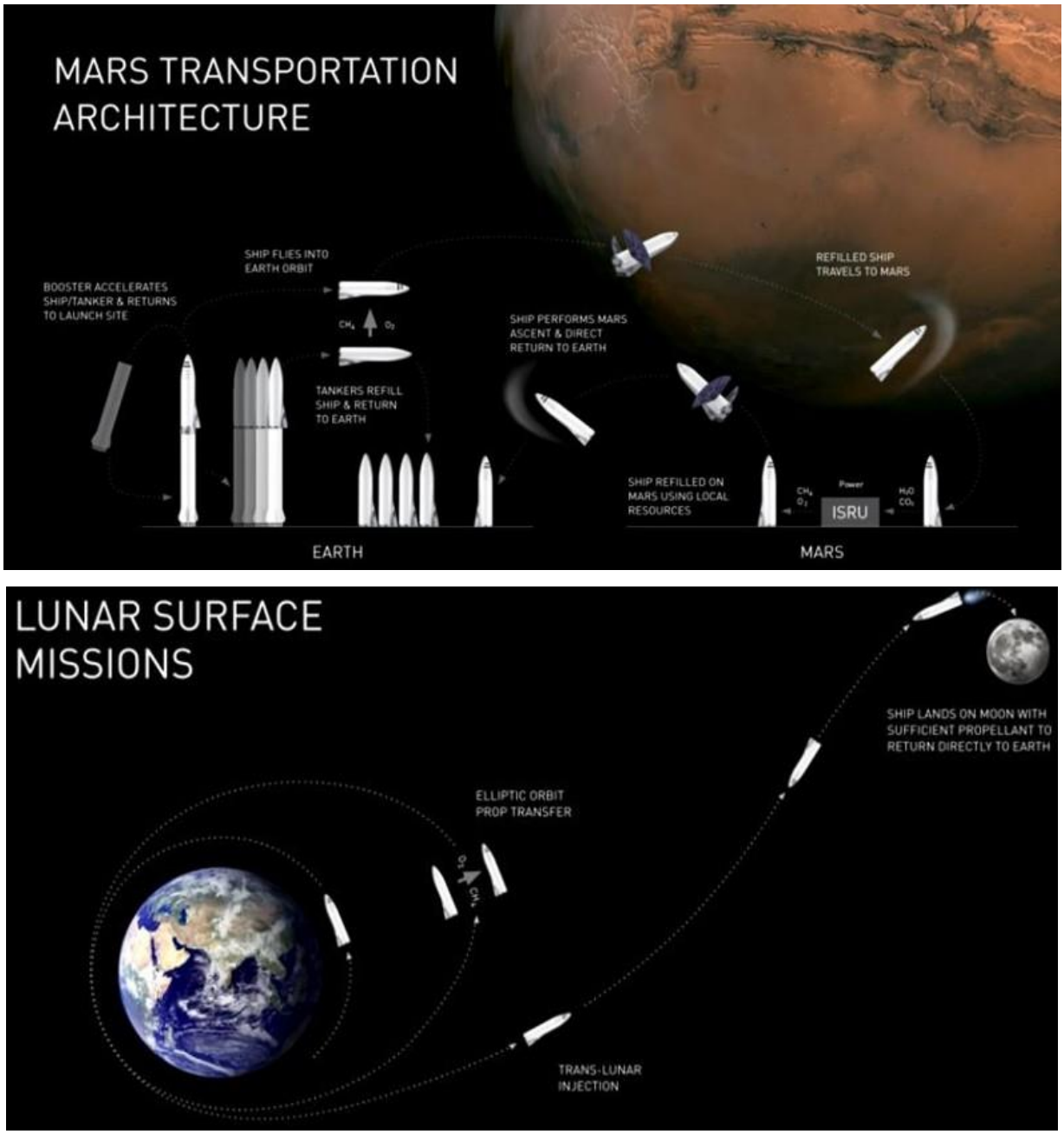

Figure 22. Above, SpaceX Design for Travel to Mars. Below, SpaceX Design for Travel to the Moon (Source: SpaceX).

3.3 Mission and Vision

Elon Musk once stated: "You want to wake up in the morning and think the future is going to be great – and that's what being a spacefaring civilization is all about. It's about believing in the future and thinking that the future will be better than the past. And I can't think of anything more exciting than going out there and being among the stars"[2].

What can be deducted from its ambitions and achievements is that SpaceX is looking at the bigger picture, focusing on the reusability of its space vehicles to make humanity multiplanetary, by building an independent city on Mars. The main drivers of its founder's success are surely his optimism and his mindset,

[2] Part of the speech Elon Musk gave at the International Astronautical Congress in 2017.

based on overcoming any possible obstacle. In fact, even though he is completely aware of the problems or natural disasters affecting the Earth, which make the future uncertain and discouraging, the entrepreneur is totally looking at the bright side. His achievements from SpaceX, Tesla and his other companies have a clear direction: making the future a better place for humanity. That is the reason why his long-term projects on Mars and the Moon are not meant only for the wealthiest part of the Earth population, quite the opposite Musk compared SpaceX's early travelers to Mars to the men that participated to the Imperial Trans-Antarctic Expedition in 1914, without any certainty about their return home. And, demonstrating how strongly he believes in what he does, Elon Musk stated in 2013 at South by Southwest that he will personally move to Mars at the time SpaceX will become independent.

The start-up can count up to 97 total launches until now, 60 total landings and 42 rockets that were reused. In addition, it is the only private company that has ever returned a spacecraft from the low-Earth orbit and the first one that has ever created a commercial spacecraft to fly equipment to the ISS and back.

3.4 Value Chain

In the last period of time, SpaceX has revolutionized the supply chain of the space industry by internalizing several operations that were traditionally outsourced. For example, the company focused on achieving expertise on rotational fictional welding (RFW), with the aim of reducing the costs of the materials used to build rockets. This is a clear evidence of the fact that, instead of outsourcing the capability to a global company and paying a much higher price only because of the lack of competition, SpaceX developed a way through which the final product is cheaper, of better quality and fast. Mirroring the mindset of its founder: "If a supplier is unable or unwilling to deliver the part, we can quickly make that internally"[3], SpaceX succeeded in covering the majority of the supply chain from the raw materials stage, for instance reaching a cost of launching the Falcon Heavy, which is nearly 35% of the closest competitor. Another event that confirmed the success of Musk's philosophy has been the development of an actuator for the Falcon 1, which was assigned to the engineer Steve Davis in 2004[4]. When Davis presented to the entrepreneur the estimate of the supplier of $120,000, Musk compared the actuator to a garage door opener and gave him a budget of $5,000. After nine months, the actuator was completed, costing the company only $3,900. However, having a vast supply chain, the company also relies on suppliers that are flexible and able to prove their expertise on the matter, differentiating themselves from the others.

What Elon Musk did, through SpaceX, was to revolutionize the mindset of the space sector, based on the belief that hardware should be expensive and robust, by showing to the legacy companies that commercial products are nowadays more advanced with respect to the military and traditional space equivalents. In fact, legacy space companies purposefully lack innovation by not adopting new designs. In this way, they can

[3] Part of the speech of Elon Musk at the 2016 Code Conference.

[4] From the book "Elon Musk" by Ashlee Vance.

avoid the cost of re-qualification and demand the use of outdated components. While Musk accepts risks and failures, having in mind a long-term vision of the new design, legacy space companies resist innovation because of the high risk of failure associated with it, as CEOs do not gain benefits from the success, instead are affected heavily by the failure.

SpaceX is headquartered in the United States, owning various facilities spread around the territory, each dedicated to a specific task of the supply chain:

- The Build Facility in Hawthorne, California, is where the design and construction of SpaceX's space vehicles happen. In fact, being a vertically integrated company, it is also one of the few currently existing ones in which the entire process of development can be completed in the same facility end to end.
- The Testing Facility in McGregor, Texas is a 4,000-acre facility equipped with 16 test stands that are used to prove the right functioning of vehicle structures or engines, such as the Merlin engine used in the Falcon 9 and Falcon Heavy, or the Draco thruster in the Dragon.
- The Cape Canaveral Air Force Station is home to the space launch complex 40 situated in Florida. The strategic positioning of this launch area is related to the easier access to low and medium inclination orbits, which are exploited by communications and Earth-observing satellites and supply missions to the ISS.
- The Kennedy Space Center is where the launch complex 39A is located in Florida. This site is famous for being home of the Apollo and Space Shuttle programs, along with being where the launches of the Dragon happened.
- The Vandenberg Air Force Base hosts the space launch complex 4 east in California, which has a strategic positioning with respect to high inclination and polar orbits, and for this reason is used by satellite communication constellations, defense intelligence and Earth-observing satellites.
- The South Texas Launch Site, located in the Cameron County, is a commercial launch site for orbital missions currently under construction. As the first of its kind, it will be home to the construction and launch of vehicles related to the Starship project.

3.5 Funding and the role of the U.S. government

In the last twenty years, the space sector has been the recipient of a large amount of investments coming from private companies. This capital resulted in the advancement of technology, which brought to a series of milestones achieved by start-ups, such as SpaceX. As space becomes a more accessible and cheaper destination, also the public-sector is starting to grow interest in potential achievements concerning the future of the sector. A clear evidence of this trend is the establishment of the "Space Force", which is the sixth branch of the U.S. military, in 2019.

In fact, in early August, the Department of Defense assigned to SpaceX 40% share of a series of launches of the Space Force, that are planned to take place in between 2022 and 2027. Regarding the remainder, it was awarded to the United Launch Alliance, which is a joint venture comprising Boeing and Lockheed Martin. These planned launches, although managed by the Space Force, will be distributed as follows: Elon Musk's start-up will be in charge of 14 national security missions, while the remaining 20 will be operated by the ULA. This scenario occurred as SpaceX successfully overtook Northrop Grumman and Jeff Bezos' space company Blue Origin in the race of the second phase of the National Security Space Launch, a DoD program focused on innovations that could enable the U.S. military to fly payloads to space. However, this came after SpaceX sued the government because of a "block buy" agreement with ULA, consisting in 28 rockets worthen around $11 billion. In Musk's opinion, it would have resulted in a monopoly that would have cut out any potential competition with other companies. In fact, after the 2015 settlement and the certification of the Falcon 9 rocket, the following year SpaceX won its first military launch contract. Considering the launches planned for 2022-2027, the first one is worth $316 million, leading to a potential maximum of $4 billion for the entire timeframe or a minimum of $2 billion, based on the price of the remainder.

Analyzing the whole history of funding of SpaceX, a timeline including the major events can be inferred:

- 2008: in August, SpaceX receives a $20 million equity investment from Founders Fund, which is a San Francisco-based venture capital firm. The firm already finances companies such as Facebook, sharing the revolutionizing mindset of Elon Musk.
- 2012: SpaceX is valued at $1.3 billion, as Elon Musk owns two-thirds of the venture and his 70 million shares are estimated to be worth $875 million on private markets; however, after the success of the second test-flight Dragon C2+, SpaceX's private equity valuation doubles to $2.4 billion. So, as for the last ten years from its foundation, SpaceX has received a total funding equal to $1 billion, of which $100 million were invested by the founder, $200 million were coming from private equity, and $100 million from other investors. About the remainder, it came from progress payments related to long-term launch and development contracts.
- 2015: The space venture SpaceX raises $1 billion in investments from the internet giant Google and Fidelity, in exchange for 8.33% of the company, bringing its evaluation to $12 billion. The two are joining prior investors such as Draper Fisher Jurvetson, Founders Fund, Valor Equity Partners and Capricorn.
- 2017: Raising another $350 million, the company reaches a valuation of $ 21 billion. At this point in time, it is one of the few U.S. private companies having a valuation that exceeds $20 billion.
- 2018: SpaceX is receiving capital related to contracts for numerous launch missions, each one providing down payments at signing, often along with progress payments corresponding to the construction of launch vehicles components, which then will be used for the planned launch missions.

- 2019: SpaceX's total fundraising for the year equals $1.33 billion, raised through three funding rounds. The first occurs in April, when the company receives funding for $536 million at a price of $204 per share. Later in May, SpaceX has already raised a total of $1 billion, which enables the launch of sixty SpaceX satellites directed to the Starlink broadband constellation. By the end of the month, the company's valuation reaches an impressive value of $33.3 billion. In June, SpaceX receives $314.2 million at a price of $214 per share, of which a significant part comes from the technology fund operated by the Ontario Teachers' Pension Plan, which owns almost $200 billion in assets under management.

The year 2020 can be considered a major year for the space company SpaceX. In fact, in May it successfully flew two astronauts for NASA to the ISS, completing the first astronaut launch from the United States in the last nine years. Additionally, it launched and landed its Falcon 9 for a record-setting sixth time, after it operated a record-breaking total of 21 launches in the year 2019. The subsequent success of all these achievements is reflected in its 2020 most recent funding round. Indeed, Elon Musk's space company raised $1.9 billion in August, which was the second phase of its capital raise of the year from a total of 75 investors. According to a mid-August filing with the U.S. Securities and Exchange Commission, the capital arrived in the form of equity investments in the California-based facility, Hawthorne, bringing the company to an evaluation of $46 billion. Moreover, based on Bloomberg, the brokage giant Fidelity played a major role in this round, although being an already existing investor of SpaceX.

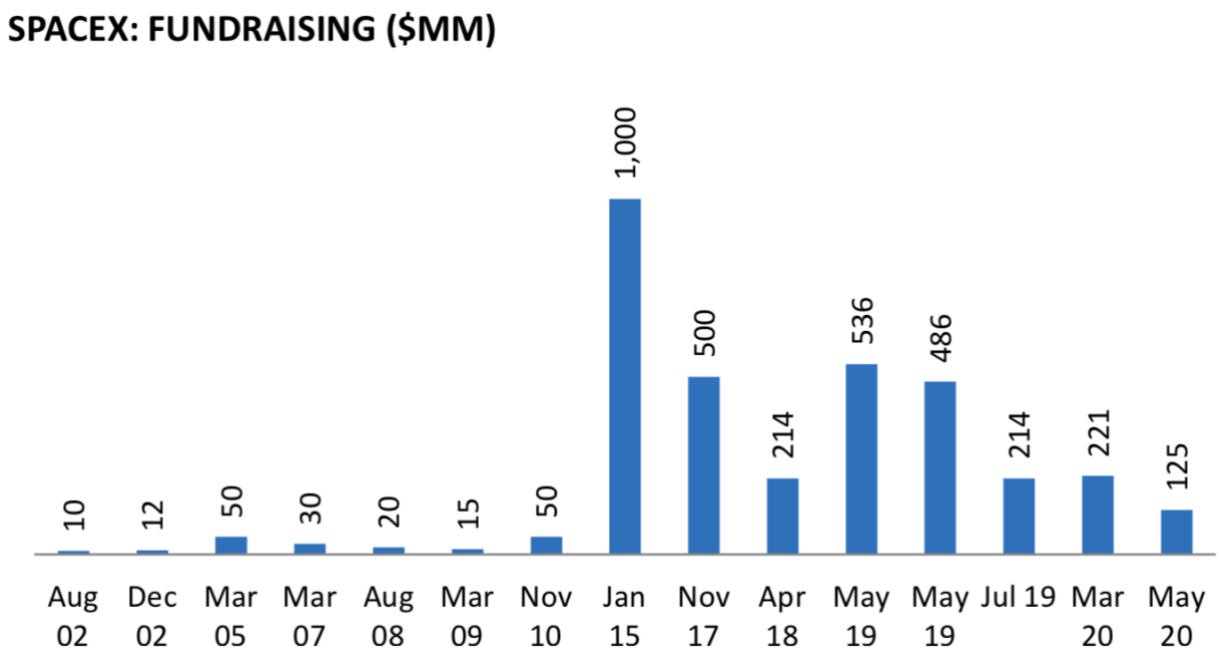

Figure 23. According to Morgan Stanley Research, CNBC and SEC, to date, SpaceX has raised nearly $3.5 billion at a $36 billion valuation.

CONCLUSIONS

To conclude, in the last twenty years, the space sector has experienced major changes. Keeping up with an ever-evolving world and a constantly developing technical knowledge, space is adapting to the new needs and opportunities emerging during this time period. In fact, at the beginning of the analyzed timeframe, this sector was mainly based on government or institutional budgets and the number of relevant players was relatively low. Moreover, the main goal of traditional space programs has always had an intrinsic value of public utility, such as environmental monitoring, response to natural disasters and so on, justifying the amount of institutional investment dedicated to them.

However, as the economic value of the space industry reaches over $300 billion, which is a significant increase from its value in 2005 (less than $200 billion), the scenario is drastically changing. Indeed, not only a new generation of private companies is entering the sector and taking traditional legacy companies' place, but also a new approach is making its way into the industry, as private firms share both the high risks and the potential returns on investment in space. In this scenario, investors are now accustomed to take risks, and firms are given the freedom and responsibility to design and produce their systems in the most appropriate way, meeting the requirements of both NASA and the market while keeping the intellectual property of the products to themselves. The new space can be then identified on the basis of a series of key trends, driving its sectorial dynamic: increasing vertical integration towards the upstream sector; new policies based on market creation; new business strategies based on innovative approaches; optimization of industrial organization; new entrants challenging space players.

Furthermore, analyzing the space start-up SpaceX, it is clear how Elon Musk strongly represents the new space. A clear evidence is the fact that, instead of outsourcing the capability to a global company and paying a much higher price only because of the lack of competition, SpaceX has developed a way through which the final product is cheaper, of better quality and fast. The company, as a matter of fact, has revolutionized the industry by succeeding in covering the majority of the supply chain, from the raw materials stage, and the mindset of the space sector, based on the belief that hardware should be expensive and robust, by showing to the legacy companies that commercial products are nowadays more advanced with respect to the military and traditional space equivalents.

At this point in time, the focus of the space sector is shifting towards space tourism and large LEO constellations, as the satellites become smaller, and the interest of private actors is getting stronger. What's next? In Musk's opinion, a multiplanetary humanity.

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