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Exploring Open Innovation processes in Greek space industry companies

MASTER THESIS

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Abstract

The purpose of this present work is to develop the nature of space entrepreneurship and to evaluate its potential with the application of innovation in space. At the beginning of our analysis we studied the financial footprint of space entrepreneurship in recent years. In addition, we collocate an extensive analysis of the individual areas of space entrepreneurship and the percentage of the total space economy occupies in each sector. In the next step of our work, we dealt with space entrepreneurship in a broader context, in the European Union, and in other countries as well, such as the USA, and India.

In further insight, we expanded to space innovation and especially to Open Innovation which is a relatively new concept that was developed. A proper definition of Open Innovation was excessively cited in alliance with an in-depth analysis of the relationship of the entity that creates the innovative concept with the external partners interaction. From this extended reciting was noticed that open innovation has significant advantages, but also disadvantages that came to our attention and covered also carefully. This included different approaches of economic and budgetary implications but also a huge profit margin if implemented properly. In addition, a great analysis was made of the most important features and peculiarities of the space sector, and also developed the reasons why Open Innovation should be used on a large scale in space applications to meet the challenges of the space sector. This paper opens a great discussion about how Open Innovation (OI) can interact with the market, commercialization and the very high level of competition that will pervade the rapidly growing space in a few years.

After an examination of several case studies of companies that have achieved significant results by applying OI, we finally present a case of promising implementation of Open Innovation at a time when it is the extremely ambitious idea of extracting mineral wealth such as metals and other elements from celestial bodies. Such celestial bodies could be asteroids. In the last chapter of our work we will list the research we conducted in Greek companies dealing with space and we will list in detail the results we have collected which are of interest for a full understanding of the Greek position and power of entrepreneurship and space innovation.

Introduction

In the last decade, a great effort has been made to further develop the space sector. This sector is the space industry, which is growing rapidly despite the huge economic problems the international economies are facing. International space industries encourage investment in space by both public and private entities. This is a very important development that will achieve the prosperity that the space sector will experience. However, this process must be done carefully and with steady and studied steps, especially today, as the planet emerges from two hostile to evolving events, the global financial crisis that began in 2008 and the ongoing Coronavirus outbreak that is still evolving.

In Chapter 1 we will deal with the entrepreneurship of space, the revenue it brings to investors, the risks it entails and the innovative applications that are already changing our lives. We will also study the financial footprint of space and each part of it in great detail. Chapter 2 presents the latest developments in space entrepreneurship in Greece and Europe. The efforts that Greece had made in order to have a place in the modern space industry will be extensively presented.

In Chapter 3 we will deal with Open Innovation in Business. We will focus on specific areas such as the advantages, the risks of open innovation, but also the legal framework that defines it. We will also cite examples of companies that have succeeded in the international firm and made the essential use of open innovation as a method of their development. In Chapter 4 we will explore the evolution of Open Innovation in space. Valuable conclusions will be drawn and we will present a very ambitious plan that is the definition of innovation. This plan is the attempt by some countries to create a project of action to achieve the extraction of minerals and other elements from celestial bodies such as asteroids. If this plan is achieved, it will provide great help in reference of the energy problem that our planet is facing and needs an immediate solution.

Finally, in Chapter 5 we list the research method we followed to approach the Greek space companies and we will present the questions and answers of the research that we provided to these companies.

In conclusion, we will present the conclusions of our research, a critical aspect of space innovation development and discuss all the outcomes and the results that occurred from this work.

1 The financial footprint of space and the sectors in which space operates

1.1 The beginning of space entrepreneurship

Space entrepreneurship is perhaps the most common topic of discussion today in the space science in Europe, the United States, and other emerging space nations. For the vast majority of people, space business activities may not be discernible at first glance, especially when viewed in an area that seems to prefer large, expensive projects. In fact, these projects are implemented with the sponsorship of national governments or large multinational companies, which have the ability to allocate financial resources and scientific staff that can implement projects of this size. We must emphasize that the traditional space industry usually has high hopes for the space sector and entrepreneurship, while taking into account the existing risks. Many companies have been very successful in space entrepreneurship and not only in the field of satellite ejection, but also the time has come for a very big growth in space entrepreneurship.

In recent years, a variety of space activities have been developed that represent a significant part of today's space entrepreneurship. Perhaps the most important brand new sector that is directly related to space is the IT(Information Technology) sector, where space entrepreneurs have demonstrated their ability to contribute with interesting technical innovations, capital and cost efficiency, new business models, the ability to effectively serve niche markets and prompt markets than traditional aerospace companies (Burton H. Lee, 2007). The business environment, however, is directly linked to the general developments of the market and the global economy. Specifically, it is necessary to have the available financial resources and the political will. Let us not forget that the worldwide economy has suffered two huge blows in the last 10 years, a major economic crisis and a pandemic with huge economic consequences in 2020. The above problems create a reluctance in terms of entrepreneurship and innovation in all sectors, since they have greatly increased the potential risks.

In fact, the modern space business could be said to have started in the summer of 2012, when the Dragon capsule of the private company Space X, managed to successfully supply part of the International Space Station, thus creating the right conditions for the launch of the private space exploration, and therefore the development of entrepreneurship in this area (Figure 1.1). It is a fact that investments in space have brought great benefits to our society in many other areas so far.

The constant monitoring of the climate and the earthly atmosphere becomes a very important chapter globally, especially in the last years that we are experiencing on our planet a rapid climate change. The immediate provision of reliable satellite communications and the achievement of fast navigation now greatly serve human needs, such as emergencies that require immediate communication between people and institutions. Such situations are natural disasters, such as earthquakes, floods, tsunamis, but also accidents and terrorist acts. It is important to note that space entrepreneurship would have developed much earlier, but serious obstacles such as the destruction of the Columbia space shuttle thwarted significant plans in this area. Nevertheless, space operations between the geosynchronous orbit and the Earth (GEO) continued to operate. More specifically, complex services based on satellites were evolving, resulting in great benefits. Over time the space industry has evolved and we are currently at a point where private spacecraft are being built and therefore even more services are being supported.

Figure 1.1 The SpaceX Falcon 9 rocket roars into space (Image courtesy of NASA)

Despite the great progress in the space industry, there are parts of it that are at an early level, while more than 50 years have passed since the first man went into space, while since then until now only about 500 people have managed to reach LEO orbit and the rest of the orbits. These few people who have traveled in space were professional astronauts and a few space tourists. It is important to note that it does not have to be in space to do business. But the big problem so far is that space targets only a few people for many reasons. We would say that it is a "very expensive sport" and is aimed at a very limited audience. Space is a very hard domain, both for the people who travel there and for the businesses that are active. At the same time a big problem is that several space companies are still dependent on government contracts. The main reason for the obstacles is that we have not understood to a large extent how this area differs from the other sectors of the economic activity of the countries. The main goal for the immediate future should be to understand the uniqueness of space as well as its own business and economic rules. We would both say that the great pillars that will lead to the achievement of this goal are science and engineering.

In addition, it is generally accepted, that the big change has been happening for a long time ago in space is the large number of private investments that are made and right here comes the birth of entrepreneurship. Until now, we have been accustomed to space belonging to public bodies and governments. First, we could mention some ideas of future space entrepreneurship. New technology launch vehicles such as those recently used by Space X and the creation of space tourism as reported by Virgin Atlantic (Figure 1.2). It is also now necessary to design and build new spacecraft to explore both the moon and other promising planets and satellites. In addition, something very important that must be implemented is the extraction of mineral wealth from space bodies such as asteroids, especially in the years to come when humanity will face a great energy problem. In all these very ambitious projects, the role of private companies and therefore of space entrepreneurship will be significantly strengthened (Gurtuna, 2013).

Figure 1.2 An artistic rendering of the interior cabin of VSS Unity. Image: Virgin Galactic

1.2 The Economic Footprint of Space

In space, as in all other scientific domains, measurements play a very important role in business. For many years it has been very difficult to find reliable statistics for the space industry. In recent years, however, we have seen rapid changes in this area. Significant data recording organizations have been set up. These include: The OECD World Space Economy Forum, several reports published by the Satellite Industry Association in the United States (edited by Futron Corporation), "Industrial Facts and Figures" published by Eurospace and the well-known "Space Report" which created by the Space Foundation. But sometimes global statistics disagree a lot for many other reasons. For example, the time it takes to compile statistics plays an important role.

Another problem is the difficulty in combining the numbers of "wholesale" suppliers to a large extent, such as Intelsat and Eutelsat with retail sales data. In addition, the line between a space supply and a terrestrial supply is not always clear. In many satellite services, such as broadcasting and telecommunications, the accuracy of the transition from a satellite service to a terrestrial telecommunications service or even an online transaction cannot be specified. There may even be double counting or improper accounting of revenue in a supply chain.

At this point the financial footprint of the space industry should now be analyzed. Of course, it is not possible to quantify all the benefits of space applications. If satellite communications were not existing, we would face huge problems. For example, thousands of people would be at risk every year from extreme weather events, severe storms, hurricanes, earthquakes and tsunamis. Air flights would not be safe, shipping would be at great risk and we would not be able to connect to the internet at all times. In addition, a very important role in how much the space industry is developing is the budgets that governments allocate for space. The OECD often reports financial data of government for space budgets around the world. The 35 OECD largest space countries currently invested a total of $ 64.4 billion in 2009 and about $ 65.3 billion in 2010, including civilian and military spending (OECD, 2011). The small difference is mainly due to the way US sophisticated space budgets are calculated and the almost non-existent circulation of information about military satellite activities for security reasons (OECD, 2011).

Moreover, it is true that the United States surpasses other nations when it comes to space spending at least so far. For every dollar spent by the rest of the world on space activities, the United States spends nearly $2 (including political and military spending). However, these amounts may not correspond to reality when conducting international comparisons of the capacity of different space nations. Working under adverse conditions is the largest cost category in space programs and labor costs are much lower in BRIC countries that have begun to operate in space. Therefore, great care is needed when comparing to international budgets.

Another key piece of space industry statistics has to do with the revenue generated. Although estimations of commercial revenue vary widely, is calculated that revenue fluctuate from $ 170 to 190 billion for 2010 (The Space Foundation, 2011). This figure includes not only annual revenue from satellite applications such as satellite telecommunications, terrestrial observation, and satellite navigation, but also other investments such as satellite construction, launch services, ground equipment and support services (Figure 1.4). However, it is difficult to accurately calculate the revenue of the commercial sector because it can be easily miscalculated or become overvalued. Therefore, it is vital to assess the value chain and take into account all the revenue growth from one stage of the process to another. If this is not performed correctly a significant error can easily occur. To understand this we can study the construction of satellites in general. Experts in this case become subcontractors with many subsystems that have to do with a satellite.

Moreover, if we do an analysis of the revenue of the trading space we can see some very interesting information. The dominant sector in the space industry is satellite applications as almost 85% of total revenue comes from a specific sector, the satellite telecommunications. For a few years now, satellite navigation has been developing at a very fast pace, since as we know all services now make use of the location. In addition, land surveillance, a sector in which there is now considerable experience, accounts for about 1% of total commercial sales (Figure 1.3). But to get a complete picture of the economic value of the space sector for each year, we need to add up the public and private space budgets. A large part of public budgets is allocated to the private sector in the form of contracts. More specifically in 2010, all global space activities ranged from $ 235-227 billion. This number excludes indirect benefits (such as spin-offs), as well as the book value of sector assets (eg, start-up launch). In other words, we could observe that many billions of dollars worldwide are moving in space every year, and to understand how significant investments are made, it is enough to look at the human resources employed in this field. According to the OECD, about 170,000 workers work in the space industry in the United States, about 31,000 in Europe, and 50,000 in China (OECD, 2011). Of course with space budgets, different sources do not always agree on these numbers, but this is a known problem. Another estimation table shows that in America the year 2011, 250,000 people worked in the space sector. For other countries, however, it is a bit difficult to gather statistics for example for India, Brazil, Turkey and other emerging economies, a conservative estimate would be at least 50,000-70,000 space professionals.

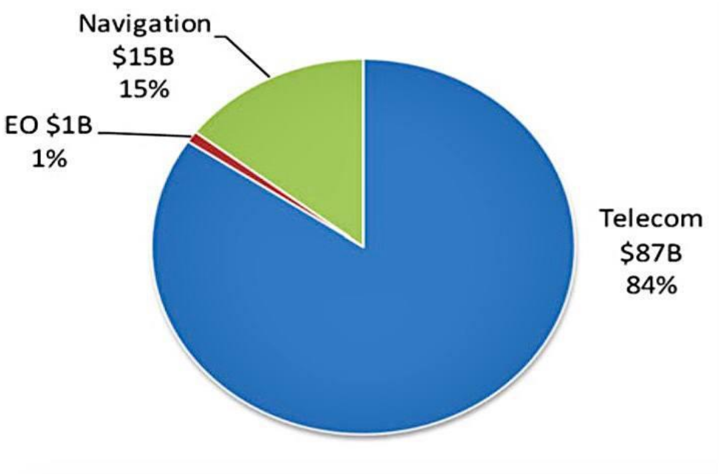

Figure 1.3 Distribution of satellite services revenues (in billion dollars) between the three main types of satellite applications in 2009 (Source: OECD 2011)

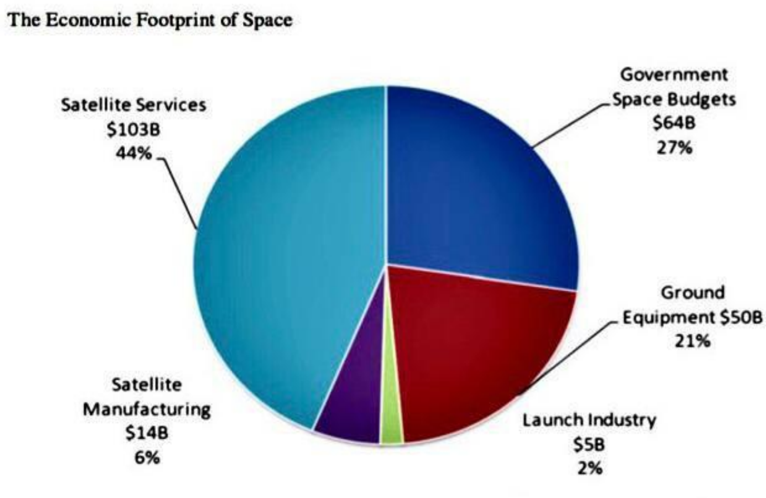

Figure 1.4 The economic footprint of the space industry in 2009 (Source: OECD and SIA)

Nevertheless, activity in government spending and commercial revenue has grown rapidly by the percentage of 73% over the past decade, according to the latest analysis by the Space Foundation. The global space economy in 2019 grew by more than $ 9 billion compared to the previous year, reaching $ 423.8 billion, according to new findings published in the second quarter issue of The Space Report (The Space Report, 2020). More specifically, growth occurs an increase of 2.2% from the global space economy of 2018, which is estimated at 414.75 billion dollars. An important parameter is the trade revenues which increased to 336.89 billion dollars in 2019, an increase of 6.3% from 328.86 billion dollars in 2018. Space materials, products and services, a major segment of commercial space revenue, totaled $ 217.72 billion, up from $ 214.18 billion in 2018 (The Space Report, 2020, Q2).

The space construction and mission support industries, the other major trading sector, rose to $ 119.17 billion, up 16.1% from $ 102.66 billion in 2018. In recent years, the space report has been recognized as the main body of information for the global space industry. It contains the most important data on the economy, infrastructure and workforce of the space industry and analyzes with great reliability the benefits of space exploration. The report is a resource for governments and all public and private actors.

Other findings published in the Space Report 2020 include the following:

Despite the global pandemic, rocket launches for the first half of 2020 were the same as in previous years. The 41 successful launches were slightly lower than the five-year average of 43.2. In 2019, the workforce employed in space agencies included approximately 47,895 employees working in the design, development and manufacture of space products. Global spacecraft for commercial missions increased 48% year on year, reaching 251 in 2019, compared to 170 in 2018 (The Space Report, 2020, Q2)

In the coming years, when the great pandemic experienced by the planet will be finally over, the revenues of the space industry are likely going to take off. The business world is now ready to invest in rockets and launches, creating an exponential increase in demand for the ability to send satellites, humans and other objects into space. Governments around the world are likely to increase investment in space. In addition, it is a fact that new ideas and new possibilities for humanity are constantly emerging when costs are reduced. This is how technology evolves exponentially. In short, as the cost of space applications decreases, so will the exciting ideas for space investment. Here are some names that have at least some activity in the space industry and may benefit from the Space Bubble that is going to blow up in the next 5 years: Space Revolution, SpaceX, Lockheed Martin, Airbus, Northrop Grumman and Aerojet Rocketdyne and Virgin Galactic. In the picture below we see how much the "space economy" has grown in 10 years.

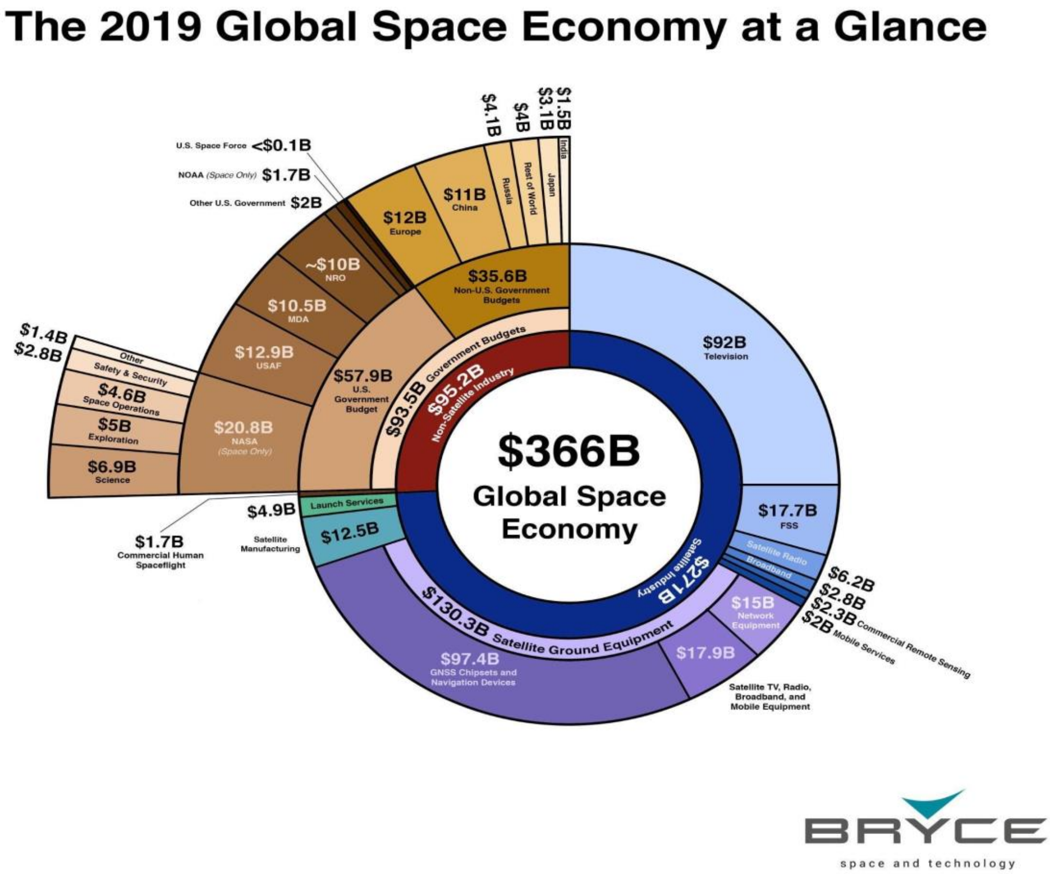

Figure 1.5 The Global Space Economy (2019)

1.3 Analysis of the most important sectors in which the space industry operates

1.3.1 Satellite Applications

It is a fact that satellite applications are growing rapidly today. The infrastructure created by space scientists has greatly facilitated our daily lives on Earth. Functions that now we take for granted are due to satellite applications. The detection of cash from ATMs to the synchronization of traffic lights depends directly on the existence of hundreds of satellites that surround our planet.

1.3.2 Satellites in Meteorology and Environment

The contribution of satellite systems to the environmental sciences has been very important in recent years. Every day more than 150 million data arrive on Earth regarding weather, climate and the environment in general. These data include temperature, clouds, humidity, waves and their height, floods, storms, hurricanes, the amount of ice and snow, forest fires, and more. What is striking is that of all these elements that reach the Earth only 15% manage to be introduced into atmospheric weather forecasting models due to general weaknesses. The meteorological satellites inform us about everything that happens in the Earth's atmosphere. These satellites are divided into 2 categories. Geostats and polar orbit satellites.

Geostats are fixed at zero (0) degrees, ie they rotate simultaneously with the Earth and from a height of 36,000 kilometers send satellite observations, which target all regions of the planet. Unlike geostationers, polar orbiting satellites are at an altitude of about 800 kilometers and follow orbits covering the entire Earth and send images every three minutes. They are the most important source of information for polar regions where there are not many ground stations and provide better visual analysis than geostables, as they fly at lower altitudes. Geostats, in turn, provide important information every fifteen minutes around the tropics and subtropics. Each of these satellites records multiple information in many different channels/ intervals of the electromagnetic spectrum. EUMETSAT (European Satellite Meteorological Service) oversees seven meteorological satellites called Meteosat-7, 8, 9, 10, Metop-A, Metop-B and Jason-2. All Meteosat satellites are geostable and consist of first- and second-generation satellites. They send us full scan images of our planet for Europe and Africa. Meteosat send information to the wider Indian Ocean region, and Metop-A, B, and Jason-2 are polar orbits that scan the Earth daily at much lower altitudes. For every satellite that goes into orbit, it needs a very large amount of energy. This energy is produced by the very powerful rockets that direct the satellite to the desired height. In order to be able to orbit a satellite, it must reach a certain height from the propellant rockets and have a certain speed. In addition, they have to operate for a long time without problems and damage and this is difficult because space is an extremely inhospitable place. The total population of all types of artificial satellites launched by states and private companies until a few years ago was over 5,000. Most of them were Russian-made.

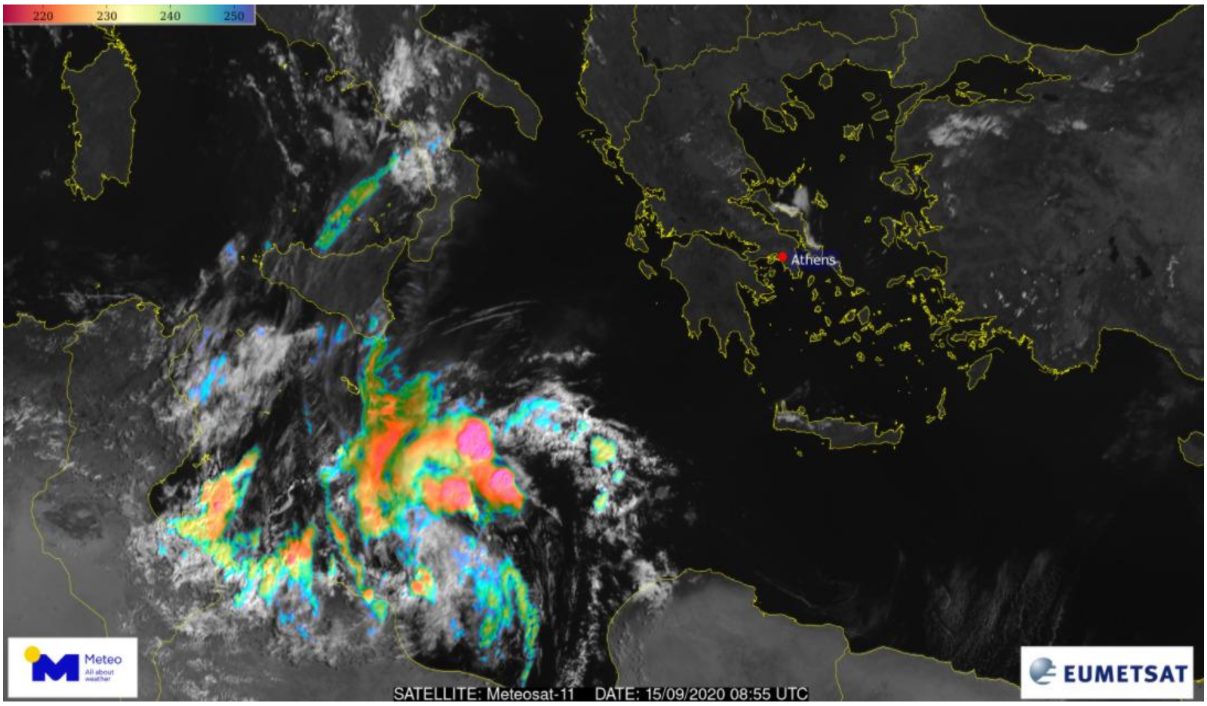

Figure 1.6 Observation via satellite of a catastrophic Mediterranean cyclone. The satellite constantly sends us information about the course and the intensity of the cyclone.

The latest generation meteorological satellites "are equipped with modern instruments for automatic photo analysis but also for receiving, collecting and analyzing emissions of terrestrial, automatic meteorological stations in deserts, polar regions, inaccessible and large mountains. These modern second generation satellites can even give the weather forecast map for specific areas and for specific minutes of the hour. "Geostable satellites can observe the same point and transmit images directly to ground stations, while polar orbiting satellites have a high resolution and the ability to observe many areas." From all this we conclude how important the space of satellites is and that there is a great future for private investment and business development.

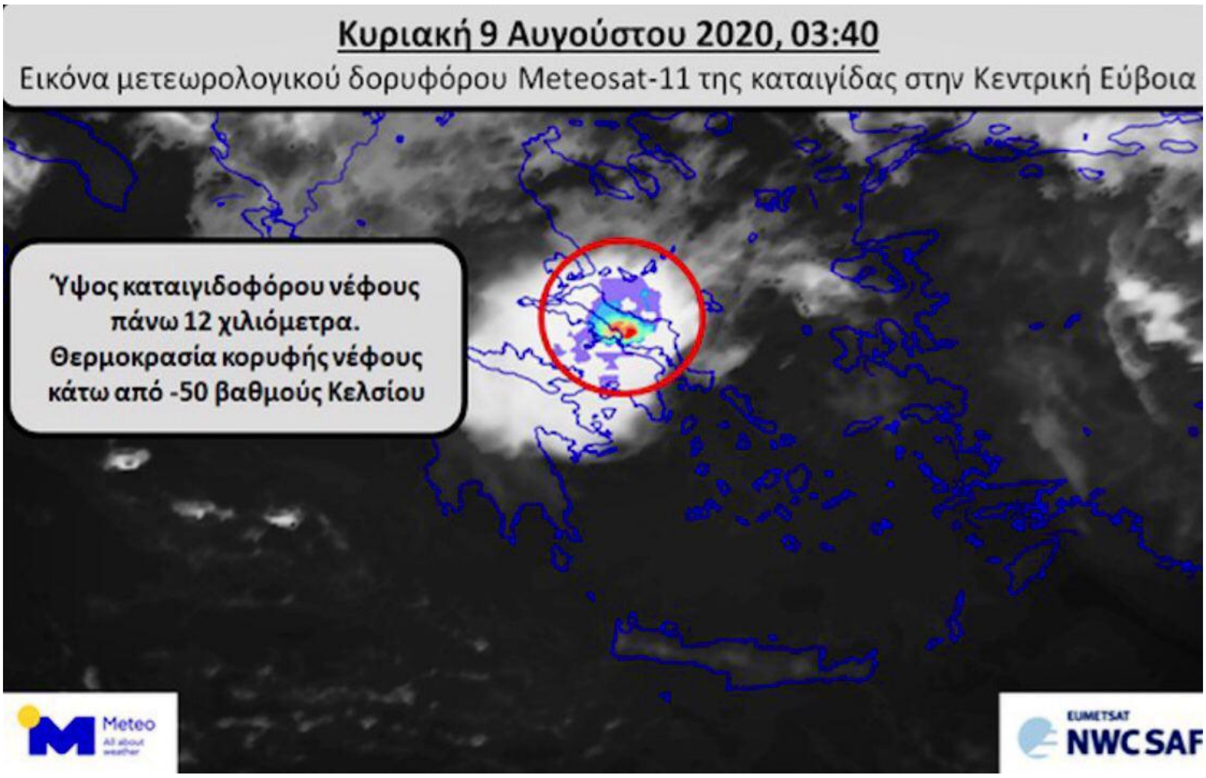

Figure 1.7 Satellite observation of the catastrophic storm on the Greek island of Evia that cost many lives. Through the satellite we can clearly see the height of the storm cloud.

1.3.3 Satellite Telecommunications

Seventy-five years ago, a British engineer wrote an article in Wireless World magazine in which he proposed a plan to cover the entire planet with three telecommunications satellites. The British engineer's plan suggested fixed points where the satellites would be in relation to the rotating Earth. This is our well-known GEO orbit. This whole project created the idea of developing satellite communications. This plan by Sir Arthur C. Clarke, which at the beginning was not taken very seriously when it was introduced, was finally evaluated several years later with the launch of a satellite, the Intelsat I Early Bird, which was the first commercial satellite to enter geostationary orbit. But the technological explosion of satellite communications started 30 years ago, that is, since the actual use of the internet began. Private companies have started investing in rocket launches and laying too many satellites especially in the LEO orbit. For instance were made many mobile satellite telecommunication systems such as Iridium, ICO, Globalstar and Orbcomm, as well as proposed broadband systems such as Teled and Astrol with huge investments from the private sector. These investments were based on the use of a very dense network of satellites in order to provide excellent telecommunications services. Unfortunately, this plan failed in part as only a few of these satellites were able to orbit. All these projects, many of which failed, created a very long delay in raising funding from space companies, in order to be able to operate. For example, two US companies, LightSquared and Terrestar, which planned to combine satellites with broadband terrestrial mobile services as a "hybrid network" after investing billions of dollars in building and launching highly sophisticated satellites, finally delayed their plans. In contrast, Inmarsat and Thuraya, which use geosynchronized satellite technology, have been able to make big profits by providing satellite data. Finally, there was a greater profitability of the fixed satellite services departments compared to the mobile telephony services.

1.3.4 Global satellite navigation systems

Global Navigation Satellite Systems (GNSS) is the general term for satellite systems that are responsible for the satellite navigation services we know how important they are today. So far there are only 2 navigation systems that provide global coverage. The Global Positioning System (GPS) and the Russian GLONASS system. Although other countries have functional navigation satellites, such as the European Galileo, the Indian Regional Navigation Satellite System, the Japanese Quazi-Zenith Satellite System, and the Chinese BeiDou / Compass systems, none of these systems currently provide global coverage (Gurtuna, 2013, p.17). Initially, satellite navigation was designed to serve military purposes, but later expanded its business for consumers applications. Such is the case with car navigation.

In recent years, the purchase by almost all people of smartphones with built-in satellite navigation capability, has greatly increased the number of people using daily GPS signals as part of their daily lives. The timing function is also vital for a number of scientific as well as important government applications. An important point is that most of GNSS revenue comes from sales of receivers and related services to end users. It is therefore easy to understand that the development of competing GNSS systems is mainly due to national security reasons and not to economic reasons.

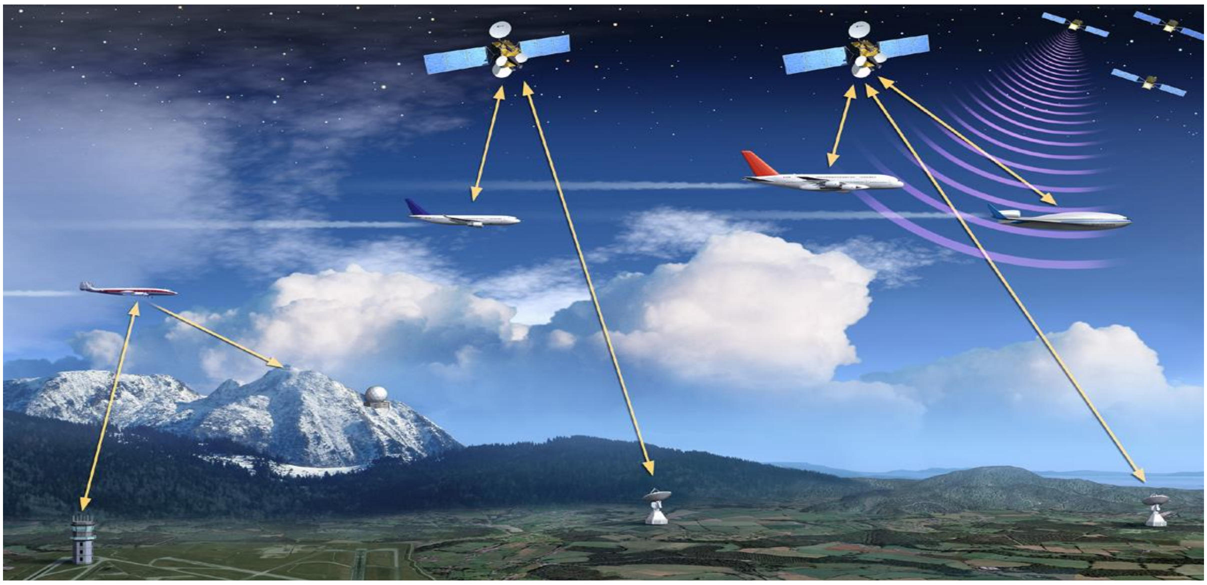

Figure 1.8 This image illustrates some of the facilities provided by GPS satellite signals

A milestone year in satellite navigation was in 2000, when the US government essentially stepped up the accuracy of GPS signals for civilian purposes. In 2007, the US Department of Defense, which supplies and operates GPS satellites, permanently disabled the deliberate degradation of satellite signals (US Dept of Defense, 2020). This was a very important decision because now GPS signals would be extremely reliable and could serve commercial purposes as well as the general public. For example, air traffic or road traffic and much more could be controlled much better.

Europe has been developing its own satellite navigation system, Galileo, for years. When fully operational, Galileo will enable high-precision satellite navigation on a global basis (ESA, 2011). Galileo is designed to be interoperable with GPS and GLONASS and, unlike GPS, will be fully politically controlled. When Galileo combines GPS and GLONASS as a satellite navigation operating system, millions of users will have access to more than 75 satellites which is amazing and will offer to people huge possibilities. In this new era we observe how many possibilities there are in space for private investments but also innovative ideas on the already existing design.

1.3.5 Remote sensing

Remote sensing, also known as Earth observation, is perhaps the most important space activity ever developed. At this time, hundreds of satellites orbit the Earth, monitoring the planet and its atmosphere with accurate measurements across the electromagnetic spectrum. So far we have had many ways of observing, such as meteorological balloons and aircrafts are used to monitor our environment. So, the remote sensing that came into our lives, is essentially an upgraded form of observation that is now operated from space. However, the access to space has brought these new possibilities of observation. The information given to us by the satellites that are in orbit provide us with significant scientific, military and commercial capabilities. Very important applications of remote sensing include agriculture such as the separation and grouping of crops, forestry as the area is now closely monitored and deforested, geology such as subsoil and mineral wealth mapping. The satellites also give us very important information on meteorology and climate change but also in the areas that flood when we have strong weather phenomena.

Also very important is the information on the increasing desertification of many areas that occurs due to climate change in recent years. If we look at the private sector we will see that many companies have started to operate in the field of remote sensing. Many companies are constantly working to develop new products and services using remote sensing components through state-of-the-art machinery. In the field of top-secret government functions, high resolution optical systems are now widely available for commercial applications (Gurtuna, 2013, p.18). Also, the cost of construction and services in remote sensing has dropped, so it is easier for many companies to operate.

Let's say a satellite imagery application is Remote Sensing Metrics, a US company that can build economic activity indicators that are then used to make accurate financial forecasts. These indicators have applications in many sectors of the economy, such as the number of cars in the parking lot of a large and modern shopping center, the number of transport containers stored at ports and airports, and even the height of storage tanks at refineries. In this way the remote sensing analysts form a very good picture of the real economic activity in an area (Gurtuna, 2013). In Figures 1.8 and 1.9 we observe the modern network of satellites around the Earth is active.

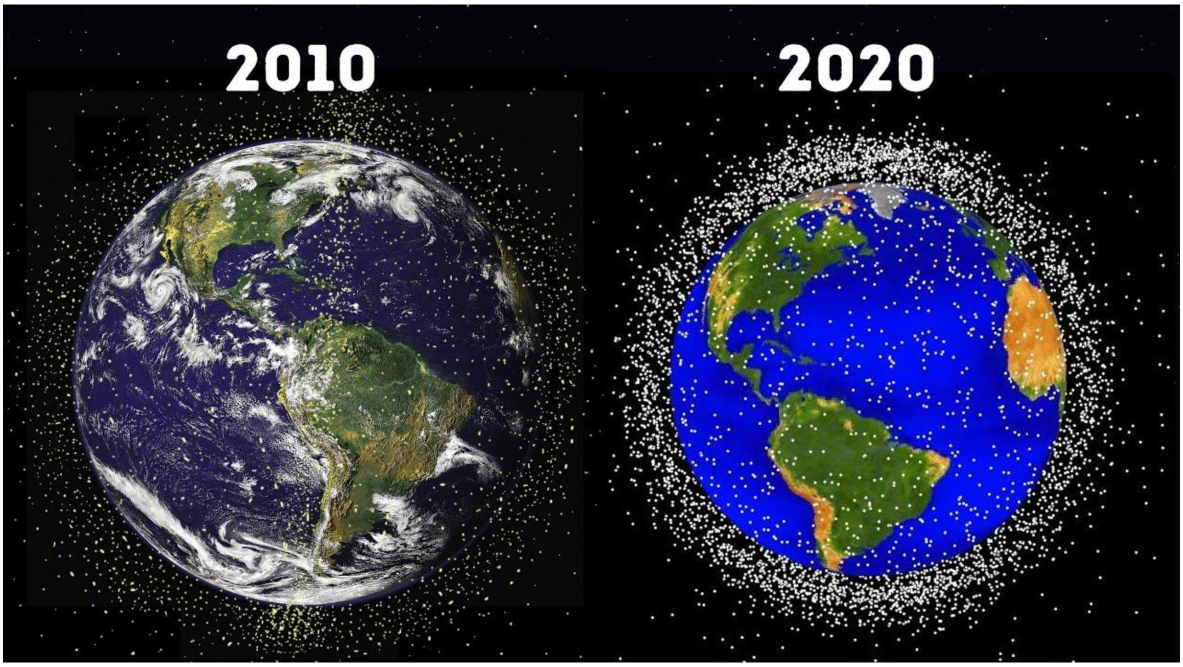

Figure 1.9 We see how much denser the satellite network has become in the last 10 years

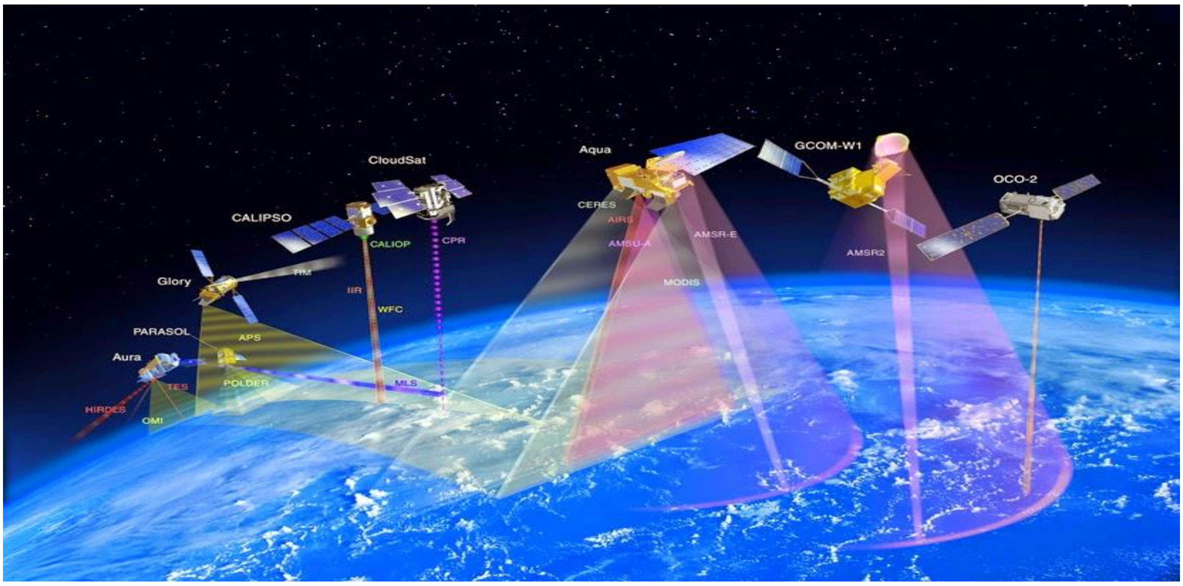

Figure 1.10 Part of the state- of- the- art satellite network

1.3.6 Applications of remote sensing in agriculture

For farmers and all those who work with the land, increasing crop yields and reducing costs with minimizing environmental pollution is a big goal. To achieve this, many farm owners are looking for new technologies to find the best solution for when and where, irrigate, fertilize, cultivate seeds and use modern pesticides and pesticides. Data collected from satellites in conjunction with a GIS environment, draw conclusions about important agricultural factors such as plant health, plant cover and soil moisture and drought. All these are studied from space and provide an excellent analysis of the earth's surface that can be combined with other modern technologies to achieve the goal, that is reducing costs but also increasing crop yields. The study of Landsat images in the long run, the study of Copernicus data as well as data from local auxiliary data such as DEM/DTM, meteorological measurements from meteorological stations, ground element measurements and production data sets, create very great opportunities not only for farmers and agronomists but mainly for entrepreneurs dealing with these issues. Using the right techniques for studying and decoding data, these datasets can enable more accurate performance predictions, as well as very good spatial and temporal analysis. For example, using different types of optical data representations such as RGB composites and new NDVI indicators, a data manager can identify issues affecting crops and act appropriately in affected areas.

We know from remote sensing that crop performance monitoring is mainly based on vegetation indices, such as the Normalized Differential Vegetation Index (NDVI), Advanced Vegetation Index (AVI), Normalized Difference Water Index (NDWI) to monitor crop status. With the analysis of NDVI indices, it is possible to monitor the growth of vegetation, the condition of the fruit and the maturity of each crop. According to the diagram below, a multi-year NDVI analysis was performed using Landsat 8 products from the Spaceye Platform, in order to find the different types of cultivation and to study its individual characteristics. These processes happened in the Illinois USA area. We can see that the soybean crop during the summer is in its highest growth, while the fallow crop is in its lowest growth. It can also be observed that it is possible to accurately distinguish all the different types of crops in more than one time period.

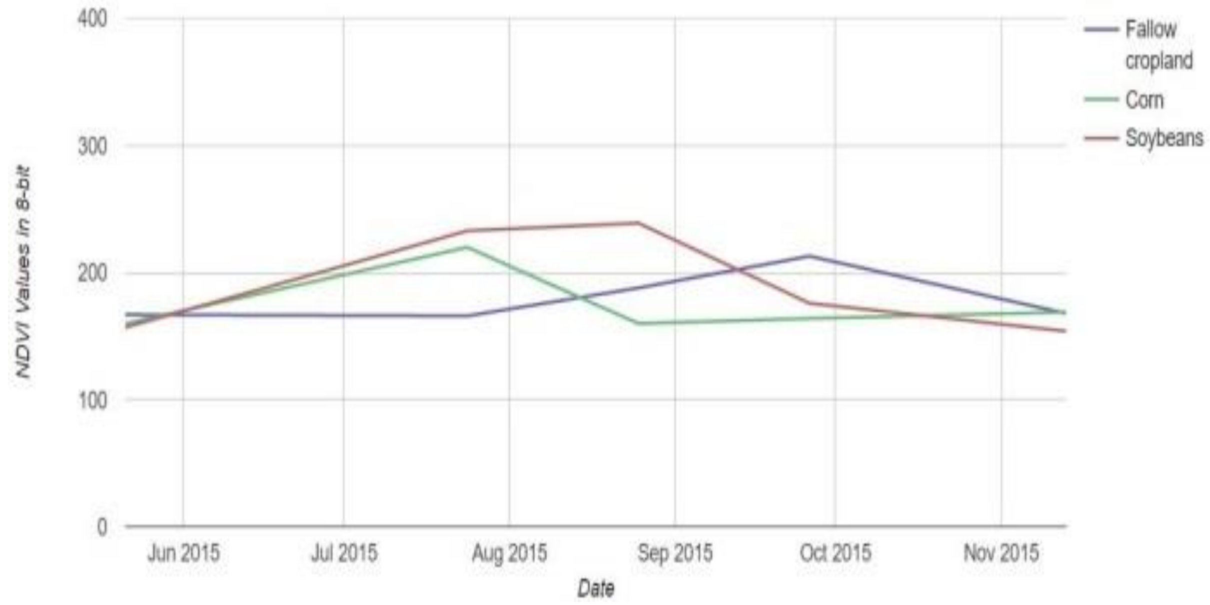

Figure 1.11 Diagram where multi line NDVI analysis was user

Another case of use by Sinergise that shows the use of Sentinel data and NDVI indicators to monitor annual changes in agricultural production and vegetation growth, is presented below. More specifically, the green areas have the largest volume of vegetation, while the yellow and red areas represent areas with less vegetation. This very important information can be used by companies to make management decisions about the most appropriate use of fertilizers and pesticides.

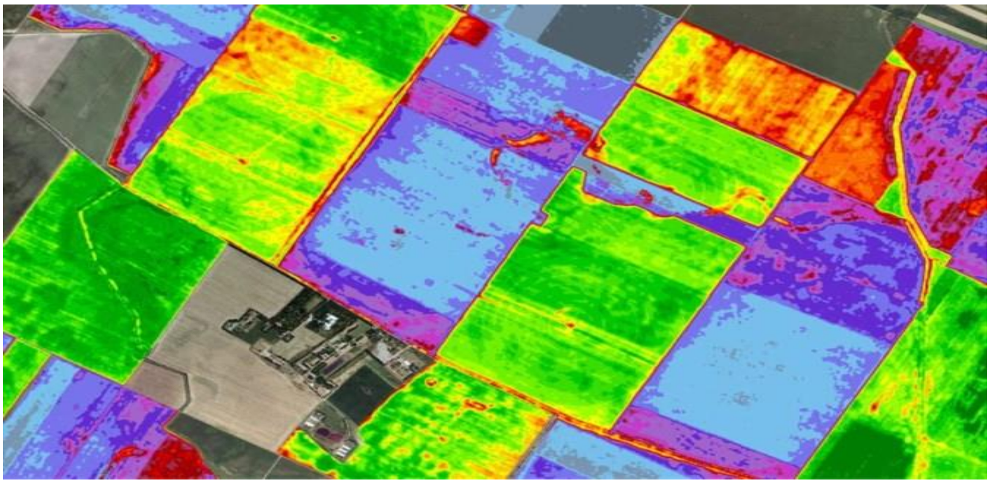

Figure 1.12 Use of NVDI indicators for the monitoring of agricultural cops and their development

In addition, Planet high-frequency imaging satellites provide a continuous flow of information enabling the long-term production of vegetation indices to calculate chlorophyll content and compare it to vegetation strength and productivity. Red tones represent a low chlorophyll content, while greens give a very high relative chlorophyll content.

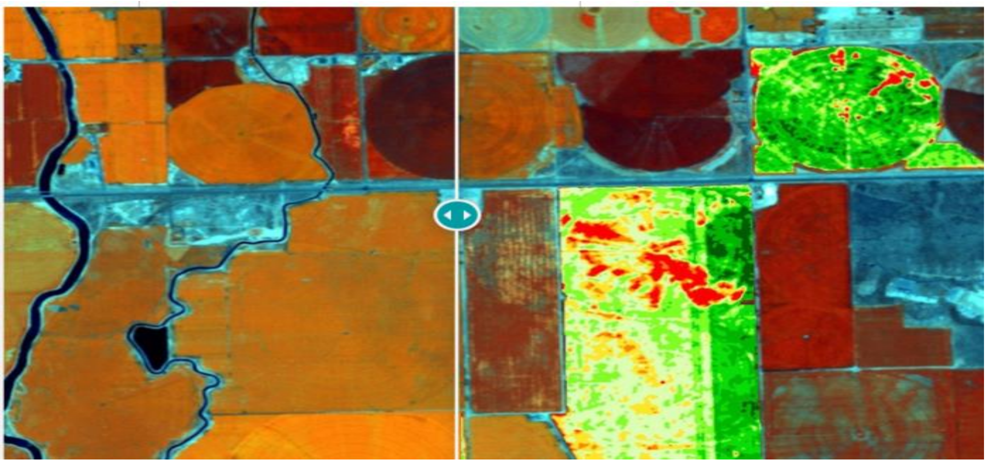

Figure 1.13 Observation of vegetation health and density. Red color indicates sparse vegetation and green color indicates denser and healthier vegetation.

We could say that the excellent information provided by the Landsat program allows us to perform robust time series analysis and examine many crop elements in order to differentiate specific types of crops. In addition, recent free satellite data from Landsat 8 and Sentinel 2 satellites as well as ultra-high resolution (VHR) satellites give us the opportunity to understand real-time crop health status, detect crop problems and monitor crops. the growth of vegetation

1.3.7 Big Data

A very important development that has greatly expanded the use of satellite applications in business is called "big data". Although there is no formal definition of big data, it refers to our ability to collect, store and process huge volumes of data. The huge reductions in the price of digital storage devices, the advent of cloud computing and the virtualization of computer systems have created the right conditions for the emergence of big data. A recent report by McKinsey notes that "the amount of data in the world has exploded and the analysis of large volumes of data will become a central theme of 21st century economic enterprise, unleashing new waves of productivity growth and innovation." (Manyika, Chui, Brown, Bughin, Dobbs, Roxburgh, Byers, 2011). All satellite applications collect terabytes of data daily from a wide variety of sensors. Analyzing this "big satellite data" and combining it with other sources of information will create great business opportunities. The competent services, by collecting the appropriate information of the big data, manage to have successful weather forecasts and other climate data from the National Weather Service. In this way they manage to calculate the weather-related risks for corn, wheat and other agricultural products.

Another interesting application of big data comes from the field of solar energy. The availability of solar radiation at a project site is one of the primary factors influencing the profitability of a photovoltaic project. Sunlight is affected by various atmospheric effects, such as cloud cover, water vapor and aerosols. Therefore, identifying the characteristics of these effects at a project site is essential to conducting a profitability analysis and monitoring the performance of a photovoltaic investment over time (Gurtuna, 2009).

Images from meteorological satellites are very useful for this purpose. Meteorological satellites perched on GEO, such as the NOAA GOES series or the EUMETSAT METEOSAT series, can image the entire Earth at frequent intervals. These satellites carry images that operate in visible and thermal infrared bands, ideal for cloud detection (Gurtuna, Prevot, 2011). To understand the usefulness of big data, it is worth noting that in order to conduct a ten-year historical analysis of solar radiation, more than 100,000 pictures must be analyzed. Today, thanks to advances in data storage, this type of analysis can be done in a matter of hours, turning the first satellite imagery into business decision information.

1.4 Entrepreneurship opportunities in Meteorology and Climatology

1.4.1 Observation methods

Temperature, humidity, rainfall, air pressure, but also the speed and direction of the wind are key observations of the atmosphere that help meteorologists predict the weather. These features have been used since the first weather observations were made. However, the types and quality of weather instruments and methods of analyzing observations have changed greatly. The main weather monitors include thermometers, rain gauges, barometers and anemometers and more modern instruments are the weather balloons, the Doppler radar and of course the satellites. Despite the highly sophisticated equipment available, ordinary human observers still provide important information about sky conditions, clouds, and the type, size, and amount of rainfall.

1.4.2 Weather forecast

Over 210 million weather observations are processed every day in the United States and used to generate weather forecasts. These measurements are taken by automated instruments, professional meteorologists and thousands of trained amateur and professional observers. Observations are recorded and converted into powerful computer models that create global and regional weather forecasts. Meteorologists at the 126 local offices of the National Meteorological Service combine these forecasts with their local observations and knowledge of local weather standards to make a fairly successful forecast for their area. Depending on the needs and interests of society, these forecasts can include forecasts for severe weather, weather conditions for air and sea traffic, fires, volcanic ash, snowfall and air quality that is very important nowadays (NOAA, 2020).

1.4.3 Observing lightning from space and how satellites can keep us safe from a storm

Lightning, the huge sparks of electricity that are created in the Earth's atmosphere, are warmer than the surface of the sun and pose a very significant danger during storms. Knowing when and where lightning strikes can tell us a lot about a storm, including its location, whether it is getting stronger, and whether the storm is capable of causing serious damage. That's where the Geostationary

Lightning Mapper (GLM) comes in. The groundbreaking NOAA GOES East satellite instrument (GOES-16) allowed us to see lightning from space like never before, mapping cloud-to-ground, cloud-to-cloud and lightning in the cloud from more than 22,000 miles above Earth. The groundbreaking GLM instrument is the first optical lightning detector on a satellite in geostationary orbit and is the first of four instruments to map lightning through most of the Western Hemisphere by 2036.

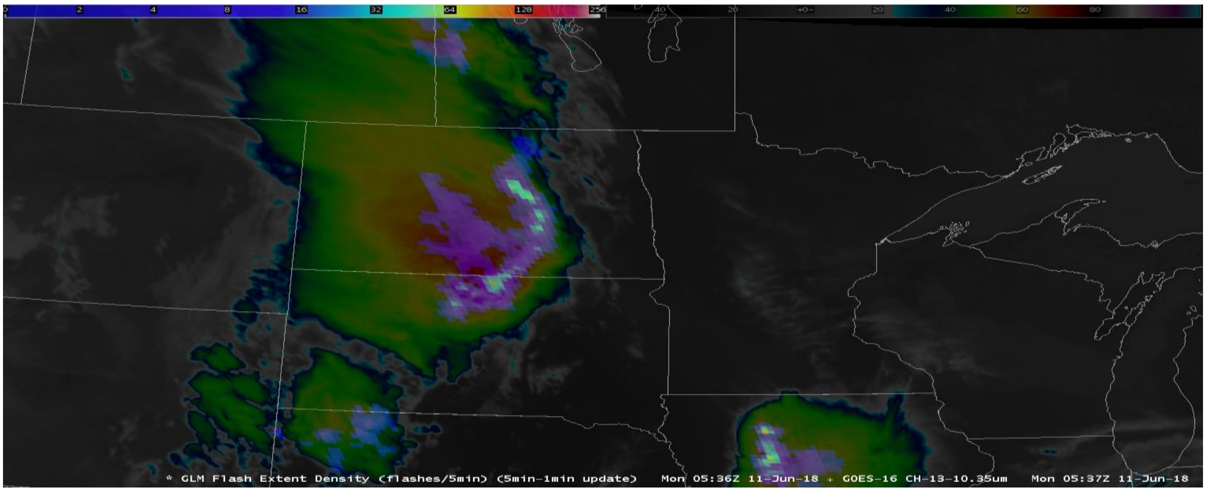

Figure 1.14 This GOES East GLM imagery shows a high concentration of lightning flashes over the Northern Plains on June 11, 2018. (Image Credit: NOAA Virtual Lab)

Until now, all the lightning and thunderbolts we observed from satellites have not been used in operational weather forecasts. But that has already changed, as weather forecasters now have powerful tools in place to monitor severe storms. While the National Lightning Detection Network uses more than 100 ground stations in the United States to detect lightning from cloud to ground as well as in the cloud, GLM offers much greater spatial coverage and in many cases detects lightning before ground lightning detection systems. The earlier we can detect lightning, the more time we will have to issue severe storm warnings. Lightning data from GLM can also help forecasters better identify which parts of a storm are most severe based on lightning density in a particular area. The new GLM "Flash Extent Density" product will allow the National Weather Service to see how often lightning strikes a specific area. When the satellite observes that the number of thunderbolts increase rapidly, it is an indication that a storm is slipping stronger and more dangerous (noaa.gov, 2020). This information provides forecasters with very important information when issuing weather warnings that ultimately improve the safety of citizens. In one case, foremen at NWS Huntsville, Alabama, used GLM Flash Extent Density to help event planners decide if a big outdoor music concert would be safe. On June 1, 2018, a small cluster of multi-cell storms began moving in the direction of the concert venue, but began to split. Using GLM data, forecasters could see all the lightning that occurred both north and south of the outdoor event, as shown in the image below.

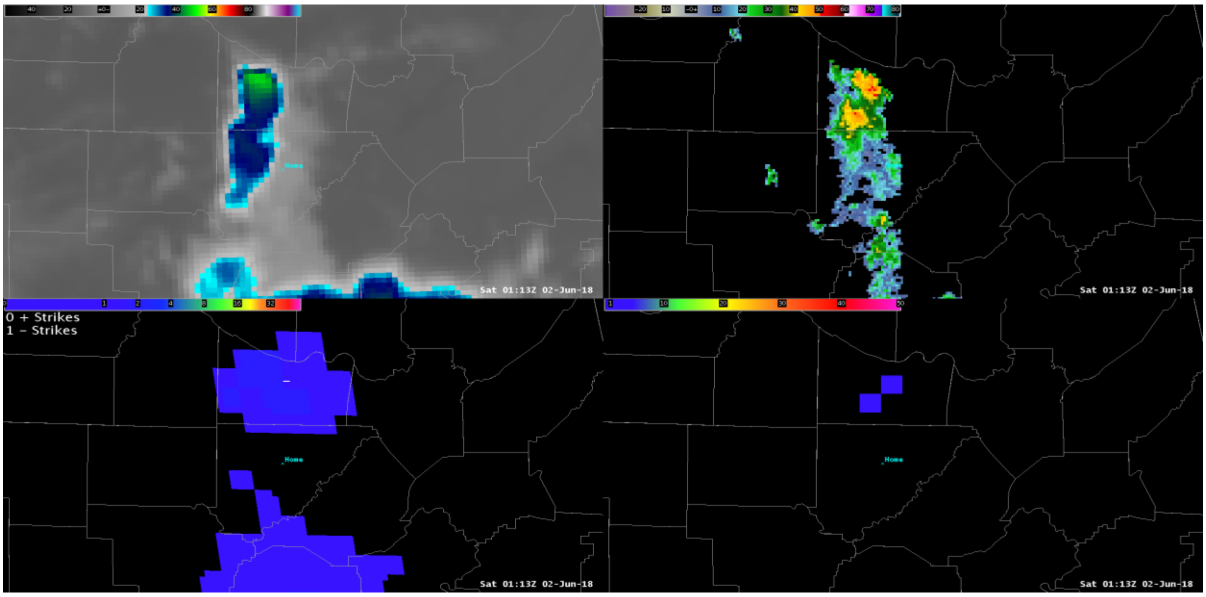

Figure 1.15 The bottom left panel of this image maps the location of lightning from the GLM Flash Extent Density product. The concert location is marked "Home" in light blue. (Credit: NOAA GLM Virtual Lab)

As the storm to the south weakened, the northern storm began to intensify. However, by combining GLM data with infrared satellite imagery and ground-based radar data, researchers could accurately determine that the storm was removed from the outdoor concert, helping to keep 30,000 people away from dangerous situations. Studies on this program have shown that the new Flash Extent Density product can capture lightning speed better than traditional terrestrial networks. Lightning can strike at a distance of 100 miles from a storm, so knowing where it is happening helps meteorologists better inform both emergency managers and the public about the onset of extreme weather events. This is particularly important for aviation safety, which relies on accurate lightning detection to keep aircraft safe both on the ground and in the air. Flash Extent Density is one of three new lightning mapping tools developed for the National Weather Service.

2 Entrepreneurship in Greece and Europe

2.1 The space policy of the European Commission and the strengthening of entrepreneurship

The European Union will play a catalytic role in the coming years in the development of the space industry. In fact, it aspires to be a pioneer with ESA in the most ambitious space programs. A remarkable European factor Maroš Šefčovič said: "The European Union is a key player in space policy. It is essential to take advantage of this and use our leadership strategically to create jobs and growth and achieve our common policy priorities: security, climate change, transport, the economy. data and natural disaster management. This requires working with our partners and stakeholders in Europe and internationally. The joint statement of the European Union and the European Space Agency on the common vision and goals for the future of Europe in space, which will be signed this afternoon, is another important step in this direction."

"Space applications are changing our lives, our economy and our industry," said Elżbieta Bieńkowska, commissioner for the Internal Market, Industry, Entrepreneurship and SMEs. The space sector is a key industry for the European economy and a strategic asset that underpins Europe's autonomy in terms of global action. But we need more entrepreneurs and more private investment to stay ahead. That's why I send the following message to industry, start-ups and investors: Space is important, and our presence there will be enduring."

EU space programs already provide us with many possibilities that make our daily lives easier. When we use our mobile phone we are essentially using space data. Also when we travel by plane or by car and make use of navigation systems again, we use space data. The same thing happens when we watch satellite TV. They are also very important for the protection of valuable infrastructures such as power stations, intelligent transmission networks or even banking. Space data make it easier to monitor the border and save lives at sea, especially in times like today when in many countries, including Greece, we face very strong migration flows. Space data also improves the management of emergencies such as earthquakes, forest fires and floods and enables farmers to plan their activities. In addition, space assistance is very important in protecting the environment, forecasting the weather and monitoring climate change, which has become the biggest crisis that humanity is experiencing today. The space strategy for Europe is a response to growing global competition, growing private sector involvement and significant technological change. The Commission of EU proposes a range of actions that will enable Europeans to make full use of the benefits of space, create the right environment for the development of start-ups in space, promote Europe 's leading role in space and increase its share in the global space markets. The full utilization of space is for the benefit of our society and economy. Now that the infrastructure of EU space programs is well advanced, the focus must shift to ensuring more extensive use of space data by the public and private sectors. EU space programs will provide additional services that will contribute to the achievement of objectives under common European priorities such as security and defense, as well as the fight against climate change. The Commission will promote the use of Galileo in mobile devices and critical infrastructure and improve connectivity in remote areas. It will facilitate innovative businesses and start-ups to access space data through industry-specific platforms to develop services and applications.

The EU's immediate goal is to make the European space sector innovative and competitive. The European space sector must remain a pioneer in an environment of rapidly evolving revolutionary innovation, it must play a leading role in the emergence of new business models as global competition is huge and expands beyond the US and Russia to Asia. EU funding will be more focused on space entrepreneurs starting or growing their business across the single market. In addition, it is very important that the European Commission will promote more private investment for start-ups, especially in the context of the Europe Investment Plan and the forthcoming venture capital fund. The Commission will also fund the creation of European industrial space hubs and cooperatives in European regions. It is also very important to maintain European autonomy in space. Autonomous access and use of space by Europe is of utmost importance for the implementation of our policies, for our industry and businesses, as well as for our security, defense and strategic autonomy. The EU is Europe's largest institutional client and aims to launch more than 30 satellites over the next 15 years under the Galileo and Copernicus programs. This creates a great opportunity, especially for the financial viability of future European-made launchers, such as the Ariane 6 and Vega C. The European Commission will act as a smart customer and group the needs of its own launchers. In addition, it will continue to support European companies access to global markets. Based on an existing initiative, it will work on the creation of an integrated European Awareness Service to protect vital space infrastructure from space debris, space weather phenomena such as solar storms and cyber attacks. With the forthcoming European Defense Action Plan, the Commission will also aim at the initiative for autonomy in government satellite communications, to ensure the provision of reliable, secure and cost-effective satellite communications services for the EU and national public authorities. As close cooperation with our global partners is needed, the Commission will work together with the High Representative and the Member States to promote and protect the use of space for future generations (Europa.eu, 2019).

European Union space programs facilitate the necessary activities of European citizens on Earth. The EU-launched satellites allow millions of people to communicate using new technologies, travel by all means of transport and enjoy the benefits of innovative applications. EU space policy is helping to revitalize employment, growth and investment in Europe by strengthening science and research and serves other policies, such as security and defense, industry and the very important digital sector. In addition, the EU space policy strengthens the EU's role as a global player. According to a survey conducted by the European Commission, the European space economy, including manufacturing and services, employs more than 230,000 people. In 2014, the value of the European space industry was estimated at around € 50 billion, which represents one-fifth of the value of the global space sector.

The overall international space framework is changing at a very fast pace and space activities are becoming more commercial and competitive, while private sector involvement is increasing. Costs are also reduced thanks to significant technological changes. The unique combination of space data and digital technologies creates great opportunities and great business opportunities for all EU countries.

Due to all these developments, a space strategy for Europe was launched in October 2016. The objectives of the strategy are: bring significant benefits to Europe's citizens and businesses, create a competitive and innovative European space sector, increase EU autonomy and strengthen the EU's leading position on the world space scene.

2.2 The EU space program for the coming years

Continuing this strategy, the EU is developing a comprehensive space program for the period 2021-2027. The legislative proposal, tabled on 6 June 2018, brings together all EU activities in one program. It provides a coherent framework for investment. By increasing efficiency, it will help develop new services that will benefit citizens and all EU public and private actors.

On 16 December 2020, the Council and the European Parliament agreed on a political agreement on the regulation establishing the EU space program for the period 2021-2027.The financial envelope of 14.8 billion euros at current prices (13.2 billion euros at 2018 prices) covers: The Galileo and EGNOS programs than will cost € 9 billion, the Copernicus program that will cost € 5.4 billion and the SSA and / GOVSATCOM programs which will cost € 442 million. The agreed text, after its political approval by the Council and the European Parliament, will lay the groundwork for the adoption of the final regulation (Europa Space Programme, 2020).

2.3 The position of space entrepreneurship in Greece

Exactly two years have passed since the day Greece announced the creation of the Hellenic Space Agency, which was semantically a very important step for the country. The first announcement of the then competent minister was accompanied by various comments on whether a country like Greece with so many economic problems in the last decade, will manage to enter the map of International Space Organizations and the great competition that exists in this area. But for those who knew more about space technology in Greece, this concern was excessive since in space in Greece are active about 50 most innovative companies in the country and more than 2,000 of the best scientists we have. The first group of companies in the field of space technology was created in Greece in 2005 with the official participation of our country in the European Space Agency (ESA). In that year there were ten companies, today they have reached almost 50, providing work to more than 2,000 Greek theoretical scientists and engineers active in this field. This creates an innovative treaty after giving the framework for companies, universities and research centers to take part in the very interesting missions of the European Space Agency.

In addition, Greece's participation in ESA is complemented by the country's financial support in this mechanism with about 10 million euros per year and according to ESA regulations this money should be returned to the country that gives it with specific programs and practical results. More importantly, the creation of space agencies shows a maturity for each country taking this step, reminding us that the space market is now a huge market, namely a $ 200 billion market with a growth rate of over 8% annually. On the other hand, Greek companies in this field in recent years are constantly increasing their turnover, which is a sign of very healthy entrepreneurship. The important thing to understand by the world is that space is not just a trip to the Moon or dealing with the other planets. Space is the many applications that we all use every day on our mobile phones and computers. We use space applications all day. Applications that show us the traffic on the roads, the area where we want to go by car, the daily weather forecast, the waves of the seas and many other necessary services. From all this we understand that space creates many opportunities for investment. It is no coincidence that for every one euro invested, seven euros are returned to the economy. The Hellenic Space Agency or a similar organization, if continued as a concept, will help coordinate the actions of Greek companies to produce products that compete in the international market. Greek companies have made significant strides in the field of microelectronics. For example, in the last NASA mission to Mars, the processing of the signal and the compression of the data coming to Earth is done with Greek hardware.

Figure 2.1 The launch of Hellas Sat

Regarding where Greece is today in the field of space technology, we see that in Corallia they managed to have a place in the most hi-tech projects of the country in the field of space. Highly sophisticated companies are now developing, companies that raise even small parts of satellites, software in space, undertake the communication with Hellas Sat satellites, as well as a set of companies that receive satellite data, from images to other data, they process them and offer services, either to the public or to individuals. It is also very important that the space industry in Greece is moving at double-digit growth, both in terms of turnover and exports. There has been a doubling of turnover in recent years as well as a satisfactory increase in jobs. But at the same time with macroeconomic indicators, there is growth in quality indicators, companies now have certifications for their products and submit many patents.

Additionally it becomes necessary that most of the companies have been at least once abroad in the biggest exhibitions. All this results in the direct connection of these companies with the Universities but also the research centers of large countries abroad.

Greece's goal is the US market, but also to expand into specialized constructions such as microsatellite constructions. In addition, in the academic community, the universities of Athens, Thessaloniki, Patras and Democritus do systematic research in space technology with impressive results. Recently, with a mission from NASA, two microsatellites were sent to the International Space Station, which were built by the polytechnic faculties of the University of Patras and the

Democritus University.

According to the professor of Environmental Physics of the University of Athens Mr. Costas Kartalis: "Greek Universities and research centers have been involved for years in issues related to space research and applications of satellite technology, environmental monitoring, the marine environment of land uses, applications that are becoming more and more accessible, as there are many more satellites from the European Union that provide their services for free. For the size of our country there is significant mobility in both the public and private sectors. To talk about the University of Athens, for example, several departments of the University of Athens and the Department of Physics and Informatics run and implement specific programs with funding from abroad, mainly, which have to do with space and its applications. At the University of Athens, the use of satellites monitors the state of the urban environment, how cities operate, the temperature that develops, in which zones there are heat-affected areas, how the city changes, how it expands, how gaseous pollution develops, etc. It is therefore worth it to have a body that will coordinate all the other bodies and will determine the policy for space as we described it above with the various applications to which we could add precision agriculture, the applications that have to do with its archaeological wealth country, etc.”

Greece has been ineffective in recent years in the field of space, because this sector is considered successful when initially public bodies use a lot of space services and then it is extended to private bodies. For example, Civil Protection in previous years did not support its development in space applications, while in recent years it has been doing so successfully in collaboration with major research centers such as the Athens Observatory. It should be noted here that each country participating in the ESA will have to pay a contribution of around € 10 million each year to the Agency's mandatory programs. On the other hand, ESA has optional programs for which each country also pays a corresponding annual subscription. These programs are created to enable companies from different countries to enter space and grow. This money, paid by each country, is returned to the country this time by ESA in the form of industrial project financing. That is, the companies of each country participate in the optional and mandatory programs and they are paid for the work they produce. Greece, apart from being a dynamic industry that is growing at twice the growth rate, also has important rights in space as it has its own very important position at 39 degrees, where the Hellas Sat satellite is located. According to Mr. Thomas Kalamaris, technical director of Hellas Sat, the participation of Greek companies in the construction of future satellites of Hellas Sat is being examined, and in fact on the occasion of the creation of the Hellenic Space Agency, taking place discussions for participation of Greek companies in the construction of future satellites intensified (CNN, 2018).

2.4 The process of creating an ESA incubator in Greece begins immediately

Last September, the European Space Agency (ESA) planned the competition for the selection of the body that will take over the management of the first ESA Business Incubation Center (ESA BIC) in Greece. The operation of the Greek ESA BIC is based on the planning of the General Secretariat of Telecommunications and Posts of the Ministry of Digital Government for the active participation of Greece in the European Space Strategy. The object of ESA BIC will be to support Greek start-ups that are active in the development of solutions and services for space. The center will enhance the transfer of technological knowledge from the applications of Space to applications of everyday life and will encourage the development of start-ups and entrepreneurship in our country. The body that will eventually be selected for the operation of the first Greek ESA BIC will work closely with ESA and will undertake a very important commitment, the support of up to 25 Greek start-ups with a subject related to modern space technologies. Within the framework of its obligations, the institution undertakes the obligation of housing the start-ups and the provision of the necessary technical and legal advice.

Figure 2.2 ESA business incubation centres

The goals of the Greek ESA BIC are: The creation of clusters in which Greek start-ups will participate with a subject related to space technologies, the active participation of start-ups in the development of innovation, the creation of jobs and the encouragement of investments but also the support of the transfer of technological knowledge and from the sector of Space. It is reminded that according to the national contribution to the optional programs of ESA, decided at the ESA Council Meeting at Ministerial level in November 2019, the Greek side has set the following goals:

- Provide support for the development, implementation and monitoring of sectoral policies such as transport, shipping, crisis management, border control, security and defense.
- The use of domestic productive forces and the strengthening of competitiveness. The efficient use of Greek assistance to ESA through fair and transparent procedures.
- Creating synergies with the industry of other countries participating in ESA programs.
- The development, use and upgrade of national existing infrastructure.
- The development of complementary synergies in the context of other European and national programs.

It is important to note that ESA launched the business incubator in 2003 and currently operates 20 ESA BICs across Europe. About 180 startups are selected each year to join the ESA BICs, and to date the institution has set up more than 700 companies employing thousands of highly trained workers across Europe (Startupper, 2019).

3 Innovation in the business world

3.1 Theories and Introduction to Innovation

Innovation has several forms, the open, the closed, the distributed, the linear, the collaborative, but also the radical. Many expressions are used to define innovation processes. Organizations are trying to innovate, but some find it difficult to do so or even understand exactly what innovation means. Here we will analyze the history of innovation and the logic behind the collective effort to create innovation. Next, we describe the dominant models of closed innovation of the 20th century and the factors that led to their downfall. Finally, we look at the very important form of innovation called open innovation.

As we know, commercial activities fall into two types of processes: exploitation and exploration (J.G. March, 1991). So companies are either trying to extract value from existing operations and develop current assets, or to innovate and find significant opportunities that may arise in the near future. While the former falls within the realm of day-to-day business management, the latter is precisely the goal of innovation efforts. In March (1991) it was argued that organizations need to balance their efforts between becoming better and more successful at what they do and learning ways to do things differently. Many companies failed to create a new profile and did not focus on the products and services they had successfully created in the past. Other companies experiment with forms of simultaneous or sequential pursuit of exploration and exploration activities in order to have a better organization (Andriopoulos, Lewis, 2008).

Another interpretation of innovation is very important. Our economists and entrepreneurs describe a different definition of innovation and its application. Sawhney defines innovation as "the creation of substantial new value for customers and the company by creatively changing one or more dimensions of the business system" (Sawhney, Wolcott, Arroniz, 2006). That is, innovation is not just a technological achievement. It can also refer to how organizations manage their activities, interact with third parties or provide their services to others. Innovation requires a collective action and a very organized environment (Hatchuel, Garel, Masson, Weil, 2009). In addition, the need and pace with which organizations must now create new value has grown to a point that is now considered ubiquitous (Birkinshaw, Bouquet, Barsoux, 2010). It is a fact that in recent years innovation has been transformed from the tool of growth into a state of survival of companies (Hatchuel, Garel, Masson, Weil, 2009).

3.2 The evolution of Innovation

We can say that innovation has never been considered an industrial activity. Successful inventions were generally regarded as the achievement of a few geniuses, and learning was accomplished through unstructured approaches such as trial and error (Hatchuel, 2009). Nevertheless, during the Second Industrial Revolution in the early 20th century and the years following World War II, innovation became a formal, streamlined, and rather closed process. We would say that during the golden age of corporate research, companies rarely commissioned the development of ideas, but preferred to innovate internally (Cohendet, 2014). Hune-Brown (2012) described it in detail when he describes how Bardeen and Brattain at Bell Labs created the transistor by placing two gold dots on a German surface to create a wave of power. However, they did not turn to external innovations to create this technology, they preferred to rely on the internal continuous innovation of the company itself. Their work at Bell Labs contrasts with the free flow of information between companies and other actors in the 19th century iron industry, who together innovated to optimize blast furnaces. This change took place in the mid-20th century, when companies had the monetary and intellectual capital to choose closed innovation over a more collaborative framework (Hune-Brown, 2012).

While innovation has always preoccupied organizations, increasing process efficiency is a key feature of ongoing development activities. As we know from a 2010 report, the tech giant IBM interviewed more than 1,500 CEOs, noting that creativity is the best quality a company can have (Berman and Korsten, 2010).

3.3 Definition and interpretation of innovation

By innovation we mean a new and pioneering idea in order to make something happen or the new process of this realization, as well as the application of new inventions or discoveries to achieve a result. Usually the term innovation is used in business, economic and commercial level. According to the definition of innovation proposed by the OECD in the "Frascati Manual", it is the transformation of an idea into a marketable product or service, a functional method of production or distribution - new or improved or even a new method of providing social service. In this way the term refers to the process. Conversely, when the term "innovation" is used to describe a new or improved product, equipment or service that is successfully developed in the marketplace, the emphasis is on the outcome of the process and not on the process itself. Innovation is directly related to research and development, especially in the business sector, with the respective departments (R&D, Research and Development). In the European Union, innovation is usually achieved through European cooperation programs between transnational partners. Innovation in the European Union is measured by the

Innovation Scorecard, which started as an institution in 2006. Innovation is measured by indicators, which are grouped into different categories.

First we can distinguish innovation in technological innovation of products and processes and in non-technological innovation that has to do with organization and trade. It is important to mention ISO certificates or the introduction of quality management and control systems, which are a technological innovation only when directly linked to the introduction of new or significantly improved services. For example, the creation of a simple website with information, without some new and original services we can not say that it is an innovation. But if there are original services then this website is an example of non-technological innovation. Also, organizational innovations are considered technological only if they are based on new technological applications and create proven changes in performance, for example increasing productivity or increasing sales. An important criterion for all types of innovation is that they must contain a change in existing products or services, processes, marketing methods or organizational structures and practices of the company. It is therefore not innovation changes that have little significance and little impact or do not bring about a sufficient degree of innovation in the business, such as cessation of a process, marketing or commercial exploitation of a product, changes resulting from fluctuations in the prices of productive factors, replacement or upgrade of a product or package, custom production, seasonal and other cyclical changes.

Summing up what we said in the end, the term innovation means the new and pioneering idea for the realization of a thing or the new process of this realization, as well as the application of new inventions or discoveries for the realization of a result. The term is often used in economic, business and commercial contexts. According to the definition of innovation proposed by the OECD in the "Frascati Manual", it is the transformation of an idea into a marketable product or service, a functional method of production or distribution - new or improved - or even a new method of providing social service. In this way the term refers to the process. On the other hand, when the word "innovation" is used, it indicates a new or improved product, equipment, service that is successfully marketed, the emphasis is on the result of the process.

The term innovation is associated with research and development, especially in business, with the respective departments (R&D, Research and Development). In the European Union, innovation is an achievable goal through European cooperation programs between transnational partners. Innovation in the European Union is measured by the Innovation Scorecard, which started as an institution in 2006. Innovation is measured by indicators, which are grouped into categories. Relevance to experience, learning and development (Wikipedia, 2020).

3.4 Technological and non-technological innovation of products and processes

3.4.1 Technological innovation of products and processes

Referring to technological innovation, we actually mean "The introduction to the market of a new or significantly improved in relation to its original features, technical specifications, embedded software or other intangible components, intended uses or user-friendliness, product or service". It still can be *the introduction into the business of a new or significantly improved production process, supply and distribution method or support process for other goods and services*. The upcoming result of the process should be significant in relation to production volume, product quality or production and distribution costs. However, we must make it clear that organizational or administrative changes are not included in technological innovation. In addition, technological innovation must be based on the results of new technological developments, new combinations of existing technologies or the use of other types of knowledge acquired by the company.

3.4.2 Non-technological innovation of products and processes

Organizational non-technological innovation is the application of new methods or changes in methods, in terms of the structure or management of the business, aimed at improving the use of knowledge in the business, the quality of goods and services or the efficiency of workflows. Non-technological marketing innovation is the implementation of new or improved sales plans or methods aimed at increasing the attractiveness of goods and services or entering new markets (Wikipedia, 2020).

3.5 Closed models in Innovation

The economic theory and management models created in recent years rank companies based on the capital they have and the strength of their intellectual property (IP). Companies were encouraged to find a competitive advantage, increase physical assets, gain competitors in the market, and protect ideas through IP mechanisms (Barney, 1991). Not surprisingly, the process by which companies bring valuable ideas to market has been portrayed as a highly protected and closed system (Chesbrough, 2003).

Among the first scholars to move away from the so-called black box innovation events and try to describe the dynamics between science, technology and the market was Schumpeter, who devised the technology push model. His work describes the process by which basic research produces knowledge that a company can be transformed into products and marketed (Schumpeter, 1934). Although this model dates back more than a century, most intensive science fields and research and development organizations follow this model today.

As we said above, one of the first scholars to move away from the so-called representations of black box innovation and try to describe the dynamics between science, technology and the market was Schumpeter, who invented the "technology-push" innovation model. Schumpeter's work describes the process by which basic research produces knowledge and ideas that a company can turn into products (Schumpeter, 1934). Although this model was introduced a century ago, most research and development-focused sciences and organizations follow this model even today (Marinova, Phillimore, 2003). For example, any use of nuclear material on the market comes from intensive fundamental research, which is carried out mainly within a limited group of organisms. The Schumpeter model does not take into account external sources of knowledge or pressures from the company's ecosystem and suggests that innovations are the result of individual work. Such an aspect approaches what Dosi (1982) calls "deterministic models" of innovation.

3.6 Open models in Innovation

The idea of open innovation has gained popularity in recent years, mainly due to the work of Chesbrough (2003, 2006). According to Chesbrough (2011), the deepening of the work sectors has created new interactions between a company and external actors, as well as many opportunities to obtain the appropriate information from specialized people who do not belong to an organization. In addition to developing new technologies between businesses and external actors, Chesbrough (2006) says the following about open innovation:

"*... intentional inflows and outflows of knowledge to accelerate internal innovation and expand markets for external use of innovation, respectively. This example assumes that companies can and should use external ideas, as well as internal ideas, and internal and external market paths as they strive to advance their technology.*"

Open Innovation is a workable idea used to describe the concept of collaboration in creating ideas and developing new products and services. It adds an extra choice to the ideal innovation, from working within the company to reaching out. While the theory we describe is a theory of recent years, OI (Open Innovation) is not new in practice. It has to do with a number of collaborative innovation practices that have always existed (Huizingh, 2011). Very important is the point made by Loilier and Tellier (2011) who made a historical review and ultimately does not support Chesbrough's claim that OI is a new development. It pre-existed on a theoretical level. Large companies that became giants, succeeded in technological fields without having developed their practice and technology internally.

Information on OI can be found in other forms of technological development, such as joint ventures (Peck, 1986), R&D alliances (Lambe Speckman, 1997) and exploration partnerships (Segrestin, 2005). While the form, scope and intensity of interactions vary between collaborative models, the logic for open processes remains the same and is based on greater efficiency, reduced risk, of course newer ideas and the ultimate goal of increased sales.

3.7 Degrees of openness and different Innovation practices

Degrees of openness and different innovation practices OI has been used to describe a wide range of initiatives incorporating external partners, but does not include all. Scholars have studied the degree of openness of companies when collaborating with external partners. The degree of transparency, free accessibility and the possibility of a wide replication describe the increasing degrees of access that a company can provide to its external partners (West and O'Mahony, 2008, Balka and Herstatt, 2010). Transparency refers to giving external partners visibility into the innovation process so that the necessary information is available. Accessibility means that external partners can interact dynamically with the process. When we say reproduction we mean empowerment of foreign partners with the tools and knowledge to build technologies in the same way that the company does something that becomes very important.

Companies can choose the degree to which they want to be open to partners in terms of relevant knowledge, production capabilities and the ability to influence design as it evolves from the idea to the implementation of the actual final product. Other companies have used other tactics to control the extent of transparency and select the partners they want to work with. This means that relying on a limited number of partners is an OI form that is described as closed, while a free contribution of someone without restrictions is characterized as an open OI form (Pisano and Verganti, 2008). Innovation interacts with a very wide range of activities, from the creation of new ideas to the commercialization of products or services that arise even with foreign partners as mentioned above.

These interactions between the company and the partners can vary as much as the degree of openness. We can say that external partners can give information and knowledge from the beginning to guide the process, enter the design, development and production phases and of course plan the successful marketing course of innovation (West and Bogers, 2014). Companies interact with foreigners in the idea generation phase to better identify opportunities but also to understand in depth and timely the real needs of the market. But foreigners are also actively involved in the later phases, giving companies the opportunity to adapt the design of their products or the experience of their services (Franke and Piller, 2004). The conclusion from these is that OI can take many forms and ultimately there is no ideal definition that includes all possible interactions between companies. Figure 2-4 shows a series of practices along the open and innovative scales.

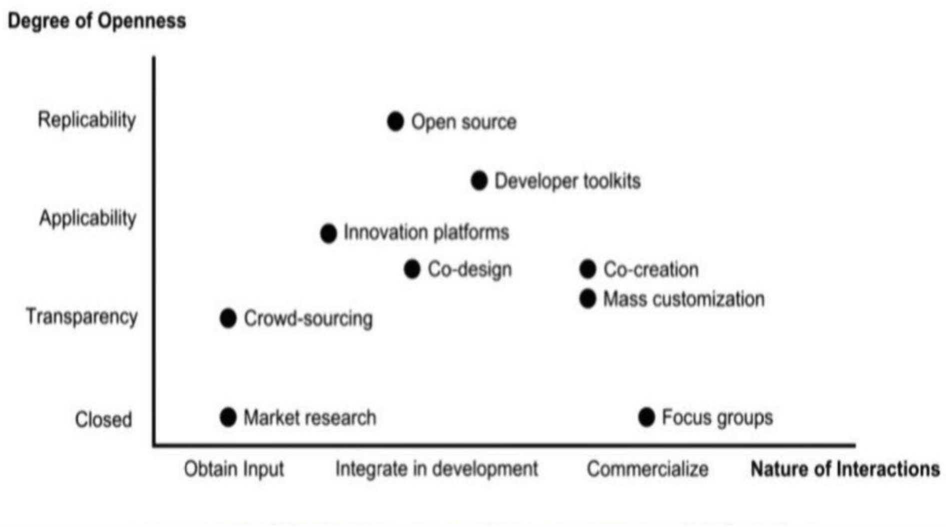

Figure 3.1 Different Open and Collaborative Innovation Practices

3.8 Job definition and key concepts

The existing definitions for open innovation refer to the development of new products and technology, excluding other applications. However, these definitions are also complex and difficult to understand, so we could give a more understandable definition of open innovation:

"Open innovation is the process of strategically managing the exchange of ideas and resources between entities to co-create value."

The European research organization EIDON Lab, creators of the Collaborative Open Innovation Network (COIN) methodology, provides a simple and intuitive model for OI with closed and open channel models (Figure 3.2 and Figure 3.3). Each channel represents the business limits of a business. In the closed model, ideas and concepts come strictly from within the company. However, many original ideas often fail to hit the market and remain unused, as shown by the red lines in the diagram. Only a few ideas such as light bulbs, described in blue lines, make it throughout the innovation cycle, from the initial stages to the delivery to the market which is the desired goal.

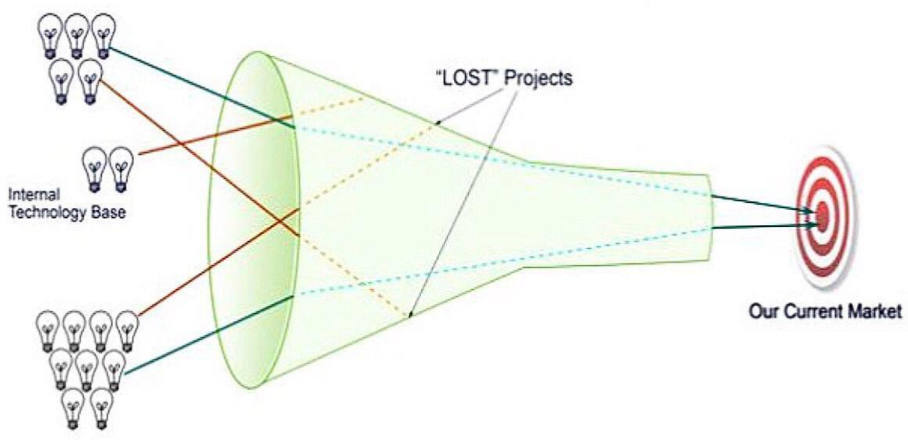

Figure 3.2 Closed Innovation Funnel (Chesbrough, 2003)

We observe that the OI channeling (Figure 2-7) can be considered porous, with holes at each stage in the innovation process that allow collaboration with external entities in order to exchange ideas (Chesbrough, 2003). Channeling describes a successful idea as an idea that reaches the market as opposed to one that prioritizes patenting. Previously set aside internal ideas can now be strategically provided to other entities for use. Once again Chesbrough (2012) tells us that this description of innovation is used more by universities, private individuals and start-ups who want to share their ideas with other entities in the hope of gaining publicity and thus succeeding in entering the their desired industries. This is a general remark but there are many exceptions. Companies need to continue in-house research to build in-house capabilities, identify new great business opportunities and create knowledge that can be used in future innovation projects (Cohen and Levinthal, 1990).

Unlike OI at home, OI abroad uses internally applied external resources to create value-added products and services in order to penetrate new markets. Out-in OI is used more by today's businesses, much more than inside-out (Chesbrough, 2012). The reasons for this are simple: companies are more willing to leverage external ideas and resources for their own benefit, but reluctant to share their own ideas with external entities. Limiting the two-way flow of ideas limits the potential benefits of OI.

To achieve an external and internal balance, companies must follow two concepts:

First the recognition of the advantages outside the PO showing us that there is a lot of information and resources outside the walls of the company that can and should be used. Second the recognition of the advantages of OI showing us that is possible to protect the IP of the company while sharing it with external bodies for the benefit of the company. It also allows them to sell or license IPs and have third parties develop completely new applications. Ideally, the flow of ideas and resources will happen in both directions for the benefit of all parties. This process of creative collaboration between entities to achieve mutual benefit better defines OI and often takes the form of a conjugate process (Enkel, 2009). It becomes apparent that in this way, companies combine the benefits of external and internal approaches, drawing on external knowledge to drive innovation and create value. It is very important that many successful organizations have been able to carry out joint exploration and exploitation activities with external actors, strategically identifying the activities that could be better pursued in a collaborative way (Gassman and Enkel, 2004).

In order to achieve all this, it is necessary to find the ideal partners, to create effective collaborations and to have knowledge of when there should be cooperation and when to do individual work. As innovation practices evolve and open up, it becomes apparent that Open Innovation does not jeopardize traditional forms of innovation such as patents. It is also very important that in the ten years since Chesbrough published his book, the annual number of patent applications has almost doubled (Office Patent and Trademark Office, 2014)

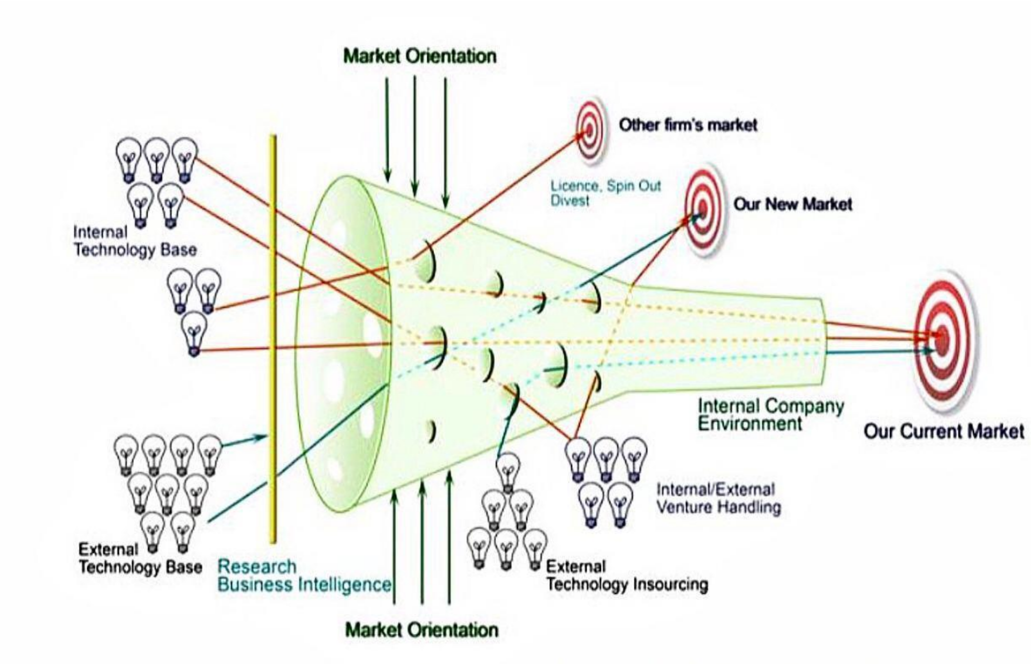

Figure 3.3 Open Innovation Funnel (Chesbrough, 2003)

3.9 The Open Innovation in the international market

Open Innovation does not belong culturally to one direction but is an intercultural concept. That is why the modern revival of OI is taking place on a global basis. First we can say that OI started in the western world. We know that public bodies in the US, the UK, Canada and Australia have begun to implement OI practices to increase citizen involvement in government. This is evident from the tests that were carried out in order to promote the research and networking of experts such as Peer-to-Patent (Lee et al., 2012). An example of such a move is the Jugaad design approach in India which seeks to provide a cost-effective alternative to traditional R&D departments (Radjou et al., 2012). The great technological surprise of recent years China has also begun research on the theory of OI almost simultaneously or a little later than the Western world, and the application of this theory becomes apparent in our time in the Chinese high-tech sector (Ping and Zu, 2011). OI is currently a global phenomenon that is successful both in the western world and in the east.

3.9.1 Open Innovation in industry

Here we can observe techniques that deal with the transparency of processes using a few examples of the most common applications of OI: inside-out-out, a combination of collaboration methods, crowdsourcing and crowdfunding.

3.9.2 Tesla Motors

Elon Musk, CEO of the largest electric car manufacturer Tesla Motors Inc., announced in 2014 that the company "will not file patents against anyone who, in good faith, wants to use our technology." This statement came as a big surprise because it was one of the few times a statement was made by a company that looked to the future beyond micropolitics. Asked about this, Musk said: "We believe that Tesla, other companies that make electric cars and the world will benefit from a common, rapidly evolving technology platform" (Tesla Motors, 2014). A visionary, Musk saw something revolutionary for the competitive age we live in, namely that Tesla's competitor are the large-scale gasoline car industry, not the few electric car companies currently. The goal of this internal strategy is to provide free patents to stimulate the creation of electric car companies, the great development of this market and the impetus for the industry to build the infrastructure that will correspond to the new era of electrical technology. In short, Elon Musk realized that in order to succeed in his plan, that is, the universal use of electric cars by a large portion of the population, other manufacturing companies would have to deal with this technology. This is a great truth because the world and people are not receptive to individual change at all levels.

3.9.3 Procter and Gamble

Procter and Gamble (P&G) is a clear example of the successful implementation of the external input method. To implement it, a large number of technology entrepreneurs came together to identify new technologies and products. The goal was to develop 50% of the products based on this method and to achieve a large increase in their revenue. For example, the electric toothbrush, SpinBrush, introduced by P&G resulted in $ 200 million in its first year on the market (Huston and Sakkab, 2006). This logic called Connect and Develop was about looking for external factors such as suppliers, competitors, research centers and universities in order to bring innovation to the company. The collaboration captures external ideas with the clear aim of increasing innovation and reducing R&D costs. In 2000, P&G may not have achieved its maximum goals, but it had increased turnover and a large reduction in production costs (Huston and Sakkab, 2006).

3.9.4 The technique of Crowdsourcing

In the context of the adjustment that had to be made, Howe and Robinson (2006) gave the following definition of crowdsourcing:

"The act of a company or an institution undertaking a function by employees and outsourcing to an unspecified network of individuals in the form of an open call is the technique of crowdsourcing." This platform is effective for more difficult tasks that can be divided into individual tasks and for tasks that benefit from the diversity of perspective. The organization owns the solutions and the contributor can be rewarded with some form of recognition. The following examples show some advantages of this approach.

3.9.5 Italian automobile factory Torino

Due to the closed nature of the regular development process, Fiat Cars did not meet the needs of their customers. To retrieve them, the company's marketing department was commissioned to design and launch an original car called the Fiat Mio with the help of internet users. With the help of the enhanced information wiki model, they developed an idea for a new open platform for direct customer intervention and interaction. Fiat did not want to have strict selection criteria but encouraged the open public to come up with new ideas for future car designs. Voting took place via the online platform, asking partners to choose the design. From the results, the designers at the Fiat Style Center came up with two separate ideas and started making the prototypes when there was enough information and the valuable help of internet users. At the Sao Paulo Auto Show in 2010, the result was the Fiat Mio, which was first introduced to the public and promoted through social media and information networks. Fiat after seeing the success of the whole concept continued to operate its platform to gain more customer reviews. The information exchanged on the platform is used to introduce new elements to their cars and gain the largest possible market shares from competitors. As a result of all this, the crowdsourcing technique was a valuable marketing tool that helped to improve the visibility and image of Fiat in Brazil and internationally. This very valuable and innovative logic allowed the participation of more than 17,000 contributors from 160 countries, creating more than 11,000 ideas (Saldanha et al.).

3.9.6 The miracle of Xiaomi

Another example is the mobile phone company XiaoMi, founded in 2010 was one of the pioneers in the use of crowdsourcing for the development of mobile operating systems in China (Xiong et al., 2013). XiaoMi's success is linked to the innovation management strategy that involves the customer in an iterative design process (XiaoMi, 2012). XiaoMi's innovative idea included 600,000 volunteers involved in the development of their mobile phone system (Xiong et al., 2013). In Xiaomi's concept, customers are not passive, but interact and participate strongly and often give feedback to continuously improve the user experience. Importantly, due to customer engagement, Xiaomi is able to continuously improve mobile software and applications through weekly updates (Ding, 2012). The crowdsourcing strategy allows them to offer customers specially designed applications that serve most customer needs.

3.9.7 Crowdfunding, the pioneering platform

Crowdfunding is a process that aims to raise money for new projects, raising small investments from individuals or organizations (Ordanini, 2009). When a project manager has the need to raise money, they have the option of proposing ideas or projects and using a crowdfunding model in order to have direct market funding. The various sponsors may then decide to financially support these projects, taking a risk and expecting a specific return. The crowd is actually actively involved in the production, choosing the offers that will be most profitable and with a better perspective. It is necessary to create a coordinating body that will be responsible for maintaining a platform that will allow all parties to work together and start the new implementation. As described by the author (Ordanini, 2001), crowdfunding has been enhanced by recent technological advances, particularly Web 2.0, which offer new opportunities and scenarios where consumers can use, create and interact with other users through the many current social networks.

3.9.8 The AppStori platform

AppStori is a relevant example of OI, both as a crowdsourcing platform and as crowdfunding. The platform seeks to implement a dialogue between developers and users in order to better design applications that respond directly to consumer needs (Appstori, 2014). The purpose of this application is to provide crowdfunding activities to help developers raise large sums of money and then bring their ideas to market. AppStori has successfully integrated a user-friendly interface that allows prospective entrepreneurs to describe their projects in detail and set funding targets. All members of the community have the opportunity to participate in a project as beta testers to promote the project's development or financial support. If a project achieves its funding target on time, the developer will be paid what they are entitled to and the AppStori will charge 7% of the total. If the funding goal is not met, no payment is made to the developer. The platform encourages entrepreneurship and the development of new mobile applications offered by specialized staff, due to the financial support provided by the contributors (Tsai, et al., 2014).

3.10 Economic and budgetary implications of Open Innovation

The main benefit of Open Innovation it that allows co-creation that increases the economic value of existing internal and external resources. A very important development from the use of open innovation is the ability to create monetary value that would otherwise have been completely lost in a closed model of innovation. OI allows companies to leverage external sources of innovation to improve the company's own products or services. External sources of innovation can lead to new products and services. Also the application of OI includes the identification of unexploited very good internal ideas and patents, for possible use outside the company. A company may decide to sell a patent or grant a license to obtain rights that are likely to generate revenue. To achieve economic value creation, the implementation of OI models requires greater involvement of users and customers in the design and development of a product. OI strategies, such as crowdsourcing, are a good example of using the public to evaluate the demand for a product or service. The same logic is used as a marketing method to improve the visibility of a company which resulted in an increase in market share and consequently profit, as in the case of the Fiat Mio car mentioned above.

An innovative idea is to allow external entities to use patents to promote a new industrial production, as in the case of Tesla. OI enables companies to reduce market time for new products or services, but also to reduce production costs. Large and ongoing investment by a company can be risky. But that risk is removed when OI enables companies to share that risk. A very important problem in the implementation of OI is the high cost of coordination associated with the use of different external factors with the internal resources of the company, ie the successful combination of external and internal factor. The storm of information would say a lot of knowledge and ideas between entities must be used effectively.

Another important issue is the redistribution of profit between actors in an environment where cooperation plays an important role. Of particular interest in this case is the definition and ownership of IP between the partners. There are several challenges to crowdsourcing techniques and strategies. One such challenge is how the factors will be evaluated for their valuable contribution, but also how the profits will be distributed in a transparent and fair manner. For example, it is common for companies to start arguing if companies start to make a profit with ideas that come from the crowd and are not primarily their own.

3.11 The role of "human" in Open Innovation and the limitations of Intellectual Property

A further analysis is made by David and Fahey, who explain mainly in their project work that: "... technology is only 20% of the image. The remaining 80% are individuals. You have to get the culture right. "This means that OI is not just an idea or a mentality and strategy, it is mainly people and skills people who need to have the right leadership skills but also culture. The use of internal and external ideas from different sectors can fuel the business innovation process. This is one aspect of this highly complex process. But here a big problem arises (David and Fahey, 2000). As good as external ideas are, a common problem in OI is the "Not Invented Here" syndrome (NIH), that is, the belief that only the inner idea is valuable (Katz and Allen, 1982) knowledge and the way in which partners perceive situations, which in turn affect the success of practices and results of OI. As David and Fahey report, "Organizational culture influences the creation of new knowledge, promotes social interaction, and shapes assumptions about what knowledge is important. It is vital that companies identify internal barriers and challenge their behavior as they engage in OI".

Successful OI processes are closely related to the company's absorption capacity (Cohen and Levinthal, 1990). Absorption capacity is the ability of a company to successfully incorporate external ideas, knowledge or technologies. In addition, companies should store and not completely reject even ideas that they do not use immediately. This retention of ideas is very important because unused ideas could be relevant and useful in future projects inside or outside the company. Another major challenge in implementing OI is tackling opportunistic behavior. Collaboration with external organizations of completely different capabilities can lead to power imbalances. OI poses great risks when large companies try to use their size as an advantage to operate disproportionately and competitively with smaller companies in all areas, from classic competition to hiring the best employees. Due to limited resources and assets, entities must try to find the right balance between the assets of external and open activities with the closed ones.

The introduction and use of IP is a very important part of understanding the impact of OI. The use of IP must be agreed and clarified before the start of a company's internal cooperation with external partners. As for the outcome of the collaboration, an important part of the study is the ownership and use of patents (co-patents, scope), patent licensing, exclusive use of the license, exploitation rights, innovation agreements related to content of the license, of course copyright and publications as well as very key and important collaborations with universities and academics. Opening up the innovation process means exchanging rare ideas and knowledge and giving up control of external factors. In addition, this opening raises questions about the use of new knowledge that is being created. Another challenge that can have legal implications is the loss of control over key assets belonging to the organization as a competitive advantage. A lax acceptance of IP sharing and patent grouping can effectively hinder collaboration because it becomes too complex to manage. For example, a company may be reluctant to work with outside entities if it is required to sign complex NDAs each time its representatives talk about working with outside people. So we see that it is necessary for companies to find a balance between managing the company's internal IP base and implementing an open approach, while protecting key IP elements. It makes sense for a successful partnership to be based on a company's ability to build trusting relationships and transparent interaction with external entities.

3.12 Technical, social implications and quality control

OI operates in different parts of the industry but also in different markets. So there has to be a deep scientific approach to improving important processes, such as the development and production of genuine products. OI can be useful in trying to develop common standards in industries and allow the use of additional products by different companies. The standards adopted allow the cooperation between companies, allowing the development of the production of new products, the quality control mechanisms but also the maximum satisfaction of the consumers. The complexity of technology could be an important issue when considering the impact of OI collaboration. We can say that in high-tech environments, quality control is a very difficult process. This is because it is more difficult for a large company, for example, to adequately manage a more complex network. So such a company may need to rely on external factors to achieve quality control. If one or more partners have a lower level of quality than required, then all the factors in the chain will be affected.

Therefore, when a high level of quality control is required, care is needed in the selection of the appropriate external partners.

It is generally accepted that OI creates many benefits in society that allow different entities or communities to share ideas, knowledge and information. This sharing is very important because it provides communities with knowledge that they would not otherwise have access to. This situation allows the enrichment of society with knowledge and information aimed at industries, organizations, communities and users. This element is important for resolving complex social and environmental issues. The exchange of information is a very fruitful process and can effectively solve unresolved issues for years.

3.13 Impacts of open innovation

The usefulness of OI also lies in the fact that going beyond the boundaries of a company improves the number of ideas that an organization receives using these OI strategies. Openness to society promotes creativity, quality, quantity and variety of ideas. Nevertheless, companies should be quite careful about the exchange of information and knowledge because if this is not done they will lose their comparative advantages. As the idea expands, however, the implementation of new ideas becomes more and more difficult. Organizations tend to converge on a single workable solution that requires a broader disciplined attitude. The introduction of new ideas and multiple players at a later stage may raise the issue of reconsideration of previous decisions. Once commercialized, OI can be valuable in reducing market time when IP is now securely defined. OI can be valuable for the company to better meet customer needs or develop new applications for an existing product or service. These new applications will eventually create new markets and encourage spin-offs and spin-ins.

4 Open innovation in space

4.1 The need to use Open Innovation in space

In this chapter we will describe the implementation of Open Innovation specifically in space. In the previous chapter we analyzed the benefits and the problems of the application of OI in general in various areas. We reported cases of OI in the terrestrial sector, covering both successes and several problems and limitations. In this chapter, we will analyze the characteristics and peculiarities of the space sector and develop the reasons why OI should be used on a large scale in space applications to meet space challenges. We will also look at how OI can interact with the market, commercialization and the very high level of competition that will pervade space in a few years.

4.2 Business motivations, management, cost and risk distribution

As discussed above, the motivation for implementing OI is value creation. Achieving co-creation leads to smaller investments but at the same time higher returns for an organization. This section examines space-specific challenges and how OI can provide us with satisfactory solutions. Based on our study, we have identified four important reasons for the application of OI in the space sector: cost sharing, risk sharing, reduced market time and the introduction of new ideas and resources.

There are several reasons why mass production and commercialization of space components and systems is a very costly process. The terribly specialized know-how required by space requires a very well-trained workforce. In the space it is necessary to use particularly durable and delicate equipment. It is important to know that long-term certification tests are performed so that some material can be used in inhospitable space. But these tests greatly increase the cost of a space mission.

If we go back to the recent past we will see that for example in 2005, the cost of launching payloads in space ranged from $ 15,000 to over $ 25,000 per kilo in orbit (Hertzfeld, 2005). The number and type of satellites launched each year do not allow the mass production of space data. So we have a big increase in space materials per unit. So we see that innovation in this area required a large investment, which could only be made by large companies or governments. This has created a problem and an obstacle for small and medium-sized enterprises that want to be actively involved in space. One of the key things that happens in OI is cost sharing. This is achieved if we divide the investment according to the partners we have available. In this way we achieve a reduction of the capital required for each individual company. This cost reduction can occur at any stage of research, development or even later.

It is generally known that the space environment is full of challenges. An important reason for these challenges is the great dangers that this space poses in contrast to the earthly environment. Challenges such as space weather phenomena, space meteorites that can destroy satellites and other spacecraft, and the high gravity and space vacuum that pose a major risk to human life concepts and space constraints place limitations on spacecraft. future shipments. Installations used in Earth qualification tests have limited capabilities for reproducing the harsh space environment. This increases the risk of hardware failure.

In order for a product to be ready for a space flight, a technological protocol must be successfully followed. In order for such a product to be marketed, it is necessary to carry out a large number of complex tests. However, many companies are unable to meet these challenges and ultimately fail to enter the space industry. All this results in OI being affected because it needs increased cooperation which eventually decreases.

4.3 Introduction of new ideas and resources

Because the risk is very high, the costs are also very high and the participating entities are few compared to other sectors of the economy, space companies are often very specialized and experienced in a particular field. All this effort requires very large funds and huge sums of money that few companies can afford. These sums of money are necessary in order to acquire and then develop the appropriate technology for space needs.

So it is very important to open to new ideas and of course resources for the success of such an endeavor. A very innovative case of introducing new ideas was the adaptation of solar panels for space applications. Solar panels were invented around 1950, but had no ground applications due to their poor performance at the time. In space, however, the advantage of solar panels over simple batteries was that they were much lighter and lasted much longer. In addition, a very important detail of space is that solar energy is not obstructed by the Earth's atmosphere and so solar panels could be placed to receive solar energy continuously and unaffected (Perlin, 2014).

4.4 Advantages of Open Innovation in Space

In the figure below we observe how the flow of information takes place in space sector. We have nodes but also connection lines. Each node represents an entity, and each connection line represents potential interactions that occur. Nevertheless, the advantages of OI in the space sector can be divided into advantages for private industries and advantages for companies.

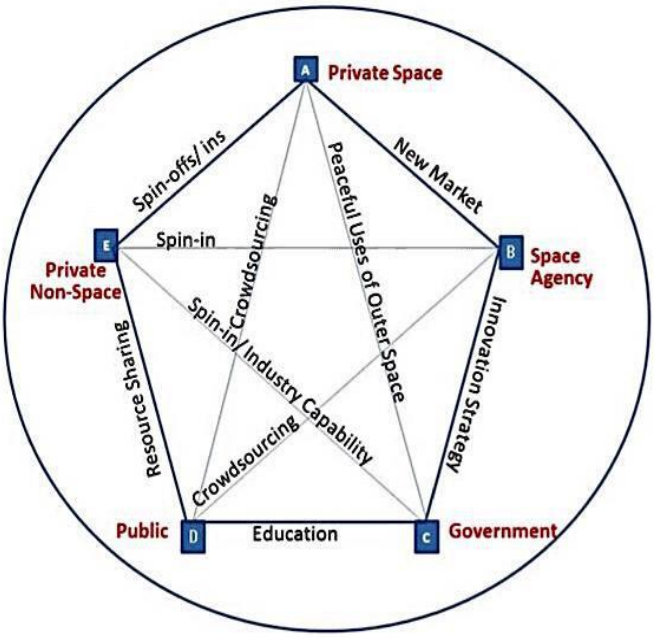

Figure 4.1 Advantages of Open Innovation in Space and Non-Space

4.4.1 Benefits for private and public sector

As we have understood there are many OI applications in the private sector. Elements such as the cost of developing a project, creating tools, and developing IPs can be shared between entities. Bringing the various companies together also means that the financial benefits and the infrastructure created during a project must be properly distributed among them. We must emphasize that by properly implementing the OI we can greatly reduce the project implementation schedules. In addition, however, in this way we can achieve maximum efficiency regarding the human resources that we will use, the distribution of money and investments, but also the construction and use of machinery. Within OI, these resources are distributed proportionally and correctly between the various entities.

Also the various entities and companies have access to resources, ideas and knowledge from larger companies and organizations. It would seem impossible for the smaller companies to do this on their own without this help. Examples of OI applications in the private sector are the activities of companies such as NanoRacks, PlanetLabs and NanoSatisfi.

It is a fact that space requires global cooperation among all other sectors of business and economy. This is necessary because in this area there is great complexity in construction, but also reduced budgets due to the generalized global financial crisis that occurs since 2008. OI is what helps organizations to create a strong environment of cooperation and mutual support in order to overcome the difficulties that will arise in the future. In addition, it helps to eliminate the enormous inaction that exists in the national services regarding the exchange of knowledge, ideas and resources with external bodies. OI is also contributing to the development of a new business model that may dominate the world in the coming years. (Svenja, 2013). So we see how important the cooperation between internal and external bodies in order to develop a successful OI.

The benefits of OI between space and non-space sector are shown in Table 4-1:

Benefits of OI	Private Space	Private Non-Space	Space Agency	Public	Government
Commercial Exploitation	*	*			
Supply Chain	*		*		
Enhance Industry Capability	*	*			*
New Market		*			
Public Participation			*	*	
Promotes Education				*	*
Promote Peaceful Uses of Space					*
Widespread Collaboration	*	*	*		
Cultural Benefit			*		*
Attract Funding	*	*	*		
Optimization of Resources	*	*	*		
Simultaneous Problem Solving	*		*		*
Access to Resources and Knowledge	*			*	
Reduced Product Development Time	*		*		
Improved Program Timeline			*		
New Source of Income	*	*			
Explore Hidden Innovation Potential	*	*			
Make Alliances	*	*	*		
Participation through Crowdsourcing			*	*	
Win-win Partnership	*	*	*		
Strategic IP rights Management	*	*	*		
Cross-Border Networking	*		*		*

Table 4.1 Benefits of Open Innovation for Different Sectors

4.5 Risks of Open Innovation in Space

While we have developed many of OI's positives so far, it is time to analyze the dangers of such a framework in space.

4.5.1 Risk of commercialization

The elements that make OI breathtaking, also contain some important risks that we must take into account. For example, an important asset in OI is the loss of control over many aspects of the business, including knowledge sharing, significant costs, and the timing that must be met. This is more common in the space sector due to the complexity of projects and technology, but also the time required to complete a project.

4.5.2 Risk of choosing a strategic associate

Another important parameter is choosing the right partners. This is an issue that concerns the commercial actors of space. A partner's reduced performance can catalyze a company's reputation in the space industry. Due to the low number of companies and partners in the space industry, a very negative performance and criticism could create a big blow to future companies.

4.5.3 Management risk

It is important to note that companies that want to move from closed to open innovation run the risk of facing significant challenges. A major change within an organization can lead to layoffs, temporary poor performance, and major ethical issues.

4.5.4 Danger of Intellectual Property

Intellectual property is an area of great concern to companies involved in the space industry. The lack of priority of IP sharing creates potential for conflict and great administrative and organizational burden. The IP risks involved in OI are:

The possibility of losing patent opportunities, loss of confidential but also highly confidential information, great risks in design and copyright. In addition, new competitors can be created through the exchange of information.

4.5.5 Risk of profit distribution

Financial incentives are perhaps the main motivation for adopting OI in the space industry. However, it can be difficult to measure the contribution of all partners to the end result. The uncertain distribution of benefits can make participants reluctant to invest in OI. Also, many associates may exhibit opportunistic behaviors, which will put OI at further risk

4.5.6 Financial risk

The space industry is characterized by a long process of partner interaction to produce the final product. This makes partners who do not show stability over time dangerous. Companies could suffer from partners who cannot sustain their investments in the long run. The factor of cooperation between different and distant countries is also important, as there is a risk of exposure to changing political, economic and geopolitical situations.

4.6 Sections for Open Innovation in Space

In this section we explore different contexts for using OI. Examples of organizations that use the concept of OI in the space sector help to link design with implementation.

The table below would show a matrix containing possible OI methods that could be used. Space activities are divided into three phases: Research, Development and the various Functions. The table follows.

	Research (Phase A/B)	Development (Phase C/D)	Operation (Phase E/F)
Sharing Cost	Co-research (universities and research institutes), Sharing laboratories (Agencies, research institutes), Open-source	Co-development, Open-source, Public-Private Partnership, Crowdfunding (e.g. Planetary resources, Nanosatisfi)	Crowdfunding Sharing of resources Open-source data mining (e.g. Space Apps)
Sharing Risk	Co-research, Public-Private Partnership	Co-development, Public-Private Partnership	Sharing resources (e.g. Nanoracks), Sharing data
Decrease Development Time	Spin-in	Spin-in, Use of Commercial Off the Shelf (COTS) components (e.g. PhoneSat)	Open-source data mining (e.g. Space Apps), Technology demonstration programs (e.g. Proba)
New Ideas / Resources	Prize-based challenges (e.g. Innocentive, Centennial Challenges), Spin-in	Prize-based challenges (e.g. X-Prize, Innocentive), Spin-in	Spin-in (e.g. KickSat), Prize-based challenges (e.g. X-Prize), Open-source data mining (e.g. Space Apps)

Table 4.2 Open Innovation Mechanisms Based on the Project Phase and Desired Benefit

It is necessary to provide a framework in which traditional contractors can use OI methods in their work. The research and development phase according to the TRL can be divided into three phases: Proof of feasibility must be done first (TRL 1 to 3): In this phase, the basic principle exists and a proof of concept is formulated and realized. This is the main research phase. Next we have the Technological Demonstration (TRL 4 to 6): In this phase, the proof of concept is validated in environments that are increasingly related to the real space environment. This is essentially the development phase. Finally we have the Validation of technology (TRL 7 to 9): In this phase, the idea is validated for its end use in space. This is the final stage of development.

Table 4-3 shows the general characteristics of the various TRLs and lists the potential OI concepts and key partners that can be used to improve the way in which different contractors can operate.

TRL	Key characteristics	OI concepts	OI Key partners
1 2 3	Uncertain applicability High investment Difficult to make profit	Spin-in of basic research outcomes Reduce costs: Research partnerships, sharing of research resources (laboratories)	Universities, research centers, agencies (funding)
4 5 6	No certain outcomes High investment No finished product, but already product which could be used	Spin-in of TRL-3 concepts from external sources Joint development Crowdsourcing Prize as development model Licensing (spin-out) of basic concepts	Research centers, industries, public agencies (funding and research facilities)
7 8 9	Joint development Crowdsourcing Prize as development model Licensing (spin-out) of basic concepts	Joint development Spin-out /licensing	Agencies (funding and research facilities), industries

Table 4.3 General Characteristics with Respect to TRL, Possible OI Concepts and Key Partners

4.7 Legal and Political analysis

When we refer to space laws, we mean a set of international and national regulations governing human activity and related to space (Kopal, 2008). While when we refer to space policy, we essentially mean a political process in which serious decisions must be made in order to implement a country's national strategy regarding its space operations. A space policy not only dictates national policy in relation to a space program, but also the nation-wide policy on the use of space for many purposes, such as military and commercial purposes (Goldman, 1992). At the international level, national space policy clearly shows the country's position on how it will move in space in the coming years, as it gives internal entities a framework characterized by transparency and obedience to both national and international rules. of international law. National space policies set long-term national targets that allow their space agencies to plan for the coming years. Some examples of national space policies include the United States National Space Policy (Obama, 2010) as well as the Brazilian Space Policy (Brazilian Space Agency, 2005). Both national space law and politics are used to determine a country's space and political and military activities.

4.7.1 Data to national countries program

Especially after the year 2000, there was a large increase in the number of actors involved in space activities. We can therefore say that almost any nation could be characterized as space, where the space race refers to a nation that uses space information for internal purposes (Sharma, 2012). But although a nation may be space, it may not have its own political or legal structure that determines its space action. The Outer Space Treaty (OST) in Article VI states that nations are responsible for the development of their national space laws, but regardless of whether they have a space policy, states must ensure that their space programs comply with international law.

Emerging and traditional operators have different purposes regarding space programs. Emerging actors focus on a political and legal framework that can be used to enable a country starting its space business to integrate external knowledge and information in order to achieve its internal development. The various traditional actors are adapting their legal frameworks and policies, not only for internal benefits, but also to upgrade their international position in the international global environment (Sharma et al, 2013). We could say that almost all national space programs owe their launch to a combination of national determination, available know-how and available resources. This is the only way to develop successful space programs. (Sharma, 2012).

In recent years, ESA, China, Japan, India, Israel, Russia and the United States have been making great strides in space. Nevertheless, the United States, ESA and Russia account for 90% of the global space budget, but it is for political rather than military activities. The great success of these countries is mainly due to the fact that they have defined a specific national space policy for years and have succeeded in international cooperation at all levels. Nowadays, national space policies do not impede the implementation of OI in the space sector, however they do not impose a specific national strategy in the adoption of OI (Sharma, 2012).

Although national space policies are designed to serve the social and economic interests of actors, the vast majority of actors have the following common goals (Sharma, 2012):

Develop specific space policies to serve the public policy objectives of the various states. To ensure that the security needs at national and defense level of the states are served in terms of space. Ensure unlimited access to specific and innovative technologies that allow states to have an autonomous entity. Finally, to expand international cooperation and to share resources as much as possible in order to develop through mutual assistance. In defining national space policy, bodies consider all the principles set out in the 1967 Outer Space Treaty (OST) to create a framework for new legislation. Some of the principles analyzed in the OST and found in (United Nations Office of Foreign Affairs, 1967) are listed in the table below.

Article	Principle
1	Exploration of outer space, including the Moon & other celestial bodies is the province of all mankind.
2	Outer Space, including the Moon and other celestial bodies is not subject to appropriation.
3	State parties shall carry out activities in accordance with international law, including the charter of the United Nations.
6	States are internationally responsible for their national space activities, including the national space activities of non-governmental actors, and States are tasked with ensuring their compliance with international law through authorization and continuing supervision.
7	States shall be internationally liable for damages to other States party to the OST for their launched space objects.
8	States retain jurisdiction and control over their launched space objects, and any personnel aboard, which are placed on their national registry of space objects.

Table 4.4 Principles of the Outer Space Treaty

The OST gives us a general framework that describes the activity of states and intergovernmental organizations in space. This framework was subsequently expanded with more conditions by the United Nations Commission on Peaceful Space Use (UNCOPUOS) for the proper enforcement of the respective obligations imposed on national bodies. While the vast majority of national actors have agreed on the principles described in the OST, they nevertheless also take it for granted that space is a very important area in order to achieve national security. A very important process for the development and application of important technologies is the encouragement of the defense capability of the states. National security, however, was a very important area in the activity of states in space, so the issue of separation of military programs and those with a purely scientific basis was raised. But in the end, the lack of clarity between different sectors creates legal issues and challenges in how OI will be implemented in the space sector. The following section describes the dual use of space technology and some of the challenges in implementing OI. Legislation applicable to space as a whole has implications for all space industries. However, the legislation, policies and legal framework established for a specific space industry do not necessarily affect the entire space sector. We therefore observe that the application of OI in the space sector as a whole, faces three important obstacles which we analyze.

Treaty Name	Abridged Name	Year of Enforcement
Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space	Rescue Agreement	Adopted by the General Assembly in resolution 2345 (XXII). Entered force: December 1968
Convention on International Liability for Damage Caused by Space Objects	Liability Convention	Adopted by the General Assembly in resolution 2777 (XXVI). Entered force: September 1972
Convention on Registration of Objects Launched into Outer Space	Registration Convention	Adopted by the General Assembly in resolution 3235 (XXIX). Entered force: September 1976
Agreement Governing the Activities of States on the Moon and Other Celestial Bodies	Moon Agreement	Adopted by the General Assembly in resolution 34/68. Entered force: July 1984

Table 4.5 The conditions and some obligations

4.7.2 Important Export Control

The dual use of space technology (ie for political-scientific as well as military purposes) creates problems in the transfer of technology to commercial applications, not only due to export control restrictions, but also due to problems arising with intellectual property as well as commercial intellectual property rights. A prime example of this would be the International Traffic in Arms Regulations (ITAR) and the United States Munitions List (USML), as enacted by the United States Department of State (DoS) and the Department of Commerce (DoC). We note that under US national law, ITAR primarily mandates space companies to interact with third parties, including entities outside the US. So we see that in essence a collaboration is needed between US entities and entities from other countries. All of this came into play in the Cold War. ITAR was created to safeguard US interests and limit US technology leakage to other countries. ITAR not only has a huge impact on US space activities, but also significantly reduces the international space technology and merchandise trade (Minerio 2011, Kaufman 2008, Air Force Research Laboratory 2007, Chao 2008, Platzer 2009). The dual role of space technology combined with the constraints imposed on technology transfer by national and international regulations such as ITAR and the Wassenaar agreement (Wassenaar agreement on export controls for conventional weapons and goods and dual-use technologies) will continue to operate as an obstacle for commercial entities aiming to implement OI in space. ITAR needs to adapt in the near future in order to more successfully support US interests, which should include major international partnerships.

4.7.3 Intellectual Property rights

IP refers to thoughts and creations of the mind, such as inventions, literary, scientific, and artistic works and images or books or symbols that can be used in commerce. IP usually refers to the following categories:

- In the industrial property which covers trademarks, patents but also design that has to do with the industry.
- In copyright which refers to literary, scientific and artistic works.

It thus becomes apparent that intellectual property rights can be defined as property rights as protected by national and international law giving the inventor or creator the right to benefit from his own work or investment in the design and creation of a product. When it comes to intellectual property in the context of OI, legal research is concerned with open source software or user-generated content (Nari et al., 2010). This focus reveals several ways of technology and is a key challenge for the application of OI in the field of highly regulated space settings for the following reasons:

- Many times there are several plaintiffs who may have conflicting interests in applying OI.
- In addition, the current IP law does not regulate the way in which rights interact with co-inventors and co-owners.
- Proper protection of inventions and new ideas becomes quite difficult under the existing patent structure.
- The contract terms contain several ambiguities and thus can be interpreted as incorrect contracts. (Nysten-Haarala et al., 2010).

According to current developments, although there is a new presence of commercial entities that want to expand in the space sector, most of the space activity is still carried out by government entities and the states are still the most important customers for commercial contractors. The legal regime under which companies are familiar with existing processes or closed innovation works as a deterrent to turning to an OI framework, where legal and fiscal uncertainty are high. Nevertheless, OI has been successfully implemented in several space industries, but its future application in the entire space sector, as well as the participation of commercial entities, depends to a large extent on:

- Removing barriers to technology transfer. In this way, the commercial market will be substantially strengthened.
- The amendment of the law on intellectual property in order to make a more correct management of rights concerning co-creators and co-owners.
- IP protection that concerns knowledge and the idea and becomes a source of income.

- Having serious and sustainable business plans in terms of space and let the state lead them.

However, the stabilization and greater clarity of international law regarding space is very important.

4.7.4 Socio- Economic implications on political intention

A very important part of space investment has to do with the political will, that is, the political support that a government offers to allocate financial resources, as required to achieve a space project or mission. Political will can be defined as the sum of domestic and foreign policy concerns that address the consequences of national space activities in very important areas of a nation, such as: national security, the domestic economy, the prestige of a country and political influence at regional level. and globally (Broniatowski et al., 2008). It is very important to emphasize that international cooperation often contributes to the greater success of a project. This is considered very serious because we realize that a change in the political support of a project will create major obstacles and perhaps a complete failure of the project (Broniatowski et al., 2006). Space projects and missions require long-term planning and the political changes that take place within each country create problems in the implementation of these projects. An example is the changes in funding that occur when governments change. This is a major concern that affects the political will. Exceedances in the cost of a space project are also common due to difficulties associated with cost estimation, including the ever-increasing complexity of the project as construction time passes (Keller et al., 2014). These concerns have led to a decline in US political will to continue funding Constellation (Review of the US Human Spaceflight Plans Committee, et al., 2009), a major mission to return humans to the Moon by 2020, something which as we know failed.

We therefore observe that OI has a direct impact on a country's domestic and foreign policy and is therefore a key issue for political leaders. Another major problem in the international implementation of the OI is the reluctance of countries to transfer know-how that can be used for military purposes. For example, a 2008 paper from the European Union Institute for Security Studies recommends that the EU continue high-tech cooperation with China, while at the same time trying to manage competitive risks in innovation and high technology without significant losses (Stumbaum, 2009).

4.8 Significant cases of company success in Space

Despite the problems that exist, some space organizations are already using OI methods and are doing so successfully. This section examines how some very important companies have successfully implemented OI.

4.8.1 Neptec

Neptec Design Group Ltd is a privately held company based in Ottawa, Canada. The company was founded in 1990 and became the main contractor of NASA in 1995, providing the organization with very important robotics solutions that eventually helped build the ISS. Neptec has helped achieve more than 40 space shuttle missions and won the 2011 NASA George M. Low Award for Outstanding Performance and Quality. In 2011, Neptec Technologies Corp. was founded to integrate and commercialize the technologies developed by the Neptec Design Group. The two companies differ in structure and their customer portfolios are quite different. However, working in the same building enables the two companies to have access to common services. Such services are the human resources but also the various offices. The high level of knowledge exchange also gives both companies a significant competitive advantage. The risks and benefits are shared between the two companies and they maintain a strong relationship of cooperation and mutual protection.

Neptec TriDAR is a 3D laser vision system that allows autonomous vessels to be guided in a wide variety of lighting conditions for various purposes whose shape, precise position and orientation may not be known. This project was funded by the Canadian Space Agency (ASC-CSA) and used in three Space Shipping missions. The TriDAR system enables different spacecraft with or without astronauts to meet equipment that is not labeled with optical connection indicators. On July 13, 2014, a commercial cargo ship Cygnus successfully approached the International Space Station (ISS) using the TriDAR vision system.

Creating successful innovations from Neptec Design Group such as TriDAR, Neptec Technologies Corp. has created a new system, the OPAL (LIDAR) detection and illumination system. OPAL is a robust, three-dimensional vision system that penetrates 360 degrees of dust and is available mainly for military applications of low visibility but also for situations of excavation and ground detection and selection of the right equipment. This new technology sensor is designed specifically for commercial markets, but incorporates many functions and technologies originally developed for space applications. Neptec Technologies markets OPAL to terrestrial industries, which provides market diversification thus reducing reliance on space companies. Neptec nevertheless has the necessary knowledge to return at any time it deems necessary to the space missions from the terrestrial operations it operates. This dual innovation system allows both companies to exchange ideas with each other, while sharing the risk and benefits in different industries and markets (Neptec, 2011).

4.8.2 Macdonald, Dettwireland Associates

Another very successful company is MDA which is a Canadian company originally founded in 1969 and has gained the forefront as a global communications and information company and a major company in the Canadian and international space sector. The MDA made a major contribution to the construction of the space shuttle and was actively involved in most of the International Space Station (ISS) programs. These programs include: communication antennas, Canadarm, Canadarm2, Dextre and the Robotic Work Station, high technology related to the construction of the ISS and its daily activities. The company also contributes to space exploration by building several scientific instruments at the Mars Science Laboratory and Phoenix Mars Lander, and most recently created a LIDAR scan for NASA's OSIRIS-REx mission to provide a high-resolution 3D map of a important asteroid being studied. Utilizing the vast experience and know-how gained from the creation and operation of Canadarm, MDA partnered with the University of Calgary to create NeuroArm, a state-of-the-art robotic system designed exclusively for neurosurgery. Working with the Seaman Family MR Research Center at the University of Calgary, MDA engineers have developed a high-tech robot that has great advantages over human hands in delicate and difficult surgeries. The control system designed for Canadarm has been adapted to allow a surgeon's hand movements to be more stable and successful in a complex operation. The NeuroArm system commands to capture very high-resolution MR images in all phases of an operation. 3D views display real-time data to the surgeon. NeuroArm was used with great success in 2008 in a very difficult surgery to remove a tumor from a patient's brain and since then more than 70 successful surgeries have been performed with this pioneering and revolutionary technique. (MDA Corporation, 2014).

4.8.3 Planetary Resources and asteroid mining

Planetary Resources is an American company founded in 2010 with the main goal of extracting minerals from asteroids in vast space. The company's initial goals include the construction and launch of new telescope technology specifically designed for Earth observation and astronomy. Planetary Resources is a company that develops fairly low-cost methods for building telescopes. It achieves this mainly by using its own facilities and its own machines. While the company appears a lot after using social media, the technical departments of the company remain closed. The company rightly took advantage of its social media capabilities and launched a major Kickstarter crowdfunding campaign in May 2013 (Planetary Resources, 2013). The campaign was successful, surpassing their goal and raising over $ 1.5 million. The ultimate goal was to awaken the asteroid mining industry. A pioneering telescope manufactured by the company and called Arkyd 100 will be equipped with a Liquid Crystal Device (LCD) screen and a small state-of-the-art camera with very high resolution. A person can upload an image to the telescope as soon as it is in orbit and the camera will take a selfie photo with the Earth as the background. The very good price of $ 25 and the revolutionary innovation attracted more than 7,000 people. The other important invention was the ability to rent time on the telescope for any reason. The company's plans are in the right direction since for example schools, universities and various organizations can rent time to perform experiments and individuals can order high resolution images of the universe. These images will be individual and unique.

4.8.4 Organization of Indian Space research

The Indian Space Research Organization (ISRO) Technology Transfer Group has developed an artificial leg based on space technology in collaboration with Bhagwan Mahavir Viklang Sahayta Samithi (BMVSS) (ISRO 2008, Suresh, Personal Communication, 2014). Prior to this invention, Indians who needed artificial legs could obtain items that required shoes to move. It should be emphasized that Indians are not allowed to wear shoes inside sacred places, which made the purchase of artificial limbs very difficult. In order to find a solution to this problem, polyurethane, which has been used as a thermal protection system in recent years in take-off rockets, has been investigated as a material for artificial limbs. Polyurethane has the material properties required to make more durable artificial feet that will not force people to wear shoes. Leading Indian researchers in recent years have developed a unique casting technique for this variable density microcellular elastomer to make these artificial legs more efficient and more visible. Because this idea was realized by the Indian organization, the mutilated Indian believers are allowed to enter sacred temples. It was undoubtedly a formidable move by the organization that made India even better known for its space-based applications.

4.9 Open Innovation in something completely pioneering: In the extraction of precious metals and elements from celestial bodies such as asteroids.

Ronald Reagan in 1986 argued that humanity must expand to other worlds in order to establish colonies in extraterrestrial astronomical bodies. In addition, the National Space Society (NSS), founded in 1987, stated that their vision is to explore space and extend human civilization into space in order to use the vast resources of space to improve humanity (NSS Statement of Philosophy, 2011). In addition, several space defense teams, such as the Space Frontier Foundation, the Space

Studies Institute, and the Mars Society, share NSS beliefs that focus specifically on colonization and space exploitation.

Concerns about the possible colonization of space were created primarily as a measure to avoid an unlikely but high-impact event referred to as the "black swan", which could dramatically eliminate all life on Earth (Taleb 2009, Rees 2003). The extinction of humanity is not at all unlikely and could be caused by a number of causes (Baum, 2009), such as changes in solar activity (Ward, Brownlee, 2004), a nuclear war, sudden pandemics of viruses, climate change that we are already experiencing very badly years, disorganizing technologies (Bostrom, Cirkovic, 2011), catastrophic consequences from large meteorites or asteroids (Gritzner, 1997, Urias, DeAngelis, Ahern, Caszatt, Fenimore III, Wadzinski, 2018), or from total social collapse after a major catastrophe (R.Hanson, 2007). Proposed solutions to such existential threats include space colonization as a solution. This implies the creation of colonies on extraterrestrial bodies such as Mars or the Moon, the development of isolated shelters far from the Earth's surface (Baum, Denkenberger, Haqq-misra,2015) or the construction of a "refuge of destruction" (Jebari, 2014).

According to studies, the population of the Earth will have greatly increased by 2040 and the reserves of natural resources of the planet will have decreased to a great extent. People will desperately look for alternative mineral resources in space. So we have to look at whether it is possible to find mineral resources on other planets or even asteroids. Celestial bodies, such as the Moon and asteroids, contain valuable chemicals and minerals in very large quantities (Wall, 2015).

These elements and metals are phosphorus, lead, silver, gold, copper, platinum and water. The concentrations of these elements are estimated to be multiples of the corresponding metals present in the Earth's crust. These materials can be used for the construction and supply of spacecraft, but also for the production of various products. It is worth noting that many construction products in our industry use platinum metals, for example car catalysts. It has also been estimated with great accuracy that a 500-meter-diameter asteroid may contain more platinum than has been mined in total throughout human history, which is extremely interesting. Asteroid mining until the year 2000 was considered a science fiction scenario and this possibility was not taken seriously by the states operating in space. In recent years, however, private companies such as Planetary Resources and Deep Space Industries have developed technologies that will allow us in a few years to extract precious minerals from space, and transport them back to Earth. It is estimated that by 2030 the exploitation of such minerals and other types of natural resources will create a market of many billions of euros (Amabile, 2016).

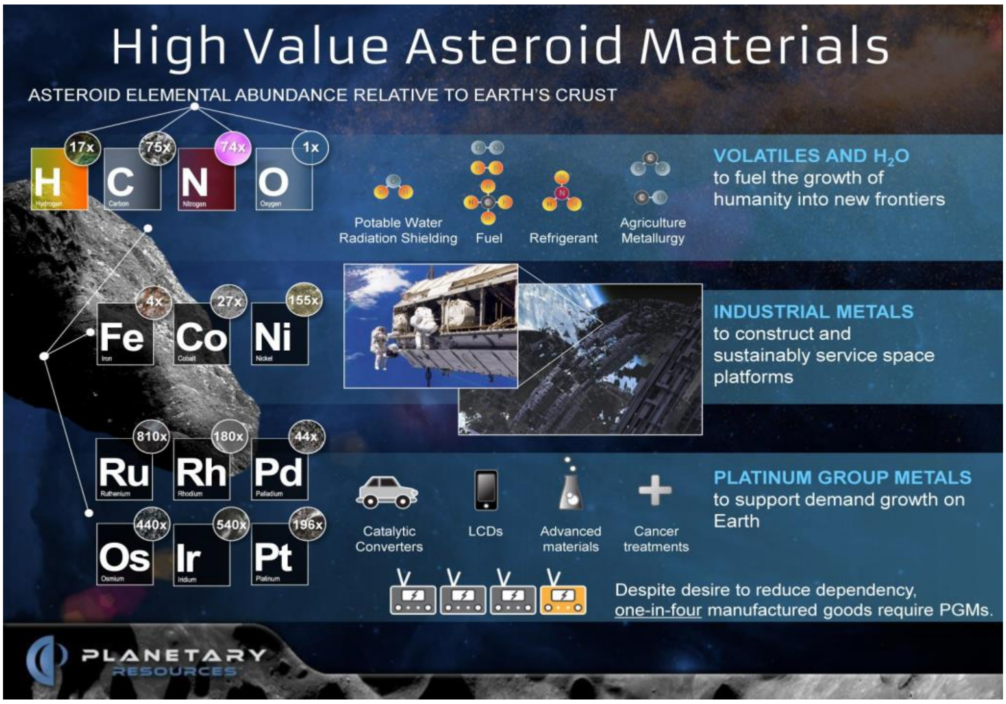

Figure 4.2 Precious metals and elements present in asteroids and already used in the terrestrial industry for many applications

In addition, in 2015, the US Congress legalized asteroid mining through U.S. law. Commercial Space Launch Competitiveness Act. Luxembourg has passed similar legislation, recognizing private companies ownership of space minerals. It is striking that Luxembourg, despite its small size, is a country with a very important space industry. The industry of this country has contributed decisively to the development and prevalence of satellite communications. It is also the first European country to legalize asteroid mining. The two countries (USA and Luxembourg) are working very closely together to successfully organize the world's first asteroid mining mission, which is expected to take place very soon. In addition, Luxembourg plans to invest at least $ 200 million in related space research projects, and has offered to buy shares in private companies, such as Planetary Resources, which has invested $ 29 million (Fernholz, 2015).

From all this comes a valuable conclusion. The great space action of Luxembourg will prove to other small states that space is open not only for the superpowers but also for smaller countries such as Greece, which has recently started operating with the launch of its first satellites. It is a fact that space has so far been the property of the superpowers, but increasing competition may put an end to the space exclusivity that has been created, as about 15 of the 196 states, including a regional agency (European Space Commission), have launch satellites (Siddique, H. 2016).

4.9.1 Legal Issues concerning all Celestial bodies, hence the asteroids.

But the main problem is the legal part. From a legal point of view, asteroid mining has resulted in controversies over its compatibility with international space law, and in particular with the 1967 Outer Space Treaty. This Treaty has been ratified by more than 100 countries, while the 1979 Moon Agreement (Moon Agreement), which has been ratified by only 16 countries.

More specifically, Articles I and II of the Space Treaty explicitly state that distant space, including the moon and other celestial bodies, may not be the property of a state. At the same time, the exploration and use of outer space must be carried out by humanity for the benefit of all countries and not just one or a few countries. Thus, it is understood that when we say the use of space for the benefit of all states, we also mean all the processes of extracting its natural resources, while also movements of ownership by specific countries are in opposition to the prohibition of sovereign rights over celestial bodies. In addition, it is argued that asteroid mining, for the purpose of exploiting and advertising this technology, does not in any way mean that there is ownership of the entire celestial body, because mining companies will acquire ownership rights over the minerals only after their extraction. So it becomes clear that companies and nations should have no element of ownership over an asteroid or other orbital body. Many nevertheless argue that this issue, although very complex, strongly resembles the law of the sea and in particular the status of the "global commons" of the high seas - an area which, yes, is not subject to the jurisdiction of any state, but all States have the right of access and free navigation, provided that they comply with other rules of international law. More specifically, the United Nations Convention on the Law of the Sea guarantees the freedom of fishing of all states in the high seas, according to which the fish collected there legally belong to whoever catches them, provided that it does not pollute and will overfishing the sea. In other words, no state has the right to claim property rights over it, but anyone can collect its fish. This view is extremely interesting and needs further research (Fernholz, 2015).

Despite strong legal obstacles, it is important to carry out the mining project in space despite its great difficulties. Extremely precious metals, such as gold and platinum, could be transported back to Earth and marketed. Selling them would bring huge profits to the economies. However, it is important for marketing to be very careful so that there is not a kind of financial collapse, due to the abundant supply from space. In addition, companies could use the minerals they mine in space and not bring them back to Earth. Unfortunately, space activities are very expensive. This is mainly because the materials used for spacecraft are very expensive. For example, large amounts of water have been detected in space, mainly on planetary satellites, which decompose into oxygen and hydrogen. In this way water is used to produce spacecraft fuel. It would be much easier to use water on site because transporting it from Earth is very expensive. It is worth noting that the transfer of one ton of water from Earth, in order to be used to fully refuel a spacecraft or to be sent to the International Space Station (ISS), amounts to $ 50 million. These costs could be significantly reduced through asteroid mining, as spacecraft will be able to refuel on other planets. In this way it will not be necessary to transport materials and fuels from Earth. We could say that the asteroids will essentially function as "gas stations", allowing spacecraft to carry enough fuel to get out of Earth's gravity and then refuel on other planets (Lewis, 2015).

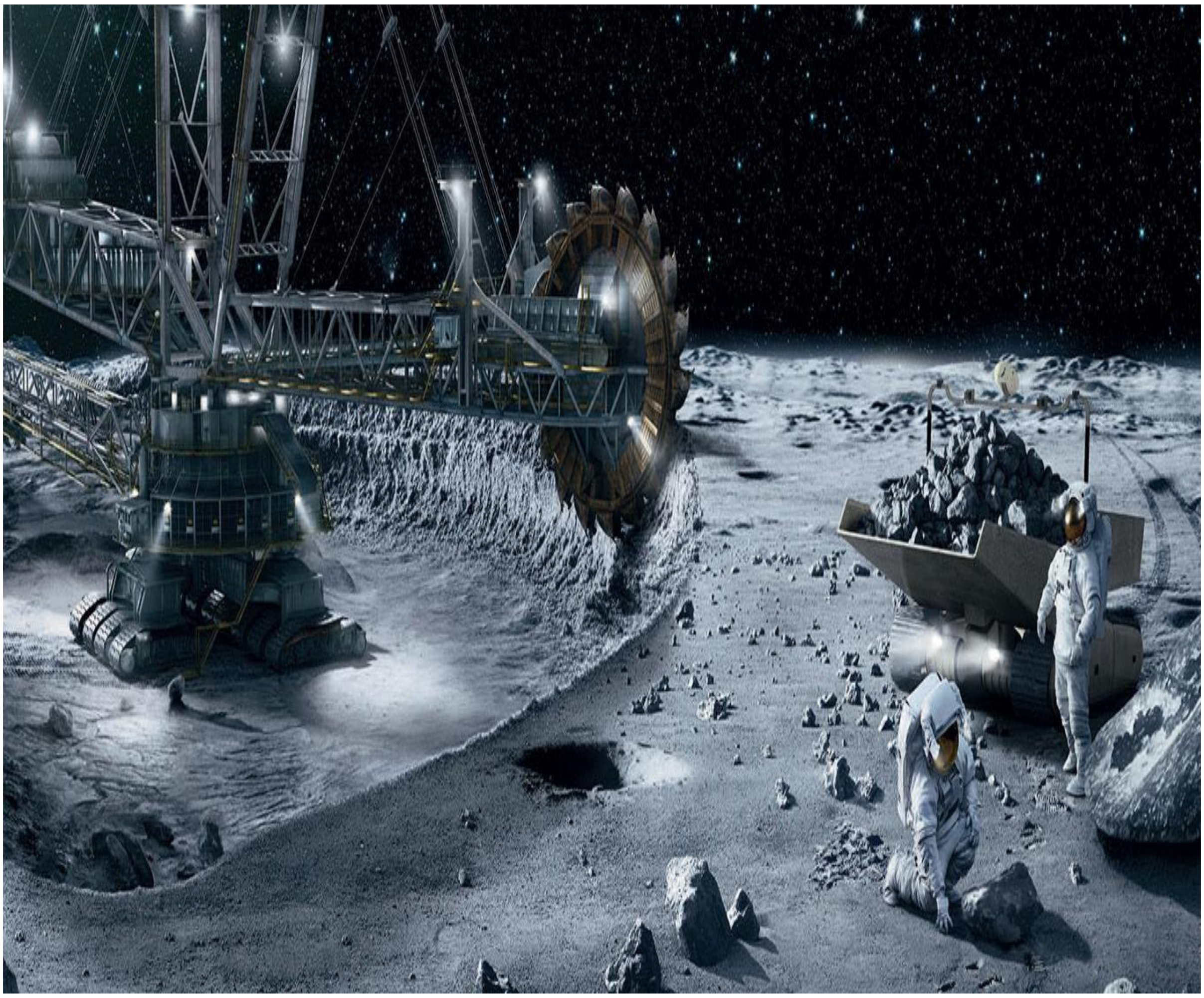

Figure 4.3 Impressive depiction of a future industrial activity of mining asteroids.

It is becoming clear that international space law is not sufficient to support space developments. The idea of extracting and economically exploiting natural resources from other planets and asteroids was not included in the establishment of international conventions almost 50 years ago. Consequently, these international conventions no longer have almost any functionality as they are influenced by the priorities of another era in which the main priority was the prohibition of the use of nuclear weapons in space. In other words, we see how important the principle is that "laws must always go hand in hand with the current social conditions". Surely many problems would be solved if we allowed all states to use and economically exploit the precious minerals they collect from other planets. However, in the absence of specific legislation, a major conflict of interest between states is inevitable and can lead to uncontrollable situations. For example, many problems could arise if two different countries issue mining licenses to the same asteroid. We therefore note that it is necessary to establish a new legal framework to prevent the creation of huge issues in the future and even military conflicts between countries that will be intensely active in space. In addition to all this, the various countries will have to move towards asteroid mining because many basic problems and dangers that the planet will face immediately will be solved (Lee, 2012).

4.9.2 More details on the ambitious asteroid mining plan

The continuous growth of the world gross domestic product (GDP) depends on the continuous economic and technological development. However, this development is directly endangered by the depletion of fossil fuels and the technology metals used in modern fuel cells, advanced batteries, computers, mobile phones, TV screens, electric motors and panels with photovoltaic components. So we observe that modern life is directly dependent on fossil fuels and classical materials. We know that minerals are, so to speak, inexhaustible, but the most important ores have been consumed, so we are forced to use huge sums of money as societies to extract poorer ores (World Energy Council 2003, Diederen 2009, Peak 2001).

Today, fossil fuels account for 81% of the world's primary energy. There is a great global need for cheap renewable energy sources, but unfortunately in 2010 non-hydroelectric renewable energy sources accounted for only 2% of world energy consumption, a percentage that is considered too small. The big issue is cost and risk. Renewable energy should not compete with fossil fuels but slowly begin to replace them. It is also very important to greatly reduce the cost of renewable energy sources. The development of a special technology is difficult because it requires very high financial costs in order to extract special and rare metals. New computers and TV screens require new trace elements of various rare materials and stocks of these materials are in small quantities, so the cost multiplies every year. The most important and useful metals were deposited in the Earth's crust after meteorite impacts after the crust cooled, so the supply is extremely limited. These elements are mainly: gold, iron, cobalt, manganese, osmium, molybdenum, nickel, palladium, rhodium, tungsten and some other rare elements. So it is understood that as humanity we must think of other ways to solve our energy problem. In the future, space resources will become competitive with terrestrial resources as non-renewable terrestrial resources are depleted.

4.9.3 Ambitious asteroid mining design

Modern space industries have begun to plan the extraction of mineral wealth from asteroids in order to solve the above energy problem of our planet. To achieve this, a space transfer architecture has been designed to place mining equipment on selected asteroids that are relatively close to Earth at the lowest possible life cycle cost (LCC). The main elements we analyzed were: the ETO system, the LEO Space Operations Center (SOC), where the most important and useful cargoes are collected and redistributed, the asteroid transport system, the asteroid payloads (mining equipment and habitats). Finally, it was examined how the mining product will be made. For the latter, a kind of capsule was designed that could return to Earth and contain the product that was mined. The whole project was studied with the help of a pioneering company in open space innovation, Planetary Resources. Our company helped with business information and important technical data.

The design is 20 years old starting around 2020, when the asteroids that will play the role of mines will be fully operational by 2040. The goals of the whole project are to exchange important transport elements in order to minimize both non-recurring and recurring costs. namely the LCC, and show that the successful implementation of the project can deliver critical asteroid metals to global manufacturers. If this concept succeeds, the cost of the metals that will be extracted from the asteroids will be much lower than the cost of mining the earth's metals, which in 2040 will be minimal on the planet. Of course, for all this it is necessary for the World Space Council to agree to provide ownership of individual asteroids and guaranteed loans to an industrial consortium for the construction and operation of the transmission system and the extraction of the nearest asteroids. The goal of the section is to achieve a discount of more than 20%, so that the project manages to gain funding. It is important to emphasize that the design of the spacecraft has been done successfully and also the architecture of the whole design has been completed. The project, in addition to the risk assessment and its mitigation, must also take into account the entire cost of the project. All core technologies were at or near the TRL 6 technology readiness level (TRL), and if a core technology is below TRL 6, then both the demo program and the backup technology development program were included in the non-recurring cost (Acta Astronautica, 2015).

4.9.4 Case analysis and structural details

The architecture of the whole project is shown in the figure below. Special spacecraft devices are launched into the Low Earth Orbit (LEO) from a dedicated launch site, retrieved at LEO by an

Orbital Transfer Vehicle (OTV) and delivered to a Space Operations Center (SOC). The SOC serves various functions as it is at the same time a research center in conditions of minimal gravity, a space tourist destination and a hub for spacecraft to anchor coming from deep space. Mining spacecraft will provide large quantities of critical metals for the earth, water for other space needs but also as fuel and other materials for space material construction and to support even the remote space industry.

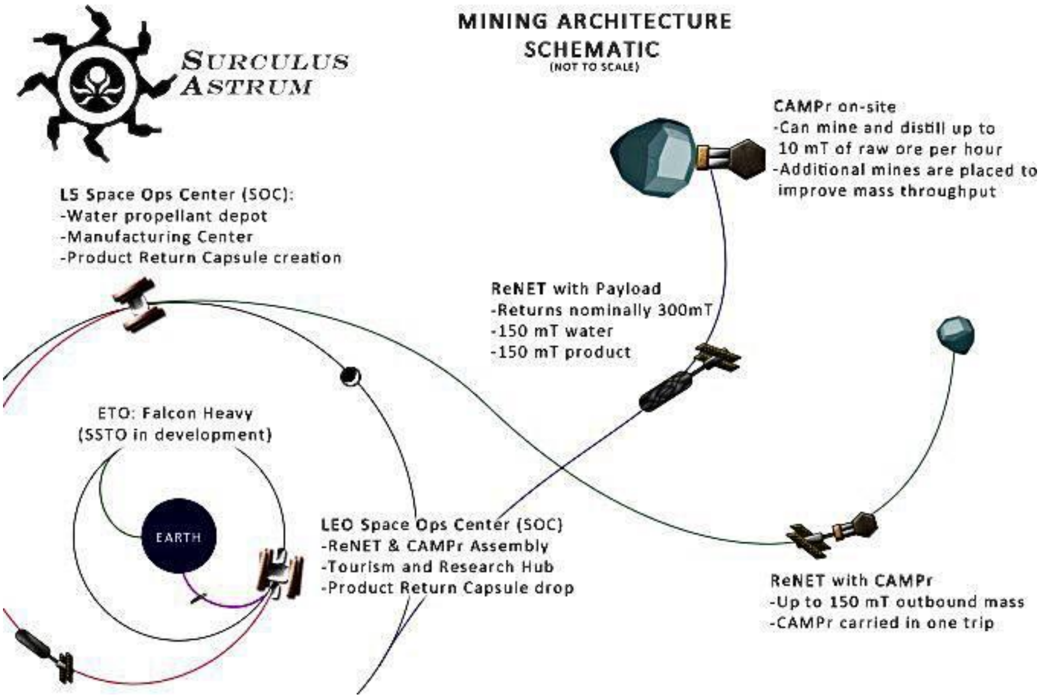

Figure 4.4 Flowchart of celestial's overall mission architecture. Processing of multiple NEO's is supported in the design, maximizing profit for development

After the first studies, it was realized that nuclear tugs and nuclear power plants were necessary to accomplish any asteroid mining process. The space trailers to be used are called Reusable Nuclear Power Trailers (ReNETs) and are general purpose trucks using a 3.5 MWe Brayton Nuclear Power Plant based on previous studies funded by NASA Various Jupiter Icy Moons Orbiter (JIMO) Studies).

These are ReNET plans for surface power plants. However, it has been pointed out that it takes a very long time to make the necessary tests that are needed. The ReNET cycle was based on a graduated version of the Prometheus Single Loop 200 kWe design with a 400 K refrigerator. The 3.5 MWe ReNET was sized to carry 150 mT of outgoing and return payload with 250 mT of payload. The good average delta speeds for asteroid travel are 6.5 km / s inbound and 5.5 km / s inbound (from HEO SOC). ELF propellers are designed to run on either argon or water and the in situ propulsion option is what really saved the business case. A very important advantage of ReNET is that it is designed to work efficiently in either argon or water. Argon is necessary for the first missions leaving Earth in the first phase and water is necessary for future missions as a propellant for the rockets to reach the asteroid. Another important element is the Carbonaceous Asteroid Miner and Processor (CAMPr) which is transported to the asteroid target by ReNET where it mines very important and precious minerals and carbonates and separates the extremely critical metals and organics for further processing into PGMs. In addition, a nuclear power plant with a Brayton-Cycle fission reactor almost identical to the ReNET power plant will supply CAMPrs. This nuclear reactor will also deliver 3.5 MWe of bar power.

The plan initially consists of 2 phases. The first phase is the development phase, lasting about five years. In this phase the spacecraft of the asteroid to be selected, manufactured and tested. This phase also includes the construction of the nuclear power plant. Phase 2 lasts about two years and concerns the tests that begin to take place in orbit.

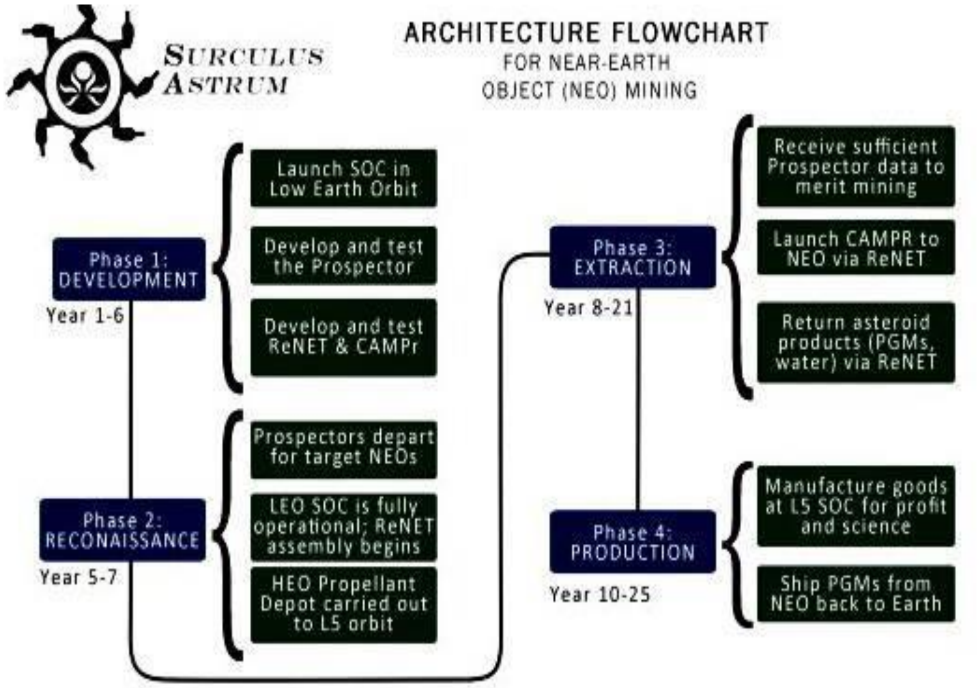

Figure 4.5 Mining architecture flowchart

If the prospective designers find rich iron ore deposits and easily exploitable during Phase 2, then the project continues and its final development begins. This includes ReNET and CAMPr, and if mining is appropriate, SSTO as well. Then the minerals as well as elements such as water are transported by special spacecraft to their destination.

4.9.5 The design for space centers

It is planned to have two or three Space Operations Centers, at an altitude of 1000–1300 km and a center at a higher altitude. There is also the possibility of having an optional SOC in GEO if the purchase of the GEOSAT platforms under construction allows it. LEO SOC is an important part, as it is the point where outgoing payloads are collected and collected by outgoing ReNETs. That is why the need for high altitude is imperative in order to have maximum security in the use of nuclear technology. It is worth noting that this orbit is also above all space debris to reduce the risk of collisions and accidents. The SOC becomes an important storage and transport station for transportable payloads.

In recent years, very large aerospace companies in the United States have joined forces to create an accurate cost estimate for the entire asteroid approach plan with special equipment. After interviewing many companies, the huge demand for research was revealed where even proprietary techniques could be explored and used. This corporate claim was never accepted because the ISS discourages proprietary corporate research. The SOC of this project was created to meet this demand but also to guarantee low launch costs and the lowest possible costs in the already costly asteroid mining program. (Andrews. Bonner. Butterworth, 2015, p. 107-116).

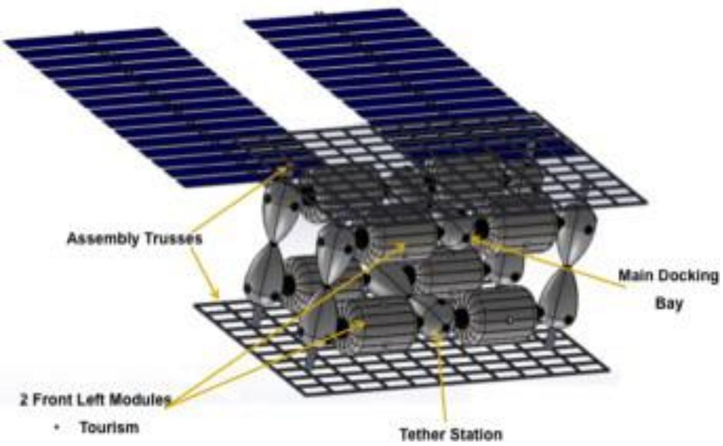

Figure 4.6 LEO SOC configuration

4.9.6 Miners & Asteroids

We will talk a little now about the Carbonaceous Asteroid Mining & Processor (CAMPR) which is actually a data collector comprising three miners with their free flying hoppers, a large and modern CPU and storage unit and a state-of-the-art nuclear power plant connected to the miners and the processor with electrical wires. A typical miner unit is shown in the following figure.

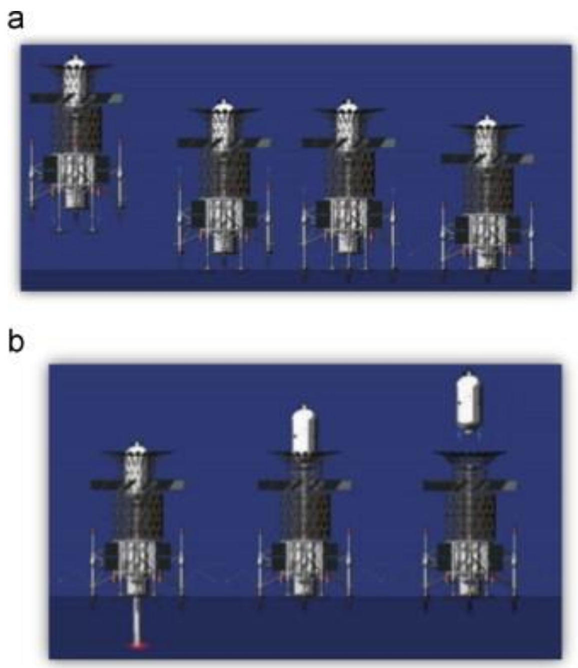

Figure 4.7 (a) Miner module operations– setup and (b) miner module harvest and transport.

The miner unit lands at a predetermined location of the asteroid where the ore is located and anchored to the surface using multiple helical anchors. He then lowers a helical tool, which is essentially a drill, into the asteroid surface and uses strong microwaves (NEAmines Group, 2007) to dissolve the frozen ore and transfer it to the hopper storage bin. When the hopper is sufficiently filled, it connects to the processor and uses the Reaction Control System (RCS). The RCS propeller is usually water and is refueled by the special processor on each subsequent flight.

The miners shown in the images below are first-generation versions that simply land on the asteroid and drill. If the ore is not what is expected, or if it encounters a large boulder and can not be mined, simply with the appropriate procedure they move to the next selected target point. However, next-generation versions would be controlled by humans using state-of-the-art computers. This is very important because through the specialized control that the computer will undertake, the miners will still be connected with cables in the power plant, so they will move less and only when there is a real need. The hoppers are disengaged when loaded and moved to the processor where they deposit the extremely valuable ore loads and then recharge their propellant tanks.

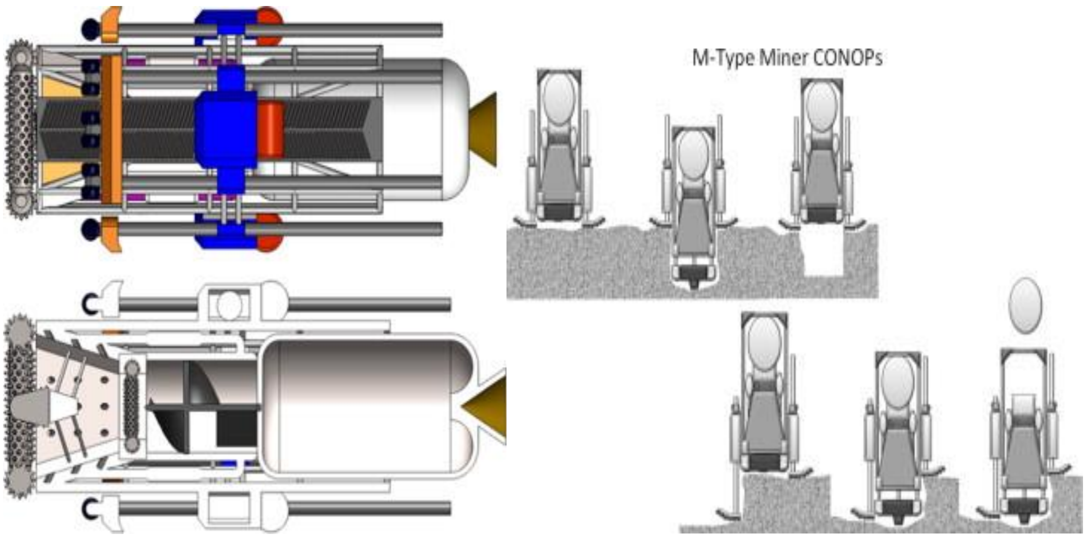

Figure 4.8 Boring head for M-Type asteroid and M-Type Miner COJNOPs (side view).

The first image shows a miner specializing in asteroids containing carbonaceous chondrites (rich in water but not necessarily minerals).

The second image shows the Concept of Operations (CONOPS) for the M-Type Miner which is a type of cutting head found in existing mining plans. This type is used for hard rocks and can be repositioned to make multiple cuts in a continuous manner.

The processor shown in the figure below crushes the ore into particles a few millimeters in size and separates the particles according to density and magnetism. The non-magnetic and less dense particles are directed towards the volatile extractor. There they are heated to 700 C to extract water, CO2, N2, CO and other elements. A small distillation unit separates the volatiles from the inflatable containers and storage tanks.

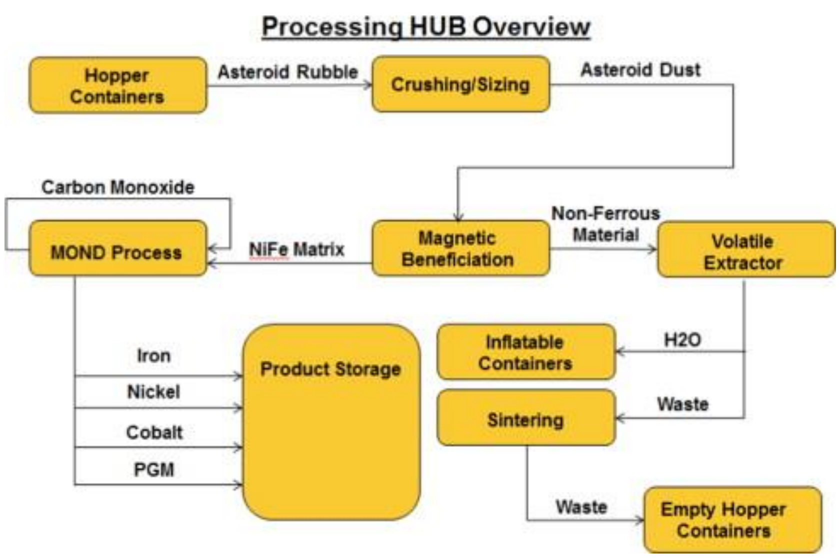

Figure 4.9 CAMPr ore processing steps

The dense and magnetic particles enter the MOND process in the carbonyl reactor. There, nickel and iron are converted to gases or metal powders for use in tanks and heat exchangers using the chemical vapor decomposition (CVD) process. Also the significant residue left behind after the gasification of nickel and iron is a combination of cobalt, special platinum type metals (PGMs), Rare Earth Elements (REEs), silicon, sulfur and phosphorus. Then we have magnetic separation again with the heavier materials being sent to Earth eventually as products. In addition, the lightest residues are stored at that point for further processing. The carbon monoxide needed for the carbonyl process is recycled and also deposited by the state-of-the-art volatile processor. It is very important to emphasize that many different miners will be sent to each of the larger asteroids, especially if those interested have reported the existence of rich ore in some asteroids.

4.9.7 Results of studies for extraction in asteroids

All plans for successful mining of asteroids in the near future have as their main parameter the financial cost of the whole project. For a normal amount of investment but also with the use of existing and relatively fast new technologies, it is possible to create an asteroid mining architecture that will have a direct positive impact mainly on the global market. In this way the industrialization of space will rapidly advance. Even more amazing is the fact that when the first mines are created, the company under study will have very large profits in a short time.

The problem of the cost of such a venture is still a major one. It is also important to be able to return products to land quickly and at a reasonable cost. If the Copernicus Orbital simulation program is used for the available trajectories, we see the results in the figure below.

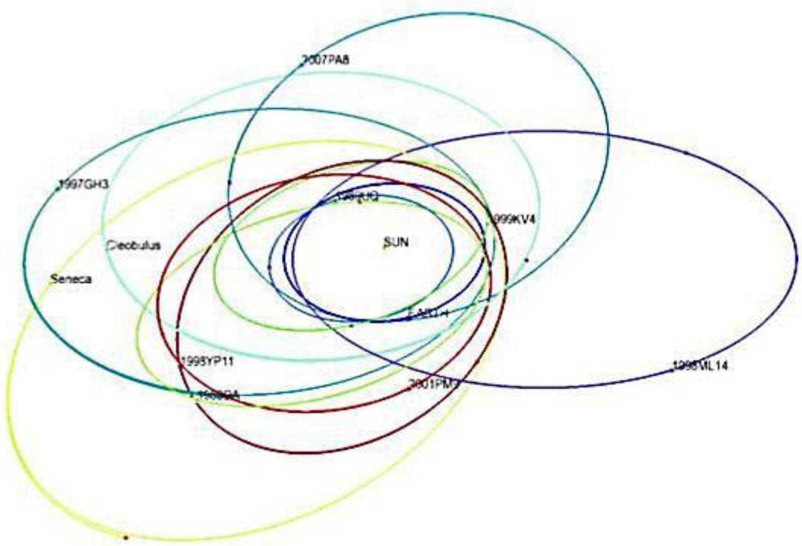

Figure 4.10 Candidate asteroid orbits

In this case we studied the asteroid 2007 PA8. This asteroid facilitated the study because it is distinguished for the high eccentricity of its orbit and has excellent characteristics for mining. This is because it is an asteroid with mixed elements, ie it contains minerals and carbonaceous elements. The 2007 PA8 is probably the most valuable piece of real estate within the main area. The average travel times in the 2007 PA8 are around 1.8 years and the DVs are around 7 km / s. Under these conditions, the 3.5 MWe ReNET provides us with about 200 mT to and from the asteroid, which is very satisfactory. However, apart from the technical part, we must also study the financial part, that is, to see if it is worth the investment. This big business case presupposes that the parties involved can claim developing asteroids and that the World Development Council guarantees significant bank loans for this purpose. In addition, if the net present value of the return on investment exceeds 20% with a discount rate of 10%, bank loans are granted.

As mentioned above, the first 5 years will be spent in order to study the project, as well as the creation and launch of the first basic vessels. The nuclear power plants will not be ready soon, but they could be operational in 5 years from the partnership of the project. The image below shows the choice of systems according to their cost. Product return capsules are too many because they are relatively small. It is worth noting that nickel is used and in the end only 1200 kg of PGMs are provided. In the end, however, their cost is only about 1/50 of the value of the product they deliver and this makes the capsules an excellent solution for transporting products to our planet. (G.AndrewsK.D.BonnerA.W.ButterworthH.R.CalvertB.RHDagangK.J.DimondL.G.EckenrothJ.M.EricksonB.A.GilbertsonN.R.GompertzO.J.IgbinosunT.J.IpB.H.KhanS.L.MarquezN.M.NeilsonC.O.ParkerE.H.RansomB.W.Reeve, April 2015).

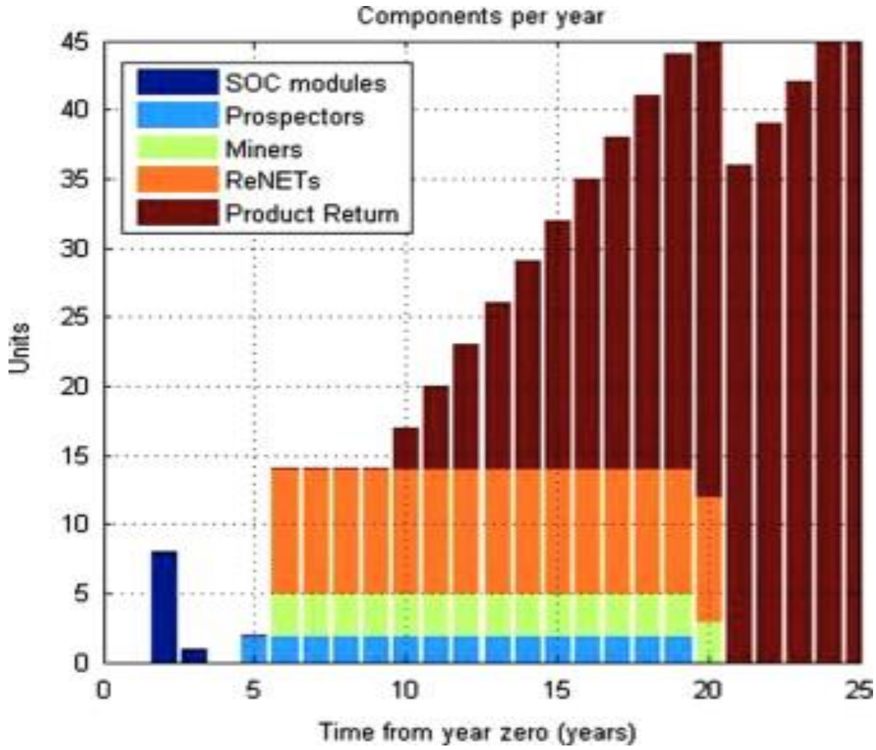

Figure 4.11 Limited master build schedule (No SSTOs).

5 Our research in Greek space companies

5.1 Limited master build schedule (No SSTOs)

In this chapter we will analyze the data we collected from the research we followed to study the business models of Greek space companies. We interacted via e-mail with 48 companies active in the space sector. In addition, we must emphasize that our research was carried out in two rounds. In the first round of our research, the questions concern the composition of the company, the specific business sector of the space that each company deals with as well as the obstacles they have encountered along the way. Following the research, we interviewed company executives and cite the corresponding questionnaire. In the first round, 8 of the 48 companies answered us. The second round of research included questions related to open space innovation. We received only 3 responses from these 8 companies that responded in the first round. Nevertheless, we will present our research on Greek space companies. We will also draw valuable conclusions about the prospects they have in this ever-growing field of entrepreneurship.

5.2 Questions of the Survey

5.2.1 1st round of the survey

1. What is the name of the company?
2. What is the legal form of the company?
3. If “other”, please mention.
4. What is your position in the company?
5. If “other”, please mention.
6. What is the department you work in the company?
7. From what year does the company operates in space technologies? (Mention the year approximately).
8. What is the number of company’s employees (approximately)?
9. What is the total annual sale of the company (turnover)?
10. What is the business sector (or sectors) that the company operates? [Satellite Communications]
11. What is the business sector (or sectors) that the company operates? [GPS Services]
12. What is the business sector (or sectors) that the company operates? [Remote Sensing]

13. What is the business sector (or sectors) that the company operates? [Space Data Processing (Big Data)]
14. What is the business sector (or sectors) that the company operates? [Advanced Materials and Constructions]
15. What is the business sector (or sectors) that the company operates? [Space Software]
16. What is the business sector (or sectors) that the company operates? [Aeronautical Engineering and Launching]
17. What is the business sector (or sectors) that the company operates? [Terrestrial equipment (infrastructure)]
18. What is the business sector (or sectors) that the company operates? [Space Consultancy]
19. What is the business sector (or sectors) that the company operates? [Space Marketing]
20. What is the business sector (or sectors) that the company operates? [Other]
21. What is the percentage of the company's operations about space applications?
22. What is the percentage of the company's operations about space applications? [Comment]
23. What is the percentage of the company's revenue that comes from the operations about space applications?
24. What is the percentage of the company's revenue that comes from the operations about space applications? [Comment]
25. Is the company a member of the following networks? [Si-Cluster of Corallia]
26. Is the company a member of the following networks? [The Hellenic Association of Space Industry - HASI]
27. Is the company a member of the following networks? [Other relative network]
28. If "other", please mention.
29. Has the company taken part in National, European or International Projects about space technologies?
30. The company develops for space: [Products]
31. The company develops for space: [Services]
32. The company develops for space: [Other]
33. Does the company come across any difficulties in the following? [Lack of legislature about space]
34. Does the company come across any difficulties in the following? [Lack of competition in space applications]
35. Does the company come across any difficulties in the following? [Lack of funding]

36. Does the company come across any difficulties in the following? [Lack of trained workforce]
37. Does the company come across any difficulties in the following? [Powerful international competition]
38. Does the company come across any difficulties in the following? [Lack of national space strategy]
39. Does the company come across any difficulties in the following? [Lack of national infrastructure about space]
40. Does the company come across any difficulties in the following? [Difficulties due to intellectual property (IP)]
41. Does the company come across any difficulties in the following? [Difficulties about national safety]
42. Does the company come across any difficulties in the following? [Other difficulties]
43. Our research aims to the study of open innovation and in the space sector. Are you available for the next step of the survey? [Interview (about 30 minutes]
44. Our research aims to the study of open innovation in the space sector. Are you available for the next step of the survey? [Questionnaire (about 30 minutes)]

5.2.2 2nd round of the survey

1. What is the name of the company?
2. What is your position in the company?
3. If "other", please mention.
4. What is the department you work in the company?
5. From the creation of innovative businesses in the space sector, in which areas of this sector do you think most jobs would be created?
6. The space industry requires materials and assembly of very high technology. In such a very demanding market, will Greek companies with innovative ideas be able to stand in this space and use materials of domestic origin or even produce components on behalf of large European organizations such as ESA?
7. A space company can either alone or in collaboration with other companies develop its products or services. Which of the two models do you consider most suitable for the Greek market? Are there specific areas of activity that fit in one model or another? Which of the two models does your company follow?

8. If you need partnerships to implement innovation in your company, who do you work with (eg individuals outside the company, other companies, research institutes or universities, public services)? Are these partners in Greece or abroad?
9. What is your view on innovation networks in the space sector? Does your company participate in any of them?
10. What do you think are the advantages and disadvantages of collaborative innovation in the space sector?
11. What do you think would significantly help innovation in Greek space companies?

5.3 Answers of the Survey

5.3.1 1st round of the survey

We will not include the answers of the first six questions due to General Data Protection Regulation (GDPR).

7th Question: From what year does the company operates in space technologies? (Mention the year approximately).

Answers: Most of the companies started their operation after 2000. Only one company has been operating since 1990's. This means that space is a relatively new field of operation in Greece.

8th Question: What is the number of company's employees (approximately)?

Answers: The employees range from 4 to 82. Three companies have 4-6 employees, the other three have 15-32 and only two have 80-82 employees. This means that most of the companies are SMEs (Small and medium-sized enterprises).

9th Question: What is the total annual sale of the company (turnover)?

Answers: Here we received different answers, too. The small size companies have a turnover that ranges from 120.000€ to 400.000€. The medium size companies have a turnover at about 1.000.000€ to 2.000.000€. The other two companies, that have 80-82 employees, have an annual turnover at about 3.300.000€ to 4.000.000€.

10th Question: What is the business sector (or sectors) that the company operates? [Satellite Communications]

Answers: Only one company from the survey is involved with satellite communications.

11th Question: What is the business sector (or sectors) that the company operates? [GPS Services]

Answers: None of the companies.

12th Question: What is the business sector (or sectors) that the company operates? [Remote Sensing]

Answers: Three companies are involved with Remote Sensing.

13th Question: What is the business sector (or sectors) that the company operates? [Space Data Processing (Big Data)]

Answers: Also three companies are involved with Space Data Processing (Big Data).

14th Question: What is the business sector (or sectors) that the company operates? [Advanced Materials and Constructions]

Answers: Also three companies are involved with Advanced Materials and Constructions.

15th Question: What is the business sector (or sectors) that the company operates? [Space Software]

Answers: None of the companies.

16th Question: What is the business sector (or sectors) that the company operates? [Aeronautical Engineering and Launching]

Answers: Only one of the companies is involved with Aeronautical Engineering and Launching

17th Question: What is the business sector (or sectors) that the company operates? [Terrestrial equipment (infrastructure)]

Answers: Six companies are involved with Terrestrial equipment (infrastructure).

18th Question: What is the business sector (or sectors) that the company operates? [Space Consultancy]

Answers: Only one of the companies is involved with Space Consultancy.

19th Question: What is the business sector (or sectors) that the company operates? [Space Marketing]

Answers: Only one of the companies is involved with Space Marketing.

20th Question: What is the business sector (or sectors) that the company operates? [Other]

Answers: Only one of the companies answered "Other" and operates in Manufacture Assembly Integration & Test for flight & Non-flight HW.

21st Question: What is the percentage of the company's operations about space applications?

Answers: Only one company answered 5-10%. Four of them answered 10-30% and in the three companies the percentage is >90%.

22nd Question: What is the percentage of the company's operations about space applications? [Comment]

Answers: Only one company made a comment. This company is involved with EO National and European Projects.

23rd Question: What is the percentage of the company's revenue that comes from the operations about space applications?

Answers: Only one company answered 5-10%. Four of them answered 10-30%, one of them 60-90% and in the two companies the percentage is >90%.

24th Question: What is the percentage of the company's revenue that comes from the operations about space applications? [Comment]

Answers: Only one company answered that besides programs, we have private contracts with companies like the Public Power Cooperation.

25th Question: Is the company a member of the following networks? [Si-Cluster of Corallia]

Answers: Seven of the eight companies are members of the Si-Cluster of Corallia.

26th Question: Is the company a member of the following networks? [The Hellenic Association of Space Industry - HASI]

Answers: Five of the eight companies are members of the Hellenic Association of Space Industry – HASI.

27th Question: Is the company a member of the following networks? [Other relative network]

Answers: Only one company answered "Yes".

28th Question: If "other", please mention.

Answers: The company is a member of Eurisy network

29th Question: Has the company taken part in National, European or International Projects about space technologies?

Answers: All the companies have taken part.

30th Question: The company develops for space: [Products]

Answers: All the companies develop space products. Two of them develop mostly space products, three of them enough and three few products.

31st Question: The company develops for space: [Services]

Answers: All the companies develop space services. Four of them develop mostly space services, two of them enough and two few services.

32nd Question: The company develops for space: [Other]

Answers: Four of the companies answered “Other”.

33rd Question: Does the company come up against any difficulties in the following? [Lack of legislature about space]

Answers: Only two companies don’t have any significant difficulties due to lack of legislature about space, while the other five come across few to enough problems about that.

34th Question: Does the company come up against any difficulties in the following? [Lack of competition in space applications]

Answers: For every company there is lack of competition in space applications.

35th Question: Does the company come up against any difficulties in the following? [Lack of funding]

Answers: For every company there is lack of funding in space applications to a great extent.

36th Question: Does the company come up against any difficulties in the following? [Lack of trained workforce]

Answers: For every company there is lack of trained workforce to a great extent.

37th Question: Does the company come up against any difficulties in the following? [Powerful international competition]

Answers: Every company comes up against powerful international competition.

38th Question: Does the company come up against any difficulties in the following? [Lack of national space strategy]

Answers: For every company the lack of national space strategy is a problem.

39th Question: Does the company come up against any difficulties in the following? [Lack of national infrastructure about space]

Answers: For every company the lack of national infrastructure about space is also a problem.

40th Question: Does the company come up against any difficulties in the following? [Difficulties due to intellectual property (IP)]

Answers: Most of the companies come up against with difficulties due to intellectual property (IP)]

41st Question: Does the company come up against any difficulties in the following? [Difficulties about national safety]

Answers: Few companies come up against with difficulties about national safety.

42nd Question: Does the company come up against any difficulties in the following? [Other difficulties]

Answers: Many companies come up against with other difficulties.

43rd Question: Our research aims to the study of open innovation in the space sector. Are you available for the next step of the survey? [Interview (about 30 minutes]

Answers: Only three companies answered "Yes". Three companies answered "Uncertain" and two answered "No".

44th Question: Our research aims to the study of open innovation in the space sector. Are you available for the next step of the survey? [Questionnaire (about 30 minutes]

Answers: All the companies answered "Yes".

5.3.2 2nd round of the survey

Like the 1st round, we will not include the answers of the first four questions due to General Data Protection Regulation (GDPR).

5th Question: From the creation of innovative businesses in the space sector, in which areas of this sector do you think most jobs would be created?

Answers:

Company A: The areas are: mechanical ground support equipment and Earth observation

Company B: Exploitation of data from Space and Construction Hardware.

Company C: Development of applications based on artificial intelligence in combination with the needs of the market. Not only in combination with research

6th Question: The space industry requires materials and assembly of very high technology. In such a very demanding market, will Greek companies with innovative ideas be able to stand in this space and use materials of domestic origin or even produce components on behalf of large European organizations such as ESA?

Answers:

Company A: As a first priority I would put the production of mechanicals components on behalf of other companies (small or medium) which work for ESA, maybe not from the beginning.

Company B: Yes and they already do it.

Company C: I believe yes.

7th Question: A space company can either alone or in collaboration with other companies develop its products or services. Which of the two models do you consider most suitable for the Greek market? Are there specific areas of activity that fit in one model or another? Which of the two models does your company follow?

Answers:

Company A: Due to the size of most Greek companies, I believe that the development model in collaboration with others is the most suitable for the Greek space market. It is also the model applied by our company.

Company B: Since we are talking about hardware, it is much more affordable to provide your services. Providing your own product requires a very laborious certification process. Since we are talking about software, a Greek company can provide both product and service. But especially in the product, emphasis should be placed on innovation because the competition is very high. Our company mainly provides hardware manufacturing services.

Company C: In collaboration with other companies.

8th Question: If you need partnerships to implement innovation in your company, who do you work with (eg individuals outside the company, other companies, research institutes or universities, public services)? Are these partners in Greece or abroad?

Answers:

Company A: Mainly other Companies from Grrece and abroad.

Company B: We work with companies and institutes from Greece and abroad.

Company C: With everything mentioned. Mainly from Greece.

9th Question: What is your view on innovation networks in the space sector? Does your company participate in any of them?

Answers:

Company A: I would not like to comment on the innovation networks in Greece because we believe that there is a great lack of real and honest cooperation.

Company B: We participate in almost everything. It is in the right direction, but it is still at an early stage, for the European space market. They have not brought the expected results and have not significantly strengthened the spirit of cooperation between companies.

Company C: Very positive. No, the company does not participate.

10th Question: What do you think are the advantages and disadvantages of collaborative innovation in the space sector?

Answers:

Company A : The biggest advantage is the acquisition of experience and know-how through these collaborations. The disadvantage is that you do not have complete control over the Technology that you may use.

Company B: Advantages: You can offer more complete solutions, Complementarity, reduction of required investment capital per company, reduction of delivery times, know-how.

Disadvantages: All partners must give the same weight to the project, Any obstacle in a company's Task, is a high risk for others.

Company C: The advantages are many and are mainly related to the development of innovative applications. The downside is that many companies participate without actually doing anything (either because they do not have the potential or because they do not have the experience) just to have their CV listed. As a result, no solution is created that has to do with reality except on a theoretical basis.

11th Question: What do you think would significantly help innovation in Greek space companies?

Answers:

Company A: The existence of a large Greek aerospace company (Prime) which in turn would supply the other Greek companies in the area.

Company B: Closer cooperation with Universities and companies abroad. Especially the cooperation with Primes, helps you to see the trends and the requirements of the market.

Company C: To involve companies and individuals who really deserve it, are willing to offer, need to increase their sales and not just enrich their resume.

5.4 Geographical distribution of the Greek Space Companies

In the map 5.1 that follows, we observe the geographical distribution of the Greek space companies and laboratories collaborating with Universities. It is of great interest that the vast majority of space companies and laboratories are located in 2 cities, in Athens and Patras. More specifically, in Athens there are about 40 companies and technological laboratories, in Patras 11, whereas 1 in other cities, such as Alexandroupoli, Thessaloniki, Heraklion, Sitia, Veria, Ioannina and Rhodes. This is not a coincidence, since Athens is the capital of the country and gathers half of the population and Patras has one of the best Universities, with great research activity, especially in the field of software and electronics.

Apart from the space companies, in the city of Athens there are many technological laboratories dealing with space and are located in the area of the National Technical University of Athens. This fact also concerns the city of Patras, where the technological park is located.

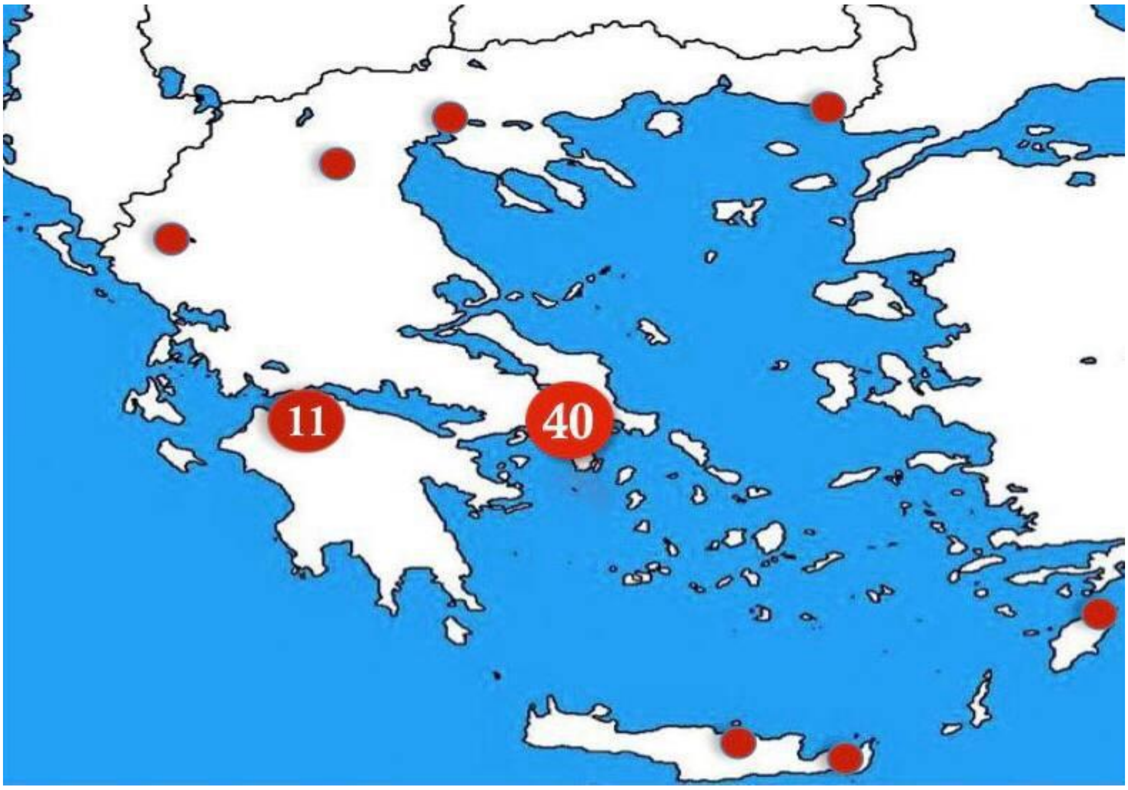

Figure 5.1 Greek company map: In the above map, we observe the geographical distribution of the Greek space companies and laboratories collaborating with Universities. It is impressive that 40 companies and laboratories are located in Attica and 11 in Patras.

Taking all the aforementioned into consideration, in many cases, space companies and laboratories are located in close proximity to or within Universities. This is essential, due to the fact that the cooperation among companies, technological laboratories and Universities is the key to success in the field of space science in each country. Finally, it is of paramount importance, that technological laboratories and space companies continue to be established nearby the Universities and research centers of our country.

Conclusion

In recent years, Greece has made its appearance in space sector. Although the citizens may ignore that the country has 7 transponders satellites connected to the Hellas Sat, everyone definitely enjoys the very useful services provided by Space. Satellite channels, the vast coverage offered by telecommunications, the technology used for meteorological forecasts and climate observation, forecasts and the consequences of major natural disasters, mobile phone applications, and even complex military applications are some of the valuable services that space industry provides us.

The most recent space achievement was the launch on behalf of Greece and Cyprus of the Hellas Sat 4 satellite, built by Lockheed Martin. Another invention is the 51-meter-long Arianne 5 rocket carried the Hellas Sat 4 satellite, which weighed almost 6.5 tons. Also Hellas Sat 4 is connected to the Hellas Sat 3 which was launched in 2017 and together they serve a very wide range of services. These launches, as well as the construction details of these satellites, substantially extended the activity of Greek private companies in space, since they managed to cooperate effectively with the public administration of the country. From this point the results may be seen clearly from now on in our daily lives. Hellas Sat 4 is also the largest non-governmental, non-military satellite in the space industry ever built by Lockheed Martin Space.

That is because of an important innovation which was implemented in this satellite. Its huge solar panels with a length of 20 meters each, are collected in a different way like a "bellows" and open, as they are not classically foldable as in most satellites to date. Another innovation is referred to its motors, which are used to correct its orbit, do not run on liquid chemicals but on electricity. All this upgrading situation creates an extremely positive climate for the country in terms of the continuation of its action in space.

It should not be forgotten that the positive climate is strengthened by the decision of ESA to create the first ESA Business Incubation Center (ESA BIC) in Greece. The operation of the Greek ESA BIC is based on the planning of the General Secretariat of Telecommunications and Posts of the Ministry of Digital Government for the active participation of Greece in the European Space Strategy. ESA BIC now deals with the support of Greek start-ups that are active in the development of solutions and services for space. This center will enhance the transfer of knowledge and know-how from the applications of Space to applications of everyday life and it will thus promote the development of start-ups and entrepreneurship in our country.

The research we have conducted in our work on entrepreneurship and open innovation of Greek space companies showed us that the effort made by these companies is important and very promising. But it is still the beginning of this great step and it takes a lot of effort and investment of capital to follow a similar course, so that Greece holds a consistently promising position in the field of space entrepreneurship and innovation. This will contribute to a substantial recovery of the Greek economy, which unfortunately was interrupted by the great health crisis brought by Coronavirus in Greece and worldwide. In this composition and organization of space companies, it is deemed necessary to continue the existence of a Greek Space Agency such as ELDO and its replacement.

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