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Global Executive Applied Research Thesis

Assessing potential disruption in the satellite-based Earth Observation market caused by Small Satellites

An analysis of potential impacts of Small Satellites on the Earth Observation industry based on the theory of disruptive innovation

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1 Executive Summary

Context

The arrival of small satellites is promoting significant impacts in the space industry as a whole. By building and launching multiple of these smaller spacecraft, young and innovative companies have the potential to collect data from space at lower costs and more frequently. In particular, the Earth Observation industry has the potential to be completely disrupted by the arrival of this new class of satellites.

In this context, it is crucial for established firms of the Earth Observation to map and understand the possible implications that new entrants might bring to their industry. This report focused on analyzing the potential threats that small-satellites-based companies are bringing to this industry.

Methodology

The analysis was based on the concept of Disruptive Innovations, which defines the process by which new and innovative products are introduced in an established industry and are able to slowly gain most of the market share from established firms. Data about the Earth Observation industry, including the main customer segments, product requirements and trends were gathered from secondary sources such as market reports and company investor presentations. In particular, the data and strategies of two established firms and three new entrants in the EO business were analyzed. Research and academic articles were equally used to support the methods employed throughout the report.

Findings

The investigation showed that small satellites have the potential to disrupt the EO industry through two main channels. The first possible disruption process might happen in the customer segment that generated most of the EO industry revenues: Defense and Governmental. In this case, the offerings of small-satellite-based companies are attractive to a low portion of this market segment, which is composed mainly of emerging nations that are willing to invest in space assets and technologies. This low-end portion is not the main focus of established players and is already being addressed by new entrants. If these young companies manage to improve their products over the next few years, they might at some point start addressing the mainstream parts of the market and significantly threaten established players in their most lucrative customer segments.

The second possible channel for disruption takes place in the commercial customer segment. These customers currently represent the smallest fraction of the EO market share, but the market indicated that it will soon become one of the sources of revenue in this industry. New entrants are currently addressing this market by offering low-cost imagery products and services while, at the same time, introducing new commercialization models based on the concept of Constellation as a Service. This adjacent market is currently not fully targeted by incumbents because of its limited revenue potential. However, if trends are correct, new entrants might benefit from the rapid value growth of this segment in the upcoming years. This might represent an important but nevertheless lower threat to established firms.

Given these results, traditional EO companies need to pay attention to market dynamics to quickly respond to shifts in the technical and business requirements of the customer segments identified in this report. In addition, internal innovation strategies and investment or acquisition of new entrants might be suitable strategies to mitigate the impacts of these disruptions in their market positions.

2 Introduction

2.1 Overview

The space industry is going through important changes. The development and arrival of small satellites as part of the context called newspace has brought significant uncertainty to an industry that typically relies on stable demand from public institutions and cyclic demand from commercial businesses (Denis et al., 2020) (Sweeting, 2020). Among the different application domains of space technologies, the earth observation segment might be particularly impacted by the emergence of this new class of spacecraft. The technical features brought by large constellations of satellites at lower costs along with the advancement of current sensor technologies have the potential to disrupt the EO industry (Denis et al., 2017).

While startups and new entrants to the industry are quickly adapting to the new market demands and leveraging these technological advantages, the role of traditional space companies is still unclear in this scenario. Partially, this indecision is due to the fact that the opportunities and threats created by the NewSpace Era are not a consensus. Market experts and top executives of traditional space companies cannot pinpoint or forecast the impact of these changes in their market (Bayır et al., 2021). These established players now need to adapt their strategy to try and address new market opportunities or threats while leveraging the experience they acquired throughout the decades in the space sector. In this context, this report investigates the potential impacts of small satellites in the Earth Observation market.

The analysis was conducted based on the concept of disruptive technologies, introduced by (Christensen et al., 2015), and their impact on incumbents in an established industry. This type of technological innovation has been historically identified in other industry segments where performance metrics brought by new products have the potential to completely shift and reshape market segments. In this sense, when analyzing the motivations and characteristics of past disruptive technologies, it is possible to identify a few key characteristics that are also present in the Earth Observation industry. Hence, by combining innovation management theory and information about the current EO industry, important conclusions can be drawn about market trends. One of the goals of this report is to further investigate this link.

Chapter 4 presents the main business and management concepts related to disruptive technologies. Chapter 5 focuses on providing the key elements of the space industry and, more specifically, the Earth Observation industry. In Chapter 6, the disruptability of the EO industry is assessed using methods to analyze the potential disruption of the traditional EO in face of the rise of small satellite technologies. Finally, the conclusions about the work conducted are given in Chapter 7.

2.2 Innovation Management and Technological Disruption

Innovation Management encompasses the methods that organizations can use to improve their internal processes and offerings. When combined with Change Management, which focuses on adapting established processes to deal with market and economic dynamics, the result is a powerful set of tools for companies to survive in competitive and lively markets. In this scenario, companies that do not pay attention to new trends and to innovations that are happening within their industry are likely to be left behind (Pisano, 2015). Managing innovation, both internally and externally, is critical for the medium to long-term performance of any business.

Although sometimes the concept of innovation can be broad, it can be approached from a micro or macro perspective, as shown in the Figure below (Peers, 2022). In the former, the improvement process follows a stepwise approach and is focused on improving the internal components of an organization. This includes the methods that are employed internally to generate innovative solutions (products or services). For the latter, the target is to analyze possible new factors that might affect an industry, reshaping it from a business and strategic perspective. While micro innovation aims at establishing processes to develop internal capabilities, macro innovation aims at understanding how the outcome of these processes affects an industry or market. This report targets mainly innovation at the macro level.

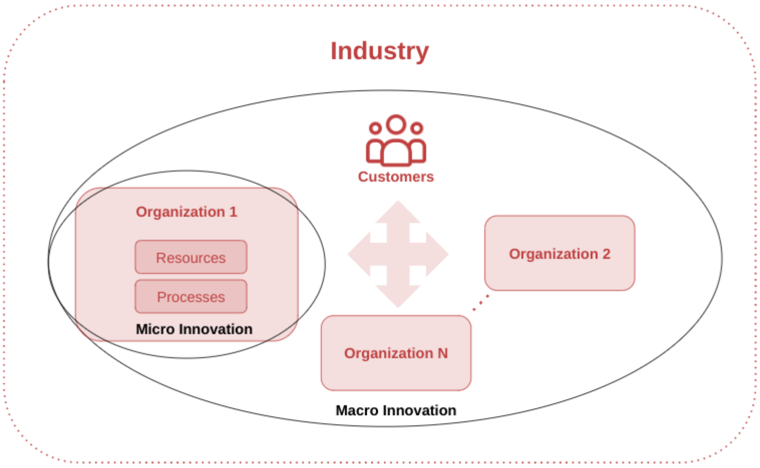


Figure 1 - Micro and Macro Innovation.

When dealing with innovation, there are two main challenges that established players (incumbents) face: (1) foreseeing the impact of new trends in their current markets and (2) defining and implementing a set of actions to mitigate the effects of these changes (Pisano, 2015). In both cases, whether the innovations are technology or business-related, companies tend to struggle to come up with a complete strategy that encompasses new possible scenarios for their business and a set of policies and actions to enable them to move to a better competitive position. The problem becomes more significant since the innovation strategies are specific to every industry and cannot be easily adapted to adjacent markets.

Often, when incumbents are able to identify potential threats created by new entrants, it is already too late and their market position has already been severely compromised. As such, being able to perform ex-ante analysis and predictions about an industry's behavior becomes a critical strategic skill for established players. Given this context, the concept of disruptive innovation creates an interesting link between technological novelties and market dynamics. This concept was first introduced by (Christensen et al., 2015) and analyzes the behavior of an industry when facing an important technological or business innovation in their sector.

The disruptive theory and a few other deeper concepts enable established players to identify possible risks and perform ex-ante analysis related to the introduction of new innovative products and services in their market (Paulino & Le Hir, 2016) (Schmidt & Druehl, 2008). In this report, the main concepts of technological disruption theory will be explored focusing on their impacts and their potential to completely reshape the competitive landscape of an industry. This research model will be used to analyze the impact of the arrival of small satellites in the space-based Earth Observation industry.

2.3 Earth Observation Market Overview

The Space-Based Earth Observation (EO) industry comprises all the components of the supply chain which are dedicated to the collection, storage, processing and diffusion of Earth's data collected from space. The type of data collected can be quite diverse, ranging from information about CO_2 pollution to RF spectrum occupation. However, the main part of the market is concentrated around imagery collection from space. The analysis presented in this report will focus on this imagery market as it captures roughly 70% of the sources of revenues in the EO industry (VALENTI, 2022).

The figure below shows the main components of this industry. On the space side, satellites are used to collect data from a specific area of the globe (Target Area). The collected data needs to flow through a series of communications blocks to get to end users, who will then use the imagery in their specific industries.

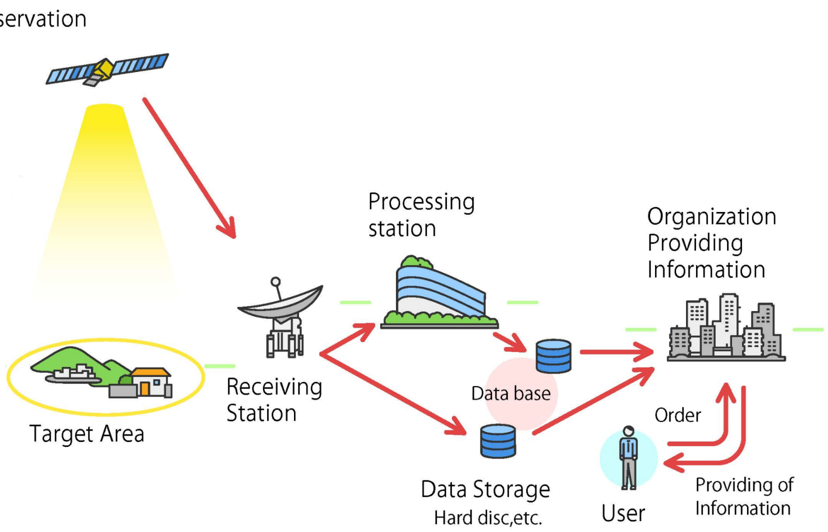


Figure 2 - Earth Observation satellites overview.[1]

The applications for EO imagery data can be quite varied and is dependent on a number of economical, geographic and technical factors. For instance, the following industry sectors are known to be using satellite imagery in their daily activities (EUSPA, 2022):

- **Precision Agriculture**: crops mapping, nutrient and irrigation management;
- **Forestry Monitoring**: forestry mapping, health and fire monitoring;
- **Air Quality**: air quality control of urban areas and pollutant tracking;
- **Security**: satellite imagery is used in a number of applications such as land border surveillance and support for military operations.

The EO satellite market is the third main space-based application comprising 5% of the $337B global market, behind navigation services (50%) and Telecommunications services (41%) (Valenti, 2022). Nevertheless, the EO industry is currently one of the fastest-growing space industries, presenting a compound annual growth rate (CAGR) of almost 7% in 2021. For instance, the amount of private investment in EO-related companies has also been significantly increasing over the past few years. The expectation is that almost 52% of the investment in the space sector will be in EO-related companies by 2025 compared to 18% in 2015 (Puteaux, 2022). These

[1] Extracted from here

numbers show a dynamic scenario for a market that has been experiencing constant growth over the past years.

This report will analyze how the EO industry is being impacted by the arrival of small satellites. So far, as it will be shown in Chapter 5, this industry has been dominated by a few established players that operate in all parts of the value chain. These established players leverage their decades of expertise to design and deploy complex space systems in orbit and deliver reliable EO data to their customer base, which is mainly composed of public organizations. The arrival of small satellites has allowed new entrants to enter this market and offer lower prices by basing their technology on smaller and simpler spacecraft. In this context, these new players have the potential to significantly impact the margins and revenues of incumbents. However, the level and probabilities of these impacts to materialize are still not entirely clear.

2.4 Objectives

The main goal of this report is to answer the following question:

Are small satellites a potential threat to the established Earth Observation market?

In addition, the following secondary questions will also be addressed throughout the report:

- Are small-satellites-based companies competing in the same EO market as traditional satellite-based companies?
- Do customers of established players value the same performance criteria as the ones brought by small-satellites-based companies?
- Are small satellites addressing/creating a new market in the EO Industry?
- What are the underlying conditions that are required for the potential small satellite threat to happen?

3 Methodology

From a macro perspective, the work presented in this report can be divided into three main phases which include bibliography review, data analysis and report preparation. These three phases compose the overall research design used to carry on the analysis presented in this report.

During the initial stages, the references presented in the last Chapter were carefully studied in order to establish the theoretical basis of the study case analysis. This task included mainly the review of the core business and management concepts related to Innovation Management and Disruptive Innovation. For this review, academic articles and books were studied with a focus on disruptive innovation and its impacts on industries in general.

After establishing the research basis through the study of academic sources, the bibliography review was finalized based on empirical sources related to the Earth Observation Space industry. In this case, the focus was mainly to understand the main components present in the value chain, the customer segments and the main trends that can be expected in the upcoming years for this industry.

A comprehensive list of market reports, investor presentations and secondary data sources was gathered for the data analysis phase of the project. In order to compare the performance metrics and overall strategies of large-satellite-based and small-satellite-based earth observation companies, the data and information of the main players of the industry were used as a benchmark. For the large satellite context, Airbus DS and Maxar were used as references because of their large market share in the EO sector. Likewise, data from Planet, Satellogic and Blacksky was used to assess the performance of EO companies using small satellites.

In addition, several meetings were conducted to gather feedback from academic experts and members of the industry. The data collected in these meetings was not explicitly presented to avoid confidentiality issues.

After collecting and filtering the most relevant sources of information, the data was used to analyze and measure the potential for disruption brought by NewSpace companies to the Earth Observation sector. This included identifying the opportunities and threats for the Earth Observation industry in the face of the NewSpace context. In this sense, the academic methods studied during the early phases of the report were employed to assess the disruptability of the EO industry using the data collected.

In a nutshell, during the **Data Analysis Phase**, the following steps were taken to arrive at the final conclusions of the report:

1. Analyze how the space market structure to understand how the value chain works in this industry and who the main players are.

2. Analyze the Earth Observation market to identify the main types of customers, the performance metrics valued by these customers and their requirements in terms of costs.

3. Investigate the main features and performance metrics introduced by nanosatellites in the context of the Earth Observation industry.

4. Perform a potential disruption analysis by comparing the performance features brought by nanosatellite constellations to the ones expected by customers in the market.

5. Discuss what happens in case the predictions are true or false

The final phase of this work was dedicated to writing this report to summarize the main arguments developed.

4 Disruptive Innovation: Threats and Opportunities

4.1 Types of Innovation

The overall goal of this report is to study and discuss the impact of technological innovation (small satellites) on an established market (Earth Observation industry) and their main players (large-satellite-based companies). As mentioned in the introductory chapter, the concept of disruptive innovation is useful to provide a link between new technology and its impacts on a given industry. In this chapter, this type of innovation will be discussed.

At first, it is important to look at the concept of innovation from a macro perspective and narrow it down to possible cases that might impact the strategies of incumbents in an industry. In this context, it also becomes relevant to identify and categorize the different types of innovation that might be happening in a particular industry. Through this, it is possible to perform a more specific analysis of the market behavior, have better predictions of trends, and, hence, better devise strategies to mitigate possible negative effects of these trends.

The distinction between micro and macro innovation presented in the introduction chapter is the first layer of categorization that can be performed. In addition to that, innovation can still be divided according to different models (Satell, 2017) (Pisano, 2015). A commonly used model was introduced by (Satell, 2017) and uses a simple matrix to split innovation into four main types, as shown in the Figure below:

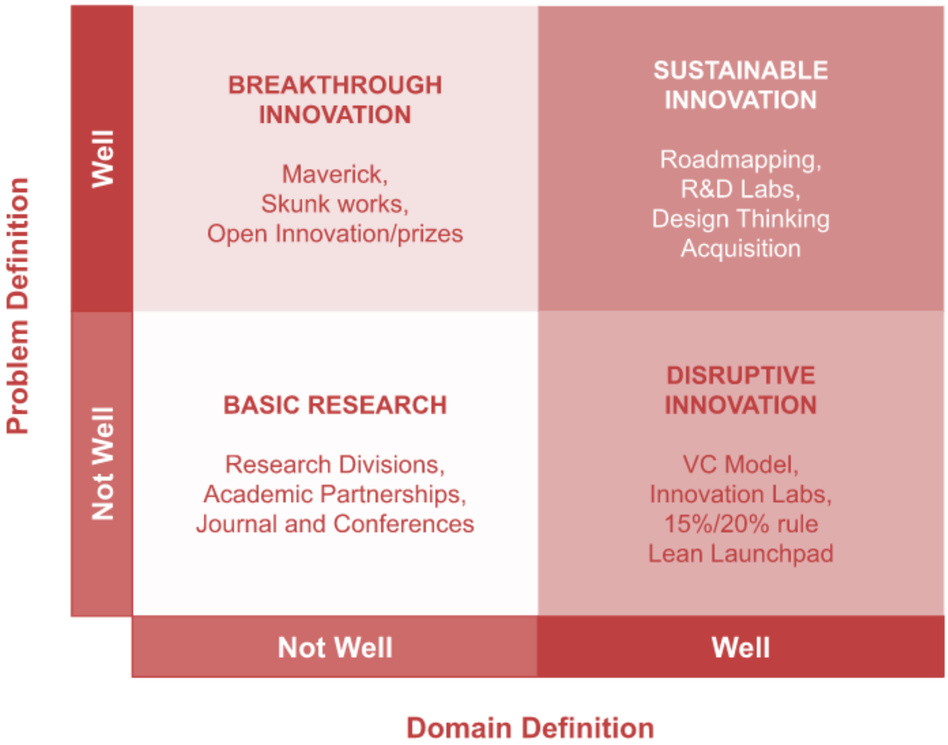


Figure 3 - Innovation Matrix. Adapted from (Satell, 2017).

Based on this model, Innovation can be categorized into 4 different types according to two main factors: how well-defined the problem is defined and how well-defined the domain is defined. The specificities of each type of innovation are described below:

- **Basic Research:** This type of innovation represents the early stages of any major technical or business innovation. At the beginning of the innovation process, often, the problem and the domain of the solutions are not well known. In this case, organizations need to start from scratch to acquire expertise in their domains/markets and then start the heavy innovation processes. This scenario typically happens in partnerships between members of the industry and research organizations.

- **Sustaining Innovation:** Related to the process of continuously improving the performance of a given offering. This type of innovation is usually favored by established players in the market, who want to keep improving their products or services to increase the value provided to their current customers. This is usually a slow process that happens over the course of the years that the established players spent in the market. In this case, the variables (problem and domain) are well known given the expertise of the established player in the market. The continuous improvement of iPhone products is an example of this innovation process.

- **Breakthrough Innovation:** Happens when a problem in the industry is well defined but the solutions to this problem are not trivial nor well-known. In this case, incumbents are required to explore unconventional skill domains to try and find a solution. These usually result in radical changes in the competitive landscape and are based on revolutionary technology or business shifts. The introduction of the Internet in the early 90$_s$ is one possible example of this type of innovation.

- **Disruptive Innovation:** The concept of Disruptive innovation was first introduced by (Christensen et al., 2015) and is related to a new low-end product entering an established market. This new product starts by acquiring a small portion of the market (low-end customers) that are not addressed by established players, who prefer to focus on the high-end portion of the market. Over time, new entrants improve their offerings and start to tackle the mainstream portion of the market, reducing the market share of established players. At some point, the former low-end product takes over the majority of the market, and incumbents are not able to adapt their offerings to regain market share. At this point, market disruption occurs and fundamentally changes the competitive landscape of the industry. A typical example of this is the rise of Netflix (new entrant) and the bankruptcy of Blockbuster (incumbent) in the early 2000$_s$.

Although the four types of innovation are equally important and should be taken into account by any company that is devising an innovation strategy, this report will focus mainly on Disruptive Innovations. Given the context of the space sector, as it will be seen later, this type of innovation is the closest to what is currently happening in the industry. More specifically, the Earth Observation market is currently facing a potential disruption due to the arrival of small satellites in the context of the newspace era (Denis et al., 2017). Hence, the next sections will be dedicated to analyzing and discussing how disruption might occur in an industry or market segment.

4.2 Understanding the Disruption Process

Disruptive innovation happens when an established player leaves room for a new entrant to offer a different class of product to a customer segment that is currently not being addressed. In most cases, this happens because incumbents are more focused on adding value to their products and services through Sustaining Innovations, by slowly increasing their performances to satisfy their current range of customers (Daneels, 2004). In this upper portion of the market, the margins are more significant than the ones found at the lower end of the market segment and, hence, incumbents are even more biased to address their current markets instead of the low-end ones. This creates opportunities for new entrants.

This effect by itself would not be a problem to established players if new entrants kept indefinitely addressing this lower portion of the customer segments. However, over time, new entrants are able to gather more experience and customer feedback to improve their solutions. Technological advances might also allow new entrants to improve their products. At some point, their product becomes an acceptable option for the mainstream part of the market, which comprises the majority of the market share. Then, new entrants start to compete directly with the solutions provided by incumbents. Meanwhile, incumbents focused so much on improving their offerings to high-end customers, that their products are not adapted anymore to mainstream customers (higher cost, over performance, etc...). Finally, established players can no longer compete in their main markets and they have to make a decision to either retreat to specialized niche markets (low market share) or restructure their business and products entirely to assess new markets.

The curves below can be used to illustrate the process mentioned above. The "Entrant's disruptive trajectory" shows the path the new entrant's product follows to go from the low-end portion of the market to the mainstream part of the market. Meanwhile, the incumbent's trajectory moves from the mainstream to the high-end part of the market, leaving an opening for new entrants. In this case, the product's performance is evaluated according to a specific parameter.

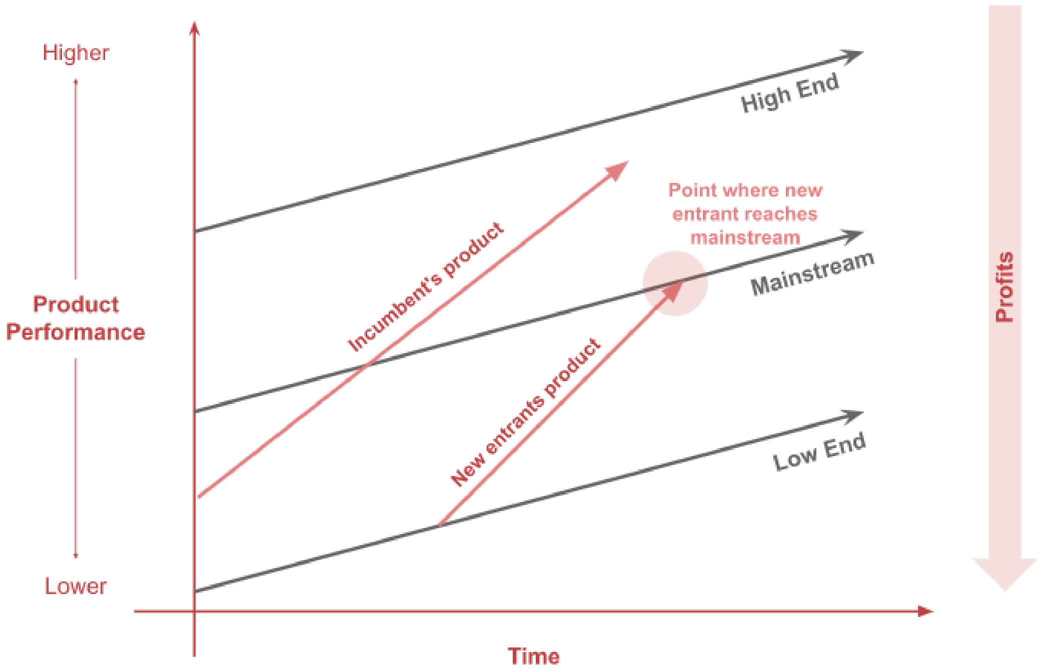


Figure 4 - Disruptive innovation process. Adapted from (Christensen et al., 2015).

Recently, in order to incorporate new concepts, Christensen proposed a few modifications to the originally proposed model. The main one is related to the fact that, originally, a potential disruption from new entrants always started by addressing a low-end portion of the market, as shown in the graph above. However, in some cases, the disruption process might start when new entrants initially focus on a completely new set of customers that did not exist before. In this case, the potential disruption comes from the process of this new market becoming, at some point, more relevant than the original mainstream one. This process can be seen as an extension of the previous scenario, as shown in the graph below.

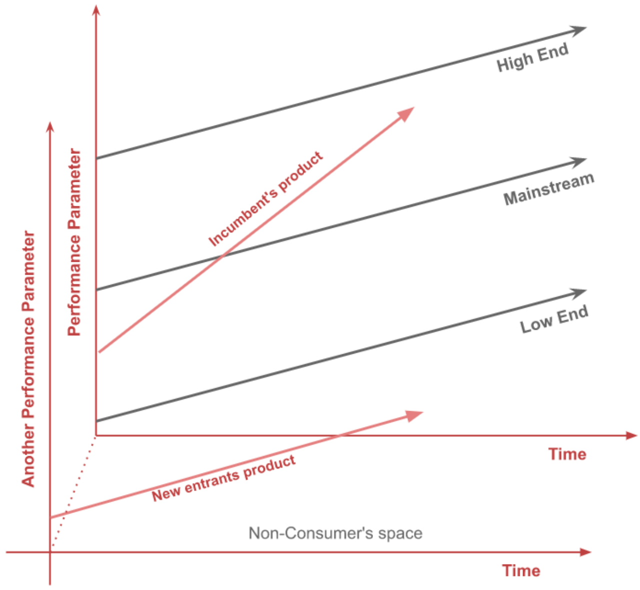


Figure 5 - Disruptive innovation process from a new market. Adapted from (Christensen et al., 2015).

The model proposed by Christensen is useful to explain important dynamics that happen to industries when established players are faced with a powerful strategy of a new entrant. The process described above has happened in several industries like media rental (Netflix x Blockbuster), cameras (Kodak x Canon), airlines (RyanAir) and so on. However, the model has a few limitations when it comes to analyzing and categorizing specificities within the disruption process, how it might take place and how to predict the process (Daneels, 2004).

The update made by Christensen to his original theory helps understand the impact of different performance metrics in the disruption process. Ultimately, the impact of the entrant's new product on incumbents is tightly related to which performance metrics are introduced or modified by the incoming products. In case they are competing in the same performance space, the risk to incumbents is higher because their solutions are in direct competition against the new ones. In case the innovation happens in an adjacent market or performance space, the risk to incumbents still exists, but it is limited by the course of this new market toward the established market.

The image below shows an alternative representation of the disruptive process using four performance dimensions. In this case, the market characteristics are evaluated according to four performance metrics (A,B,C and D). The plot in **red** shows the required performance from mainstream customers, while the **gray** plots show the performance metrics reached by incumbents and new entrants.

The metric A is quite valuable to customers and this requirement is completely met by the products of established players. The same happens for customers' requirements in terms of metrics B and C. In these cases, however, incumbents are overperforming when compared to market requirements. A part of mainstream customers also values feature D, which is currently not met by established players but is met by new entrants. As of now, new entrants cannot compete for the whole mainstream market, but they might tackle a specific market share that is interested in feature D. This situation represents a potential market disruption for established players, especially if market dynamics make customers change their requirements and appreciate even more the performance metric D.

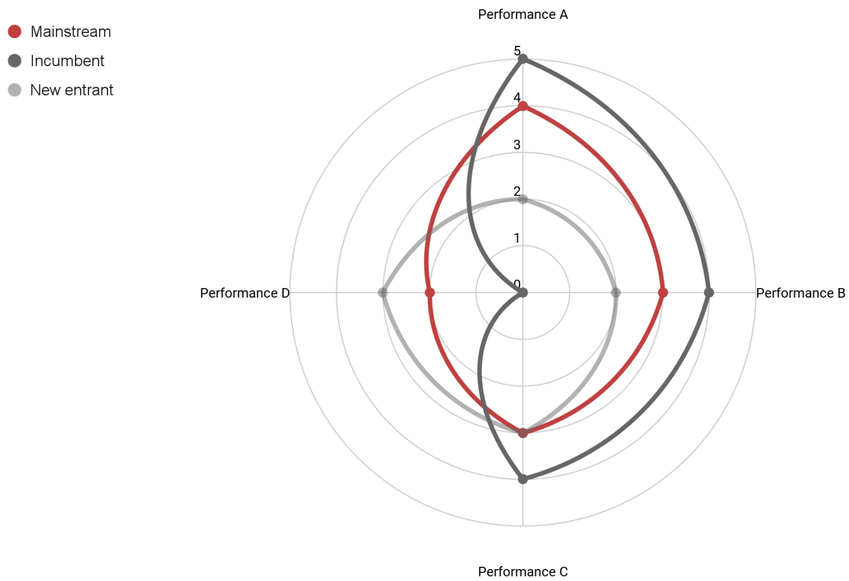


Figure 6 - Disruptive innovation in a multi-dimensional scenario.

The situation presented above is useful to understand the impact that different performance metrics have on potential disruptive innovations. These metrics can be related to quality, delivery time, and so on, and they can be used to properly define different sources of disruptive innovations. In specific, often an important performance metric is the cost of the products and solutions proposed. In the next subsection, the disruption process will be segmented into different types according to how the new entrants and incumbents are positioned in the performance metric space. As will be seen, the cost will be one of the main variables assessed during the discussion.

4.3 Types of Disruption

When multiple dimensions are evaluated as part of the disruption process, it is possible to draw deeper conclusions about the behavior of the market in face of potential disruption. In particular, analyzing the disruption process in terms of different metrics and how they are expected to change over time enables the creation of different categories, later, different preparation strategies.

The first important and universal performance metric that needs to be taken into account is the cost of the product. In general, the level of investment required from customers defines the portion of the market that will be addressed by the products. Low-cost products tend to target low-end portions of the market while high-cost products target the high-end spectrum of customers. Taking these definitions into account, (Schmidt & Druehl, 2008) proposed the concept of **encroachment** to explain how the adoption of a new product takes over an existing market. This concept was also discussed in (Paulino & Le Hir, 2016) with a stronger focus on the space industry. The disruption process can be split into two possible encroachment processes:

- **Low-end encroachment**: happens when a product that is initially targeting the low-end portion of the market gets later adopted by the mainstream customer segments. In this case, the adoption of the new product starts at the low end and goes upward.

- **High-end encroachment**: In this case, the new product initially addresses the high-end portion of the market and moves downward in the customer base.

High-end encroachment happens mainly through a sustainable innovation process, where new features are added to an existing product with the goal of targeting customers who are willing to pay more for performance. Later, this product is inevitably adopted by the lower portions of the market. A typical example is the introduction of new iPhone models by Apple. Companies tend to be very reactive to any type of innovation that tries to tackle the high-end portion of the market because that is where the high-profit margins are. Low-end encroachment processes, on the other hand, tend to be neglected by incumbents because the margins are low. For this reason, the low-end encroachment mechanism is directly related to the disruption process described in the previous section.

For the low-end encroachment, customers are willing to invest in the same or a similar product as the one provided by incumbents, only provided that the cost is lower. In this case, the specificities of the encroachment process can be categorized in terms of the type of customers and their valued performance metrics. For instance, the customers who are willing to buy the new product might not belong to the same segment as the ones buying the existing product from incumbents. In addition, the performance metrics valued by the customers might be the same or completely different from the ones valued by mainstream customers. These variations lead to the segmentation of the disruptive innovation process shown in the table below:

Table 1 - Types of Disruptive Innovation. Adapted from (Schmidt & Druehl, 2008).

Type	Description	Valued Performance Metrics	Customers Segments	Threat to incumbents
1	**Immediate** New entrants compete for customers who value the same performance criteria as the ones provided by established players. In this case, however, new entrants offer lower prices for comparable performance marks.	**Same** as mainstream customers	**Same** as mainstream customers	**High**
2	**New Fringe Market** New customers value almost the same performance criteria as mainstream customers. Still, they are not willing to pay for the innovation improvement.	**Slightly Differently**	**Different** than mainstream customers	**Moderate**
3	**New Detached Market** New customers value performance criteria that are completely different from the ones valued by mainstream customers.	**Completely Different**	**Different** than mainstream customers	**Low**

The types of disruptive innovation described in the table above provide more details about mechanisms that lead to a new entrant taking over an existing market. By analyzing the characteristics of a given industry and comparing them to the characteristics of each disruptive innovation type, it is possible to identify which threats and opportunities will possibly be created.

Type 1 innovations represent an important threat to established firms because the new product is a direct replacement for the products currently offered to mainstream customers (Paulino & Le Hir, 2016). In this case, the new entrant's product exhibits a lower performance compared to the incumbent's products, but it is proposed at a lower cost as well. For this reason, the product addresses first the low-end part of the market, which considers the new entrant's solution as the "second best" alternative. Incumbents are protected solely by the performance limitations of the new product, which could be quickly improved by business or technological innovations. If these improvements take place, new entrants' products might immediately take over part of the mainstream customers from incumbents.

When disruptive products address a fringe market, the threat to incumbents is moderate since the new solution is not a direct replacement for current products. In this case, the performance attributes valued by customers are slightly different from the ones of mainstream customers. Although the costs of the new product are lower, the performance does not reach the requirements of current customers. In this sense, new entrants are creating a new market with new customers that are not the same as the ones addressed by established firms. Only a small portion of current customers will adopt the new product. The threat in this case is dependent on the trends of current customers to change their performance metrics and start to appreciate the performances of the new products (Schmidt & Druehl, 2008). Also, incumbents might be indirectly affected in case the fringe market becomes larger than the current mainstream one in the future.

Finally, Type 3 innovations represent the lowest threat to incumbents because the new products are introduced in a performance space completely different from the ones valued by mainstream customers. In this case, the risk of existing customers migrating to this new market is low. Even if prices are significantly reduced by new entrants, the market share of established firms will likely be kept intact. Both markets can co-exist without significant impacts on one another.

Given that the types of innovations and their impacts are quantified, the next section will focus on providing the key concepts and tools to identify the type of disruptive innovation, forecast and anticipate its impacts for a given industry. This tool will be useful for the analysis performed in Chapter 6 to analyze the EO industry.

4.4 Anticipating Disruption

When assessing the disruptability of an industry from a strategic and management point of view, one of the most expected outcomes is being able to forecast market dynamics and how they can be potentially influenced by new disruptive businesses (ex-ante analysis) (Paulino & Le Hir, 2016). In addition, once this potential threat has been identified, it is equally important to be able to devise countermeasures to mitigate the possible impacts of new entrants in the current strategy. The goal of this section is to define and discuss the main steps required as part of this analysis. Later, these steps will be employed to analyze the potential disruption that the Earth Observation industry is facing nowadays.

In the definition of the three types of disruptive innovations, two main characteristics were taken into account to categorize the disruption that an industry is potentially going through. These two main characteristics are the segment of customers and the performance metrics that they use to evaluate products in the market. As a result, the process of identifying and forecasting a disruptive innovation in a specific industry inherently goes through carefully studying these two aspects of the market. In this context, the process of assessing if a new product or service might be disruptive in a new market can be based on the following steps:

Table 2 - Steps to identify and forecast disruptive innovations.

Step	Description	Outcomes
1	Identifying the main customer segments	List of customer segments
2	Identifying the main performance dimensions that are valued by each of the customer segments defined in step 1.	List of performance criteria valued by each customer segment

3	Identifying the potential changes that might happen in the industry shortly (potentially disruptive technologies or products). These changes should include potential modifications in the performance metrics of customer segments.	List of emerging technologies and innovations in the industry and the performance criteria that are added or modified by these new technologies
4	Comparing the current performance dimensions to the new ones brought by the new entrants. Set the type of disruptive innovation for each of the new products found in step 3. Compare the results of steps 2 and 3.	List of types of disruptive innovation that the industry is subject to.
5	Extrapolate the evolution of the performance criteria of the new technologies. Assess the evolution of the performance metrics given different economic and technological scenarios.	List of possible future scenarios and how they might impact the disruptive innovation process.
		Outcome: a detailed analysis of how the new products and services meet the customer's expectations.

By performing the tasks shown in the table above, it is possible to benchmark how much of a threat the potential disruption is to established players in the industry. This analysis will be performed in Section 6 of this report.

5 Earth Observation: Space and New Space Industry Overview

5.1 The Space-Based Earth Observation Industry

5.1.1 Value Chain

The first step to understanding the impact of the arrival of new technology in a given industry is to analyze its value chain and the main components that are part of the value-generation process. The Earth Observation value chain is shown in the diagram below and can be divided into three main categories:

- **Upstream**: The Upstream portion of the value chain focuses on all the aspects of satellite manufacturing, launching and operating. It also encompasses ground segment development and deployment. In a nutshell, this portion of the value chain is dedicated to providing the space infrastructure required to acquire data in space and beam it down to earth.

- **Midstream:** In this case, the focus is on data collection and distribution. The network to interconnect the ground stations and also to re-transmit data to end customers are part of the section of the value chain. With the recent advances in satellite communications and big data technologies, the Midstream value chain has become even more important.

- **Downstream:** The connection between customers and satellite data is done through companies operating in the downstream end of the Earth Observation value chain. This part is where the Value-Added Services (VAS) companies are positioned. In general, downstream-positioned companies are responsible for providing direct insights to key industries around the globe using EO data as input. Because of the size and potential of the market, the majority of the companies in the Earth Observation market are operating at the Downstream end of the value chain (EUSPA, 2022). This is also due to lower technical and capital requirements when compared to the Upstream end of the chain.

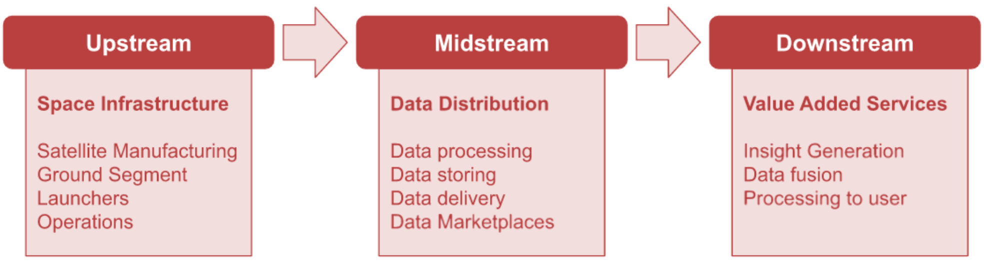


Figure 7 - Earth Observation value chain. Adapted from (EUSPA, 2022).

The diagram below shows the distribution of revenues between the different parts of the Earth Observation market value chain. The EO value chain is still fairly unbalanced since the main source of revenues is concentrated on the upstream part of the chain (satellite manufacturing). The share dedicated to commercial customers in the downstream part of the value chain also provides important information about how the EO industry is organized.

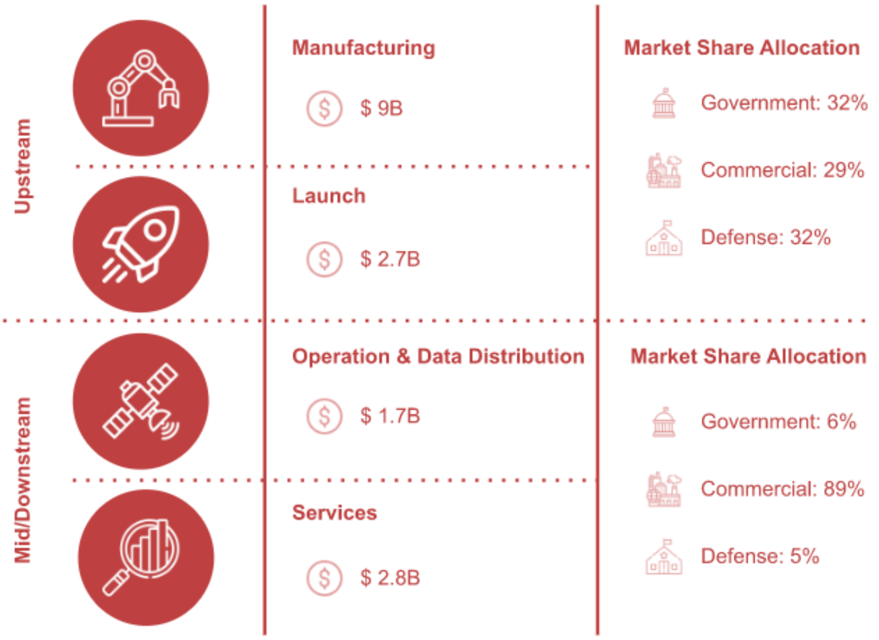


Figure 8 - Market Value distribution across the EO Value Chain (Valenti, 2022).

These two distortions in the revenue distribution of the value chain can be explained by the fact that the EO market is still centered around governmental and defense missions, as shown on the right-hand side of the picture. This type of customer tends to place orders for EO satellites directly to manufacturers and perform their data analysis internally. This behavior expands the revenues generated by companies in the upstream part of the value chain while limiting the revenue potential of the downstream part of the market.

Finally, although the value chain is presented as a very segmented set of layers, in reality, players in the Earth Observation industry tend to operate in multiple levels of the value chain (Bousedra, 2021). This implies a high level of consolidation in the industry as a whole, where players are highly vertically integrated. In some cases, companies are responsible for designing, building and operating their satellites (upstream), but also to process the collected data and deliver it to customers (downstream). Although this behavior is strongly present in incumbents, new entrants are also following this strategy as will be seen later.

The unequal value distribution across the different steps of the chain and the level of consolidation of the industry can ultimately be explained by looking at performance dimensions envisaged by the different types of customers. The next section will focus on these performance criteria as a way to understand which metrics are considered critical to the different types of customers.

5.1.2 Performance Criteria

As in most of the space-related markets, the demand that arrives at the upstream portion of the value chain is strongly influenced and dictated by companies who are in direct contact with end users on the downstream portion of the value chain. This behavior is especially strong in the EO industry because of the high level of vertical integration found in the main players. Hence, it is necessary first to study the needs of the Earth Observation market on the downstream side to understand the requirements for EO platform providers.

At the downstream end of the value chain, data collected from earth observation satellites are differentiated according to several technical features. These technical characteristics are carefully chosen according to the requirements of the end-user applications they serve. In addition, a few economical characteristics are also important to customers at the downstream part of the value chain. The Table below summarizes the main properties of Earth Observation satellites, including their differentiators and general descriptions.

Table 3 - Main technical and economical features of Earth Observation satellites.
Sources: (EUSPA, 2022), (PwC, 2019) and (PwC, 2022)

Type of differentiators	Technical differentiators	Description
Type of Sensors	Passive *Do not transmit any active signal to perform their measurements*	**Optical sensor**: Capture visible information (shape, color) of objects. **Infrared sensor:** Capture thermal information of objects **Multi/HyperSpectral sensor**: Able to separate light in tens to hundreds of bands to image across a continuous and contiguous range of wavelengths
	Active *Transmit a signal and measure its response to perform their measurement*	**SAR sensor**: Capture the shape and change of object, enabling night time and all-weather monitoring
Quality of Data	Spatial Resolution	The area captured per pixel. A higher spatial resolution allows the precise identification of objects.
	Spectral Resolution	The frequency band sharpness (frequency granularity). Allows for more precise discrimination of different types of objects.
	Geolocation Accuracy	Absolute accuracy to a fixed point on the ground, measured in terms of deviation in meters.
	Collection Model	Collect (1) every possible region of each data or (2) collect only a specific region each day (1) imposes more requirements on memory capacity.
	Reliability	Guarantee that the data will be delivered to customers
Availability of Data	Temporal Resolution	The amount of time between images taken at the same location. Related to the frequency of satellites passing over the same location.
	Swath	Mowing width or footprint in one pass
	Agility	Time to slew/point from one target to another.
	Geographic Coverage	Area of the globe that is covered by the satellite (worldwide, a specific region, etc)
	Acquisition Capacity	Amount of km^2/day that can be stored and downlinked to earth
	Delivery Speed	The time required to deliver to customers data from a given region
Mission	Lifetime	Life duration of the satellite in orbit. This property depends on factors like the quality of components onboard, orbit, fuel capacity and so on…
Economical	Price/km^2	The cost of images per km^2. The lower the space infrastructure and operations cost, the lower the cost of images sold to end customers.
	Business Model	CAPEX-oriented: focus on large initial investments from customers OPEX-oriented: initial investment internally absorbed. Revenue based on Constellation-as-a-Service (CaaS) model.

The type of sensors used to collect data plays an important role in the final application that the imagery can be used for. The imagery collected by these sensors provides different and, in some cases, complementary information about the area being monitored. Nevertheless, currently, the EO imagery sector is mainly centered around images collected by optical sensors, as shown in the figure below. Because of the market dominance of optical imagery, this report will focus only on this type of product. This limitation in the studied data allows the analysis to be more detailed about the impact of small satellites on the industry.

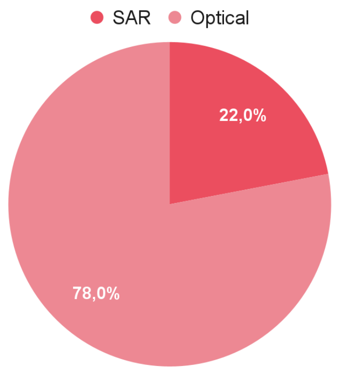


Figure 9 - Market share of Optical and SAR imagery in 2018. Adapted from (NSR, 2019).

Considering the optical imagery market, a few key parameters from the Table above need to be specially taken into account when considering customers' requirements. For the analysis presented in this report, the parameters spatial resolution, revisit time, reliability and cost will be used as performance metrics in the EO industry.

The spatial resolution is related to how well objects can be identified in the picture and with which precision. Although multiple scales are used in the literature to specify spatial resolution, this report will be based on the resolution scale described in the Table below.

Table 4 - Classification of spatial resolution according to pixel size[2].

Classification	Pixel Resolution
Low Resolution	> 5
Medium Resolution	1 ↔ 5 m
High Resolution	0.5 ↔ 1 m
Very High Resolution	0.3 ↔ 0.5 m
Ultra High Resolution	< 0.3 m

This parameter depends on a number of factors like the size of the image sensor, the quality of the optics, the size of the lens aperture, and the type of image processing algorithms used. In EO applications two main factors can be highlighted: the distance to the target object (orbit) and the size of its imaging sensor. The lower the orbit of the satellite, the higher the resolution of the images taken by the satellite. This partially explains why earth observation satellites are placed in LEO orbit mainly. This orbit enables high-resolution images to be taken without significant impact on the instrument and hence the satellite's size.

The graph below shows the downstream market share for the different spatial resolution levels in 2022. In this case, more than 60% of the revenues come from high and very high-resolution images. In addition, 70% of

[2] Adapted from ESA's "Newcomers Earth Observation Guide"

these revenues come from defense and public customers. The Ultra High-Resolution category is not displayed in the graph because it represents a very small and specific portion of the market. Images taken with a resolution below 30 cm need special legal clearance from governments and hence are mainly dedicated to defense purposes.

A final important factor is that customer demand is shifting towards high and very high-resolution optical images (PwC, 2022). This illustrates an important trend in the market related to this technical performance metric.

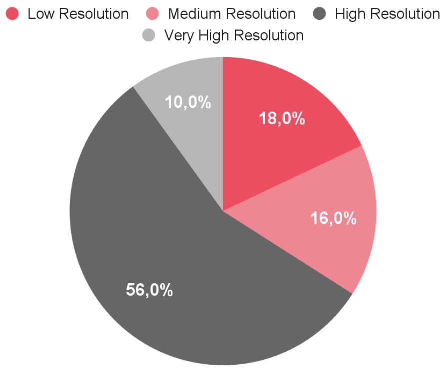


Figure 10 - Downstream market share per image resolution (EUSPA, 2022).

The frequency or revisit time at which the pictures of a single region are taken is another key parameter of Earth Observation imagery. For instance, the freshness of images is critical to applications in the defense market or forest monitoring, which expect new images on a daily or hourly basis (Satellogic, 2021). However, applications like crop and land monitoring might accept refresh rates of higher time periods (months).

The graph below shows the different data requirements for the main EO applications as a function of the required spatial resolution and revisit time (Frequency). Most of the current applications require spatial resolutions below the 1-meter range while the required revisit times are spread throughout the whole range. However, it is important to notice that large and/or fast-growing markets such as Agriculture and Infrastructure Planning require high resolution and high revisit time data.

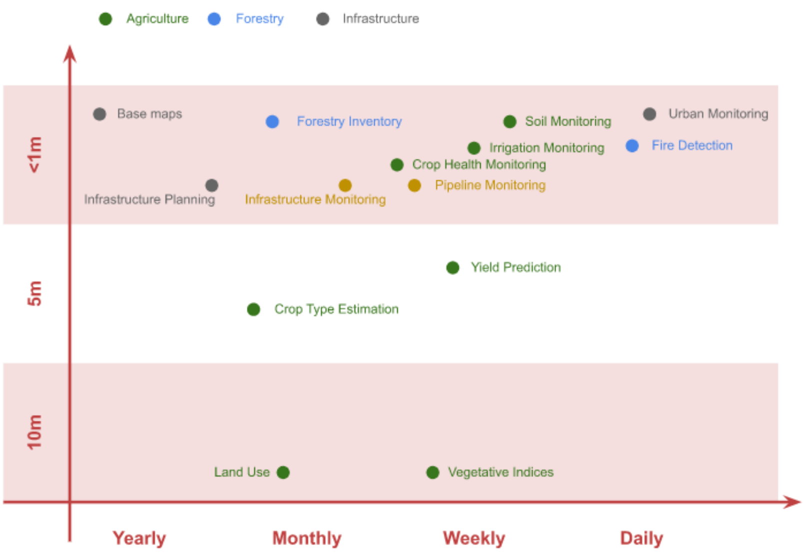


Figure 11 - Resolution and frequency required for each application. Adapted from (Satellogic, 2021).

The overall reliability of the system is also critical for a number of EO applications. Although it is complex to precisely quantify the reliability of an EO satellite constellation, there are a few parameters that can be used to estimate how reliable the constellation is. In this report, the reliability of constellations will be measured according to the following qualitative criteria:

- **Satellite Availability**: This criterion is related to the availability of the system to perform specific tasks requested by customers. This might include pointing the satellite to specific locations or configuring certain parts of the instrument.
- **Data Integrity**: Data must be received from the satellite in its original form, with no errors or corruption.
- **Data Availability**: Data must be available to users quickly and without interruption.
- **Redundancy**: Satellites should have redundant components to ensure that they can continue to function in the event of component failure. The satellites should also be redundant when considering the constellation scale.
- **Performance**: The ability of a satellite system to meet specifications and performance requirements.
- **System Security**: The ability of a satellite system to protect itself from unauthorized access or attack.
- **Support**: The capacity of EO satellite manufacturers and data providers to provide technical support to customers.

The last critical parameter for earth observation imagery products is the cost of the data. Usually, EO data is sold on a per km^2 basis (Denis et al., 2017) and the three parameters aforementioned have a direct impact on the final cost rate. Traditionally, images with higher resolution and higher revisit time require more complex space systems and, in turn, a higher capital investment from companies, leading to higher prices for the end user.

Apart from these quantitative performance criteria, it is also important to consider the commercialization models adopted by companies to sell satellite imagery. As mentioned before, satellite images are usually sold on a per km^2 basis, however, recent business innovations introduced by new entrants are proposing data transactions based on subscription models. In this case, customers subscribe to a data platform and have continuous access to satellite imagery in real time. This concept is frequently adopted in the software industry and is known as an "as-a-service" model. In the case of space-related businesses, this model is commonly referred to as a Constellation-as-a-Service (CaaS) (Bousedra, 2021).

When combined, these technical and financial properties affect the demand for data from customers. Established players and new entrants in the EO market tend to focus on specific niches within the dimensions imposed by these characteristics. In turn, they can decide to, for instance, specialize in particular customer segments and applications.

5.1.3 Customers

In the EO market context, the applications envisaged for the collected data impose the technical and economical characteristics that were reviewed in the previous section. The main segments of customers operating in the EO market will be presented by adopting a bottom-up approach, from the downstream to the upstream portion of the value chain.

From a macro perspective, EO customers can be divided into three main categories (Valenti, 2022):

- **Commercial:** Focus on activities that can generate profit based on Earth Observation data. These applications can be related to agriculture (crops monitoring), energy infrastructure monitoring, financial services and so on.

- **Governmental:** The goal is to use Earth Observation data to acquire information about environmental conditions (climate, forest and wildfire monitoring). It can also be related to scientific experiments or general infrastructure monitoring. Government-funded space agencies also fall into this macro category.

- **Defense:** In this case, EO data is used to monitor military assets and to provide advantages in terms of intelligence and surveillance.

The image below shows the EO Data market share of the Defense (U.S. + Non-U.S.) markets compared to the other two customer types (Commercial + Governmental). In this case, the market shares over the year show a strong concentration of the EO data market value around Defense customers, indicating that this is one of the main customer segments of the Earth Observation market. In addition, the large portion of market share taken specifically by the U.S. Department of Defense (DoD) also indicates a geographically unbalanced distribution of value in the industry. This trend can also be seen when looking specifically at the optical imagery market, which concentrates most of the market value in the industry. In this case, applications related to Defence & Intelligence are key products in this market.

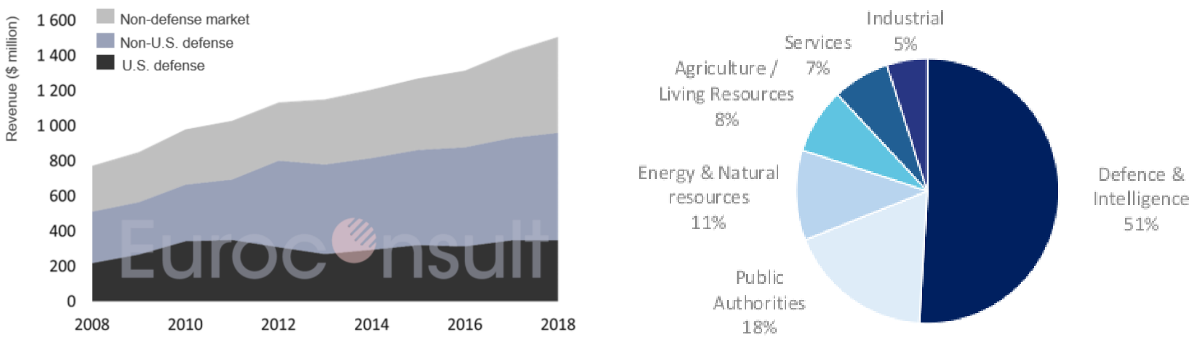


Figure 12 - EP industry Revenue for Defense and Non-Defense Market (left). Share of high-resolution EO imagery application per customer segment between 2011 and 2017 (right). Sources: (Valenti, 2022) and (PwC, 2019)

Customers who belong to the Defense segment present important requirements when compared to the other segments. For instance, they are usually interested in high-resolution and high-revisit time imagery to precisely track military assets and perform intelligence analysis (PwC, 2019). Finally, because of the high level of criticality and constraints, they usually dispose of a larger budget (high-end market) (Denis et al., 2017).

As of today, governmental customers compose the second largest customer segment of the satellite-based earth observation market, as can be seen in the graph above (left-hand side). In this case, they are most interested in applications that are of public interest to their citizens. This includes but is not limited to, the environment, natural resources, infrastructure and land monitoring (EUSPA, 2022). Because of the wide variety of applications, the technical requirements of this class of customers are also quite diversified.

Governmental customers can be split into two main categories: (1) nations with consolidated experience in space and (2) nations with ambitions in space (emerging). The former includes countries that possess an established space industry and a continuous allocation of budget for space-related projects. Countries like Japan, the U.S. and France fall into this category. The latter encompasses countries that are willing to acquire space assets but do not have the technical or financial capabilities of doing it from scratch.

The image below is in line with the discussions above and provides a good perspective on how the customer segment of the Earth Observation industry is organized and distributed. On the top of the pyramid, a few defense (DoDs) and governmental customers are responsible for the largest contracts in the market. On the top of the pyramid are the mass markets comprising commercial customers and other end-users. The bottom, although massive in terms of the number of customers, is still underexplored in terms of revenue generation.

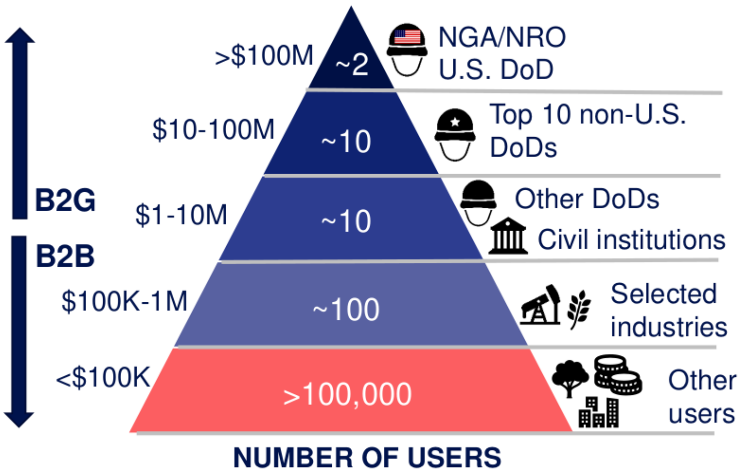
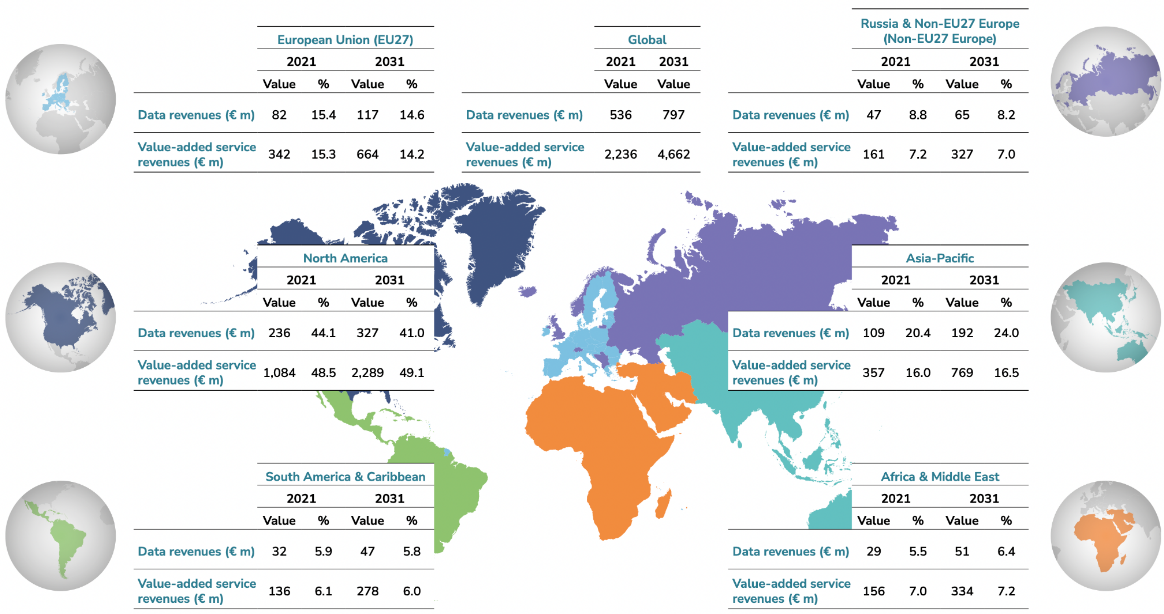


Figure 13 - Distribution of the number of customers and generated revenue per customer type (Valenti, 2022).

When looking at the commercial portion of the market, Earth Observation customers can be segmented mainly according to their region and envisaged application. In terms of region, the chart below summarizes the distribution of EO customers around the world in 2021 and the projected numbers for 2031. Similarly to what happens in the Defense segment, North America is the market with the largest demand for earth imagery in the commercial segment. Meanwhile, the Asia-Pacific region is expected to grow in data revenues to account for 24% of the global market by the end of 2031, making it one of the largest growing markets (EUSPA, 2022).



European Union (EU27)	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	82	15.4	117	14.6
Value-added service revenues (€ m)	342	15.3	664	14.2

Global	2021 Value	2031 Value
Data revenues (€ m)	536	797
Value-added service revenues (€ m)	2,236	4,662

Russia & Non-EU27 Europe (Non-EU27 Europe)	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	47	8.8	65	8.2
Value-added service revenues (€ m)	161	7.2	327	7.0

North America	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	236	44.1	327	41.0
Value-added service revenues (€ m)	1,084	48.5	2,289	49.1

Asia-Pacific	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	109	20.4	192	24.0
Value-added service revenues (€ m)	357	16.0	769	16.5

South America & Caribbean	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	32	5.9	47	5.8
Value-added service revenues (€ m)	136	6.1	278	6.0

Africa & Middle East	2021 Value	2021 %	2031 Value	2031 %
Data revenues (€ m)	29	5.5	51	6.4
Value-added service revenues (€ m)	156	7.0	334	7.2

Figure 14 - EO Data demand world map (EUSPA, 2022).

The participation of emerging economies as customers in the Earth Observation value chain is also worth highlighting. These nations, mostly located over the equatorial region of the globe, are starting to make use of advanced agriculture techniques that inherently involve Earth Observation images and data. However, as of now, this shift towards developing nations is still bounded by the limited purchase power of these new customers.

Another relevant way of looking at the EO customer landscape is to analyze the envisaged applications of the imagery data. (EUSPA, 2022) identifies 14 market segments for the EO market that are currently quantified in terms of data and value-added service revenue streams. The chart below shows these segments as a market share in million € in 2021. Applications like agriculture, energy, urban development and forestry are still the leading segments in terms of demand for EO data. However, emerging and innovative applications like Insurance, tourism and biodiversity are starting to gradually increase their demand for data.

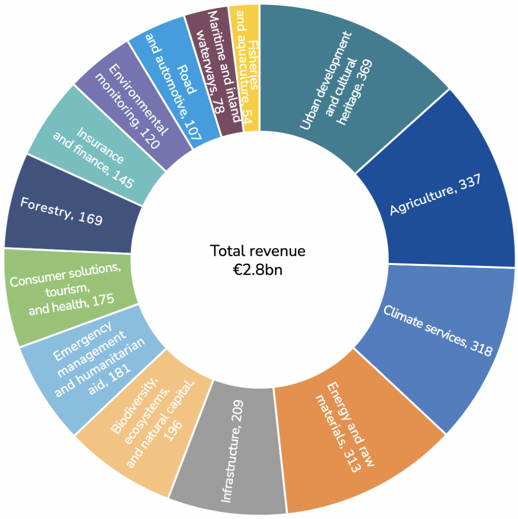


Figure 15 - EO demand world map Distribution of revenue by segments (€m, 2021) (EUSPA, 2022).

Based on the presented data and perspectives, it is possible to conclude that the commercial portion of the market is still in its growth stage. The Earth Observation industry has been traditionally based on missions and applications defined by governmental customers, as part of the defense or civilian national activities. The arrival of newcomers, like emerging nations combined with the increased accessibility of acquiring and operating space assets, might be an important booster to the expansion of commercial business involving EO data.

5.2 Large Satellites for Earth Observation

5.2.1 Overview

A typical Earth Observation platform is shown in the picture below. A standard BUS is used to manage the onboard systems and control the overall operation of the spacecraft. Solar Panels are used to harvest energy from the sun and supply it to the onboard systems. Finally, in the payload section, the imaging sensor (Imager) is responsible for capturing images of the Earth's Surface. The data is then sent to the ground via a high-bandwidth communication system.

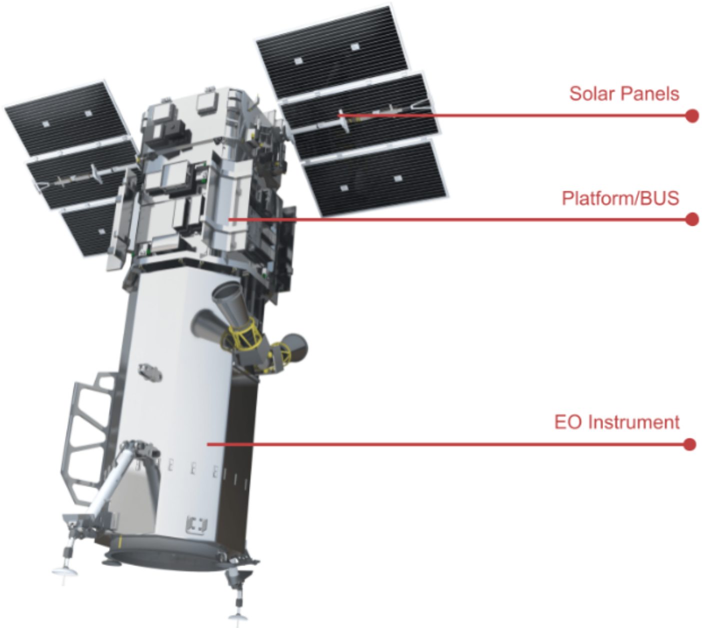


Figure 16 - Earth Observation platform overview[3].

Although the configuration of such a platform may slightly change for different applications, the overall architecture follows the pattern presented in the figure below. Moreover, a typical large EO satellite tends to weigh between 700 and 3000 Kg, including the BUS and instruments (Maxar Technologies, n.d.) (Airbus, 2022).

In terms of costs, the design and manufacturing of these large spacecraft tend to cost between $200M to $500M depending on their technical requirements (payload and overall capabilities). In extreme cases, the satellite can require a budget close to $1B (Shao et al., 2014). As a result, these platforms are built to be fully operational for roughly 10 years to reach economical break even.

The restrictive high costs of such platforms are also linked to the general data collection strategy pursued by traditional players. In order to minimize the number of required satellites in orbit, established players focus on designing and launching a few very high-performance satellites. The performance features, in this case, are mainly centered around the agility of the spacecraft to point toward different locations during its orbit. This enables established players to optimize parameters like revisit time while reducing the required number of satellites in orbit.

Due to the large size of the instruments onboard these satellites, and hence their high-resolution capabilities, these satellites are usually placed in low earth orbits above 600 km of altitude (Valenti, 2022). This enables satellite operators to optimize satellite lifetime (lighter requirements on propulsion system and fuel usage), while not compromising the spatial resolution performance of the imagery collected. A higher orbit also allows longer passing times of the satellite over a specific region, increasing the time to point towards specific targets and to download data to ground segments.

5.2.2 Main Players

In the Earth Observation industry, large satellite manufacturers and operators are considered incumbents of the industry. As mentioned before, the most important players of the market operate in a fully verticalized way by manufacturing and operating their own satellites, in addition to processing and serving data to their customers.

[3] Adapted from here

In fact, roughly 50% of the total global market value is concentrated around two key players: Airbus DS and Maxar Technologies (Valenti, 2022). In Europe, as shown below, the dominance of Airbus DS is even more prominent, representing roughly 50% of all Earth Observation payload manufacturing between 2011 and 2017. This dominance is also present in the Data acquisition and distribution domains, where these two companies rank in the top 2 in terms of global market share (EUSPA, 2022).

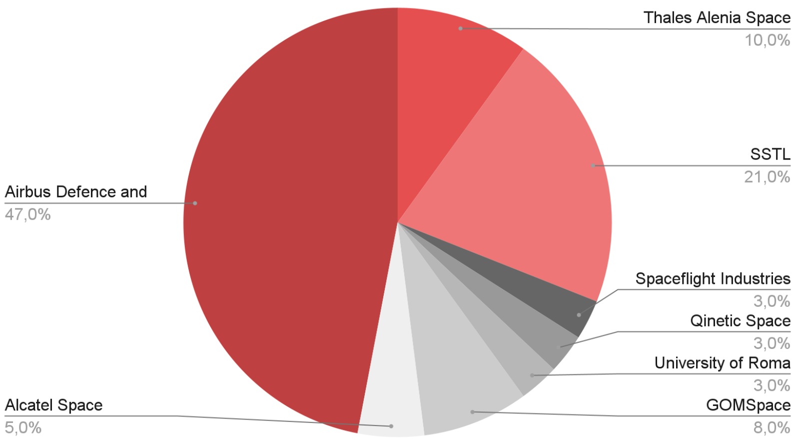


Figure 17 - Share of EO satellites by European manufacturers between 2011 and 2017. Total: 38 satellites. Source: (PwC, 2022)

Given the high market share of Airbus DS and Maxar in the EO industry, this report will focus on analyzing the data and strategies of these two companies as established players in the industry. Although there are other important firms operating in the market, this approach enables to simplify the data collection and analysis process. At the same time, because of their considerable dominance in the sector, it is fair to assume that they can provide a reliable benchmark to the other members of the earth observation industry.

The Table below summarizes the space infrastructure operated by these two companies for the Earth Observation market. Airbus DS relies on its recently operational Pleiades NEO constellation to acquire very high-resolution images with agile satellites. In their case, global coverage and revisit times are enhanced by the Pleiades and SPOT constellations (Airbus, 2022). Maxar makes use of its WorldView and GeoEye constellations also to acquire very high-resolution imagery and to reach sub-daily revisit times (Maxar Technologies, 2022). In addition, the company is investing heavily in its new generation of EO satellites (Legion) which are expected to be launched in 2023 after consecutive postpones (Maxar Technologies, 2021).

Table 5 - Classification of spatial resolution according to pixel size.

Company	Location	Founded in	Optical EO Constellations	# of Satellites	Spatial Resolution [m]
Airbus DS	France	2013 (Airbus - 1970)	Pleiades Neo	4	0.3
			Pleiades	2	0.5
			SPOT	2	1.5
Maxar	US	2017 (MDA - 1969)	WorldView	3	0.3 - 0.5
			GeoEye-1	1	0.4
			Legion (2023)	6	0.3

The plots below show the distribution of the large satellite missions from these two players as a function of the imagery cost, revisit time and spatial resolution. As a reference, other large EO satellite missions are also included in the plot. Pleiades NEO (Airbus DS) and WorldView (Maxar) aim for higher resolution and lower revisit time while keeping their price levels higher than their competitors. Even in this scenario, they still capture more than 50% of the market share as previously mentioned.

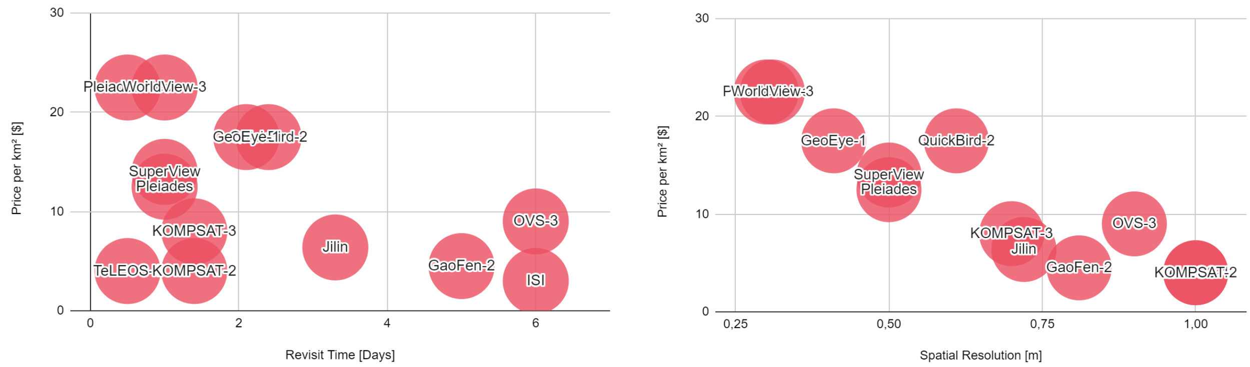


Figure 18 - Comparison between cost, spatial resolution and revisit of large satellite constellations for EO. The data was gathered from multiple market reports and online EO data marketplaces.

Taking into account the data presented in this section, it is possible to highlight two important factors of the Earth Observation industry:

- **High vertical integration:** The two main players (Airbus DS and Maxar Technologies) are highly integrated companies and are present in almost all ends of the EO value. They currently design and manufacture their own satellites (Upstream), but also operate, collect and distribute the data collected from satellites in orbit (Downstream). The processing and insight generation based on EO data is also part of their portfolio of services in this industry (Puteaux, 2022) (PwC, 2022).

- **Focus on governmental customers**: Established players are concentrated on the public organizations interested in acquiring and operating their own space assets or in earth observation imagery (Valenti, 2022).

In the next section, the main customer segments of the EO industry will be presented. The discussion will inherently take into account the technical parameters shown in Table 4, and also the characteristics of the current established players.

5.3 Small Satellites for Earth Observation

5.3.1 The NewSpace sector

After the golden age of the space industry and the space race during the cold war, the development of space technologies experienced a continuous decrease in public attention and investment levels. In the following decades, the space industry was limited to governmental and defense missions mainly led by national space agencies such as NASA, ESA and JAXA. However, the development of new technologies, combined with the recent interest of private investment funds has brought back the space sector to growth rates compared to the ones previously seemed (Denis et al., 2020). This context of technology advancement combined with market and financial opportunity is commonly referred to as NewSpace.

The term NewSpace refers to a new approach to the development of space technologies that significantly differs from the methods traditionally adopted (Bousedra, 2021). The diagram below shows the main differences between the New Space and the Traditional Space industries.

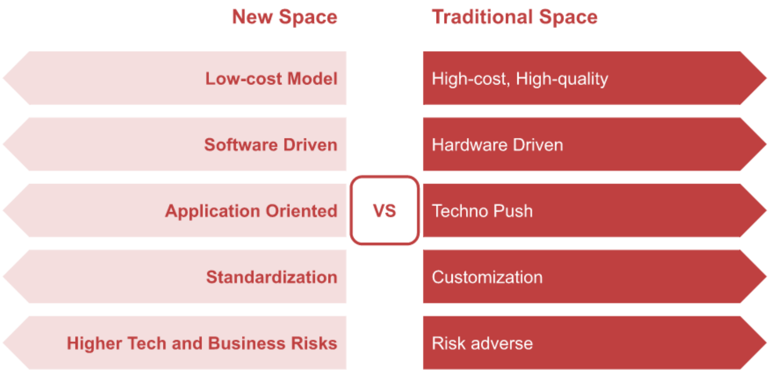


Figure 19 - New Space vs Traditional Space approach (Puteaux, 2022).

While traditional space companies focus on highly reliable and hence high-cost systems, the new space industry is more prone to risk and focuses on a low-cost business model (Howard, 2019). This is achieved mainly through the standardization of components and launch systems. Established players, on the other hand, are typically focused on designing and manufacturing custom systems specifically tailored to customer needs (ie. large satellites specifically designed for customers).

In a nutshell, the new space boom can be explained by a few key factors, such as the miniaturization and standardization of space components, the emergence of new specialized suppliers and the reduction of launch costs brought by companies like SpaceX. These factors combined have enabled small and innovative companies to join the space industry without getting blocked by the steep initial investment requirements traditionally seen in the space sector.

Another important component of the NewSpace movement is the shift toward private sources of funding (*Space Capital*, 2022). To illustrate this shift, the graph below confirms this growing trend by showing the number of Venture Funds investing in the sector over the years. This trend, as shown in the picture, has also been accompanied by an increasing amount of public investment in the sector as well, showing that governments are also interested in fostering the development of this new space industry.

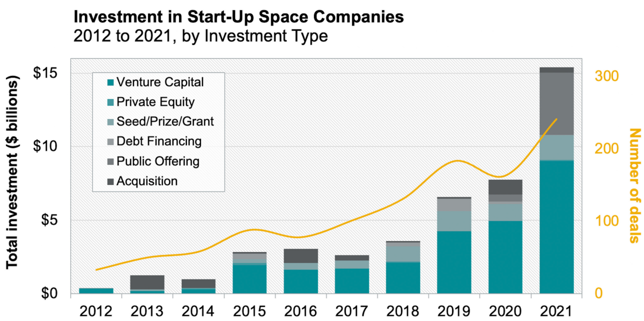


Figure 20 - Growing number of VCs investing in space over the years (Bryce, 2022).

5.3.2 Small Satellites

As mentioned before, the NewSpace model is based on the introduction of a number of new approaches to the development of space technologies. One important innovation in this sense is the development of smaller spacecraft that take advantage of the miniaturization and overall optimization of electronic systems. These small satellites are usually considered to weigh less than 500 kg and can be categorized according to their mass range.

The table below summarizes the classification of small satellites according to their mass. The analysis presented in this report focused mainly on the Nanosatellite and Microsatellite ranges. As will be seen later, this size range is the main one being used to implement Earth Observation constellations while keeping the potentially disruptive characteristics when compared to large satellites. By limiting the discussion to this class of satellites, it is possible to draw deeper conclusions about the impact of the arrival of these systems in the Earth Observation market.

Table 6 - Small Satellite Categories by mass (Bryce, 2022).

Classification	Mass Range [Kg]
Femtosatellite	0.001 - 0.1
Picosatellite	0.1 - 1
Nanosatellite	1 - 10
Microsatellite	10 - 100
Minisatellite	100 - 600

A key innovation in terms of the development of smaller satellites is related to the creation of the CubeSat standard[4] in 2001. This standard focused on establishing technical guidelines for the design and manufacturing of spacecraft with default dimensions that can be easily integrated into launchers without requiring any interface adaptations. The image below shows the basic principles of the CubeSat standard. CubeSats are spacecraft built with blocks that are 10cm x 10cm x 10 cm in size. This is the smallest size of a CubeSat according to the standard and is defined as a 1U CubeSat (1 unity). Multiple blocks can be stacked together to build larger spacecraft as shown in the figure below (2U, 6U, 12U)

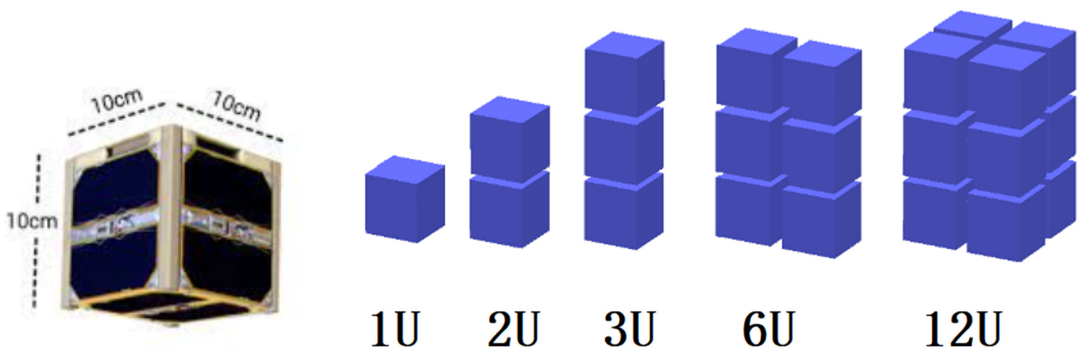


Figure 21 - The CubeSat Standard.

[4] Cubesat Design Specification

The creation of the CubeSat standard is an important component of the New Space sector because it revolutionized the way satellites are built and deployed into space. Based on these standards, the launch industry adapted itself to enable the simultaneous launch of these spacecraft in a single rocket launch campaign. This significantly reduced the cost of deploying these small spacecraft into orbit, contributing even more to the diffusion of the standard. Finally, the adoption of simplified design processes and Commercial Off the Shelf (COTS) components to the design and manufacturing of CubeSats has enabled these systems to be designed and manufactured by companies, educational institutions and governments that previously did not have the resources to work with space technologies. The result of this process can be seen in the graph below, which shows the number of small satellites over the last decades.

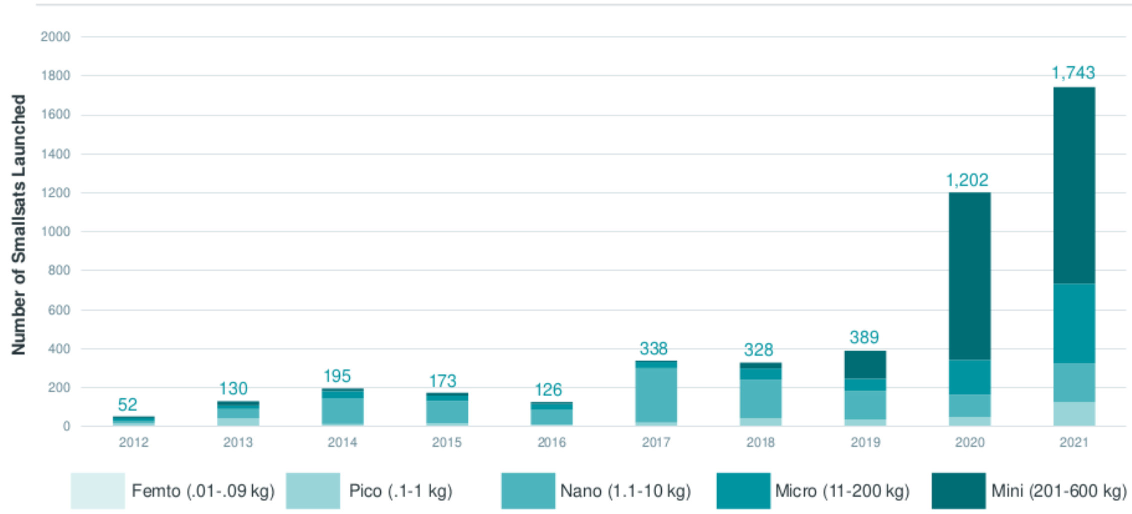


Figure 22 - Small satellite launches over the years (Bryce, 2022).

Taking into account this class of spacecraft, the typical components of an Earth Observation CubeSat are shown in the picture below. In a nutshell, the system architecture of the system is based on the one displayed for large satellites in Section 5.2: a platform is responsible for maintaining the critical systems of the satellite and a payload (camera) is used to collect images from Earth. In this case, however, the system is based on commercially available components and is constrained in terms of volume and size. The cost of building and deploying into orbit a single CubeSat can be in the range of $300k to $1M (Bryce, 2022). In addition, for an LEO orbit, these spacecraft can have a typical life expectancy of 3 to 5 years, depending on their envisaged applications and onboard avionics.

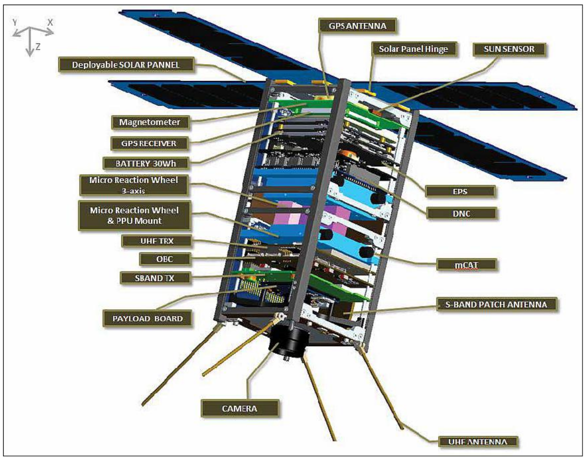


Figure 23 - CubeSat Platform Overview.[5]

[5] Extracted from Canyva-X Factsheet

5.3.3 Small Satellites and the EO Industry

The arrival of CubeSats to the space sector has created an interesting opportunity for young companies willing to address the Earth Observation market. In this case, it is important to take into account the technical and economical requirements presented in section 5.1.2 to assess what sorts of performance changes can CubeSats bring to the EO Industry.

The Figure below provides a comparison between the size of large EO satellites built by established players like Maxar and Airbus DS (WorldView-4 and Pleiades 1B respectively), and small EO satellites built by New Space startups like Planet and BlackSky.

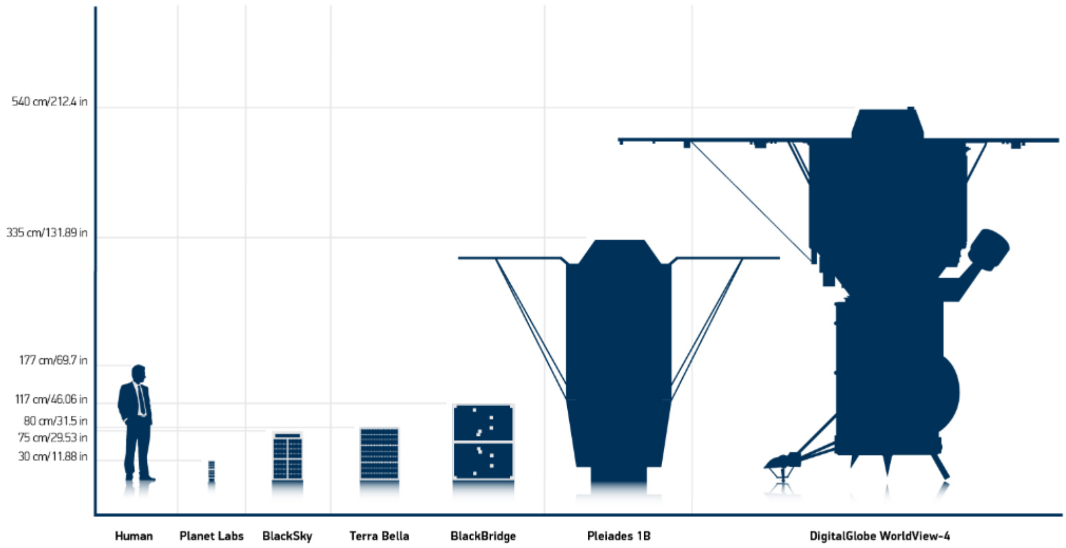


Figure 24 - Micro and nanosatellite launches over the years.[6]

When taking into account the picture above, the first important vector of change is related to the cost of these smaller spacecraft. Small satellites can be easily equipped with camera systems and deployed into LEO orbit at a fraction of the cost of larger EO systems. In addition, also because of their low investment requirements, these spacecraft can be deployed in larger numbers to create constellations of EO satellites and, as a result, significantly decrease revisit time. These two factors enable small satellites to be used to reduce the cost of imagery acquisition while, at the same time, increasing the freshness of the collected data.

The trend toward constellations of satellites is already materializing, as shown in the graph below. Although most of these constellations are targeting the telecommunications market, for now, there are a few important examples of small satellite constellations aiming to address the Earth Observation market by offering high-resolution images and low revisit times.

This last factor represents an important deviation from the traditional EO approach presented in Section 5.2. As explained previously, larger EO missions focus on deploying very agile space systems that can swiftly point to different locations during a single orbit. Small EO satellite missions, on the other hand, aim at deploying a larger number of spacecraft in orbit and hence collect multiple locations at the same time during the pass (Planet, 2021). These opposing strategies are usually referred to as "any data point" (traditional) vs "every data point" (NewSpace) (Denis et al., 2017).

[6] Extracted from [Maxar's QA Page]

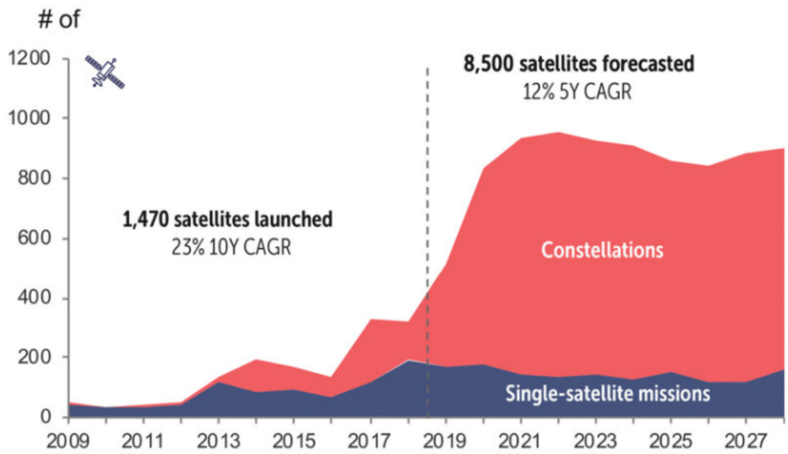


Figure 25 - Trend towards satellite constellations instead of single-satellite missions (Puteaux, 2022).

Another important point is the upgradability of these systems. Small satellites are usually expected to last less than 5 years in orbit because of the less robust components onboard these satellites. This implies that the systems in orbit need to be frequently replaced by new generations of spacecraft. Although this has a final impact on the maintenance cost of these constellations, it also enables companies to continuously upgrade their avionics and keep them very close to the state-of-the-art in terms of performance.

Finally, because of the capabilities (ie. pointing) and resource availability (ie. volume, power), the process of designing and manufacturing these spacecraft is required to take into account key technological innovations to remain competitive. For instance, data collection optimization through the use of onboard artificial intelligence and, also, ground to space communications optimization through inter-satellite links is constantly in discussions while implementing these large CubeSat constellations. Some of these points will be further discussed in Section 5.4.

5.3.4 Main Players

The Table below summarizes a few of the main newspace players operating in the Earth Observation market. These companies were selected to perform the analysis presented in this report because: (1) they already have satellites in orbit, (2) they are generating revenues through EO data or services and (3) they are publicly listed companies, facilitating the process of gathering information about their strategies and performances.

Table 7 - Main Optical Earth Observation companies leveraging small satellites to build their constellations (Christensen & Bryce, 2020)

Company	Location	Founded in	Constellation	Resolution [m]	Constellation Size	
					Current	Planned
Planet	US	2010	PlanetScope	3.7	130	N/A
			SkySat	0.5	21	30
Satellogic	US/Argentina	2010	Aleph	0.7	37	300
BlackSky	US	2013	BlackSky	1	60	

In general, these are young and very innovative companies leveraging small satellites to build remote sensing constellations (BlackSky, 2021). Their overall strategy revolves around offering images at a lower cost than the average proposed by established players in the EO industry. For instance, Planet and BlackSky are reportedly acquiring satellite imagery at around half the cost rate of established players like Airbus DS and Maxar (Satellogic, 2021). In this sense, a few of them are still in the process of deploying their constellation to achieve the envisaged goals in terms of image resolution and especially revisit time.

Planet and Satellogic are deploying their EO constellations based mainly on satellites weighing less than 50 kg and equipped with high-resolution cameras (Planet, 2021). For instance, 130 satellites of Planet's current fleet are 3U CubeSats (Dove), while the others are based on slightly larger platforms targeting higher-resolution imagery. In the case of Satellogic, their constellation is primarily based on low-cost platforms of 38.5 Kg (NewSat). Likewise, Blacksky is building its 60-satellite constellation using 55 Kg spacecraft (BlackSky, 2022).

Planet is an interesting case because it is the most advanced company both in terms of technology (constellations are almost fully deployed) and revenues. The graphs below show their main customer types and the main applications generating revenue. Similar to the large satellite case, Planet's main source of revenue is also the public sector. Nevertheless, according to the company's strategy, these numbers are expected to change and shift toward commercial applications by 2026.

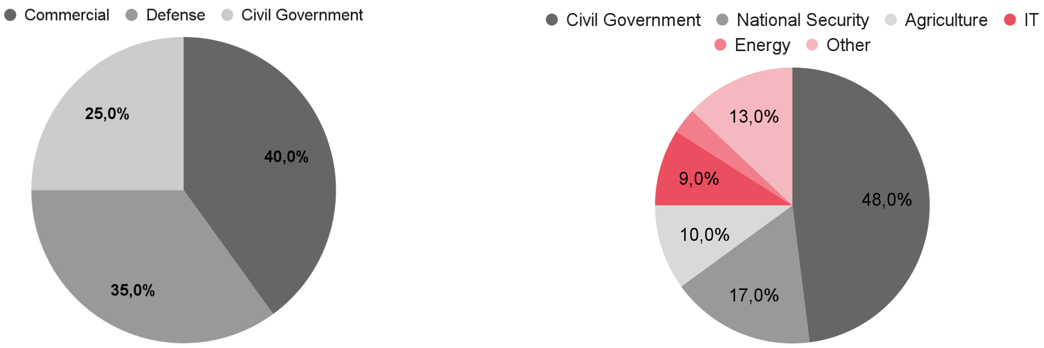


Figure 26 - Planet's customer type (left) and revenue per application (right) (Planet, 2021).

These companies are also focusing on integrating almost all parts of the value chain from data collection to data processing. In general, the design and manufacturing of the satellites are internalized and realized in facilities specifically tailored for the mass production of small satellites. Internalizing this process is an important part of their strategies to reduce the final cost of the images provided to their customers.

This vertical integration process also expands towards the downstream part of the value chain. A few of these companies are already proposing data processing and analytics services to their end customers as a way to boost their revenues. The main reason for this policy is likely related to the low margins that can be found in the imagery market, as it will be shown in the next section.

Finally, the commercialization model that these companies are adopting is also a relevant aspect of their business strategies. In general, customers can acquire images directly from these suppliers by purchasing images as traditionally done by established players. However, customers also have the option of subscribing to "constellation as a service" subscription plans where they have continuous access to data collected from the satellites in orbit. This represents an important shift from the traditional commercialization models adopted by the Earth Observation industry.

5.4 Trends

The Earth Observation industry is going through a series of changes that are boosted by technological advances, but also economic and legal trends. These shifts have the potential to create new markets and also modify the competitive landscape of the industry as a whole. In this section, the main trends and innovations will be discussed.

5.4.1 Legal aspects

Important changes are taking place in the legal realm of the space sector. Recently, nations that are leading the development of the space sector started to focus discussions on regulating the use of specific congested orbits like LEO and GEO as part of their space debris mitigation policy (PwC, 2022). In France, for instance, the new set of space laws passed in 2020 already requests spacecraft to include de-orbiting systems to reduce space debris[7]. There have also been important discussions about requiring all space platforms to include propulsion systems to enable objects to be deorbited faster after they are no longer in operation.

Since these policies are applied differently for each country or region, the place where companies are based plays a major role in defining how difficult it will be to deploy an Earth Observation constellation. In this sense, the legal barriers might be lower for companies based in countries that tend to simplify their space law policies. This might constitute an important competitive advantage for these companies. In particular, since the technical constraints on small satellites are more strict, abiding by these new sets of rules might impose significant challenges to the feasibility of these large planned EO constellations.

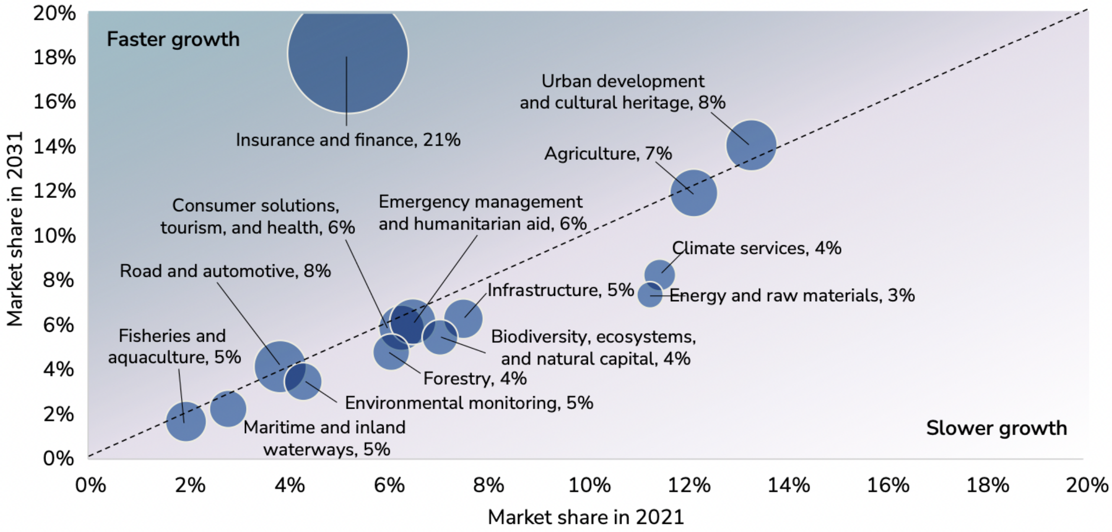
The growing demand for frequency allocation to space systems is also a key point related to the legal trends (Puteaux, 2022). As the number of satellites in orbit increases, organizations like the International Telecommunication Union (ITU) might impose stricter requirements on satellites to have their frequency allocated. This might create a bottleneck in the number of satellites put into orbit. This might be especially relevant for telecommunications payloads but might have an important impact on other applications like Earth Observation.

5.4.2 New Applications

Another important factor happening in the EO industry is the rise of new applications based on EO data (Bousedra, 2021). The graph below depicts the market share growth rate of a few key applications of the EO market. For instance, the Insurance and Finance segments are expected to grow almost 21% by 2031, boosted by the growing use and demand for parametric insurance products in the context of disaster resilience frameworks. This shift towards new applications will inherently create new technical requirements in terms of collected data, but also new opportunities for new companies operating in the EO value chain.

Also in this sense, the combination of data collected using multiple types of sensors (SAR, Optical, Infrared) might provide an additional boost to the adoption of EO data by new different sectors. The combination of these multiple channels of information enables the generation of more specialized insights that might be useful to industries that are currently not addressed by EO applications.

[7] La politique spatiale française: bilan et perspectives



Note: The size of the bubbles represent the CAGR of each segment between 2021 and 2031.

Figure 27 - EO Applications market share in 2021 and 2031 (EUSPA, 2022)

5.4.3 Economical Aspects

A few key main economical factors can be highlighted for the EO industry. The first is related to the transition that the industry is going through to migrate from capital-intensive models (CAPEX-based) to the distribution of investment across time (OPEX). Similar to what happened to the software industry in the last decades, EO data providers are looking for ways to offer data to their customers through an "As a Service" model. In this case, customers are not required to invest massive amounts of capital before starting operations.

The second economical trend is related to the way new companies in the EO industry are being funded. As mentioned before, the EO industry traditionally relied on public investment to build and deploy constellations of satellites to collect EO data. Recently, however, the amount of private investment in EO companies has been growing exponentially, as can be seen in the picture below. Also, the percentage of private investment in EO companies compared to other space applications is expected to increase from 18% to 52% from 2015 to 2025 (Puteaux, 2022). These new options for funding lower the entry barriers for newcomers and might have a relevant impact in the EO industry.

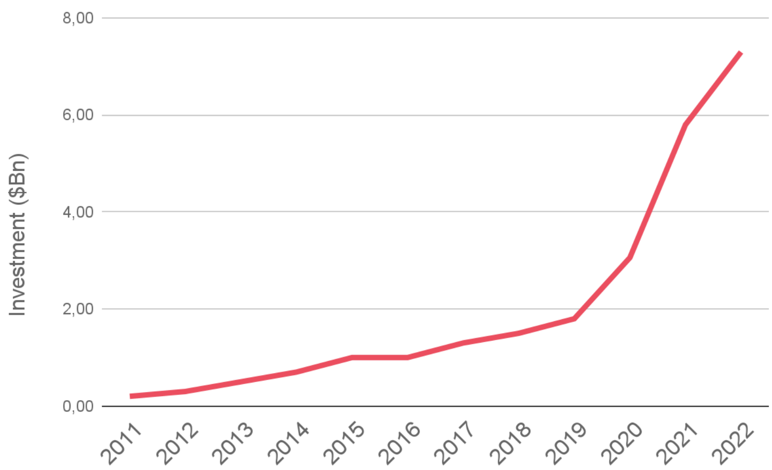


Figure 28 - Investment in EO companies over the years. Adapted from (Valenti, 2022).

The expansion of the amount of private investment in the sector is strictly related to the expansion of potential markets that can now be reached by new applications involving space systems. In this sense, as mentioned in Section 4.1, the role of emerging economies will be a key enabler in the development of new commercial businesses between companies and governments. These emerging nations are looking for ways into the space sector that do not require the same levels of investments found traditionally in the space sector. In this context, small satellites and low-cost space technologies might be an important enablers for them to join the space market as customers, partners or suppliers. This is especially true for the Earth Observation market since it is one of the main applications envisaged by governments and public institutions.

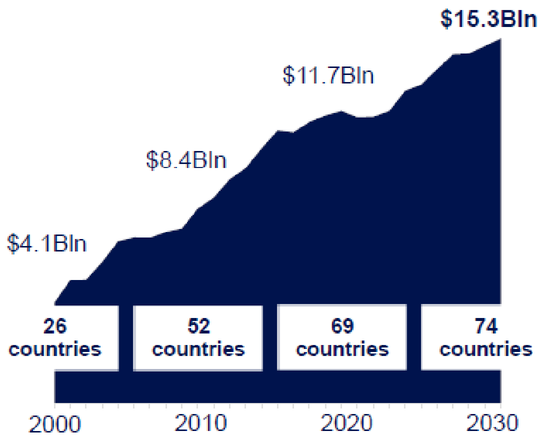


Figure 29 - Governmental investment in EO infrastructure and data worldwide (Valenti, 2022).

The final important economical trend is related to the decrease in prices of satellite imagery. The arrival of NewSpace players combined with the reduction in launch costs has contributed to an increase in the offering of satellite imagery. As a result, there is an important trend toward the commoditization of satellite imagery products. This can be seen in the pictures below which shows the slow increase in imagery revenue over the years. On the other hand, the revenues generated by image processing value-added services (VAS) have been experiencing faster growth over the years. This pattern might boost the strategies of EO companies to become more vertically integrated by providing VAS services as part of their offerings.

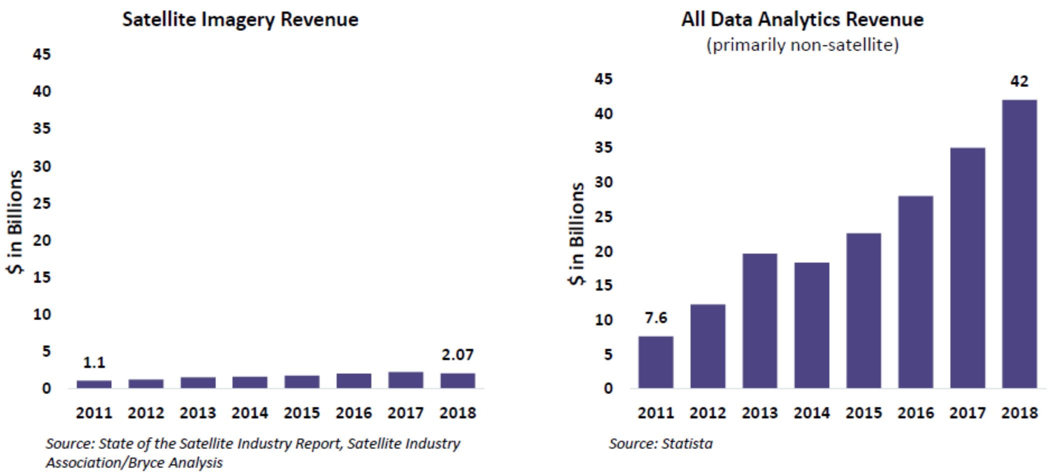


Figure 30 - Revenue generated by satellite imagery sales (left) and by data analytics (right) (Christensen & Bryce, 2020).

5.4.4 New Technologies

Among the other transformation factors taking place in the EO sector, technological advances are likely to be the most important ones. These advances are related to the development of new types of sensors and components that enable the optimization of the technical parameters covered in Section 5.1.2 (EUSPA, 2022) (PwC, 2022). The key technological factors that can be highlighted in this case are:

- **Increase in Spatial Resolution requirements:** As discussed previously, there is a clear growing demand for Very High-Resolution images from EO customers. The development of new sensors, miniaturization of components, and the deployment of constellations in lower orbits than ever will inherently enable the increase of the resolution of satellite imagery.

- **Use of different types of sensors:** The development of new sensor and platform technologies will enable the incorporation of multiple types of sensors in a single satellite. Applications that require multiple sources and types of data can benefit from this technological trend.

- **Expansion of Ground Station Networks:** As the number of satellites deployed to orbit grows, the ground infrastructure required to operate and maintain these spacecraft will also be further developed. In particular, the development and expansion of ground station networks will help to reduce the time required to diffuse data from satellites to end customers (freshness of data).

- **Onboard processing capabilities:** as the processing power onboard satellites increases, it will enable the pre-processing of EO data onboard the spacecraft. Properly filtering out parts of the dataset collected in orbit will enable the optimization of the data sets transferred to the ground. In turn, the total area covered and collected in a single satellite orbit will likely increase, without critical impacts on onboard satellite memory availability.

- **Inter-satellite communications:** the development of reliable inter-satellite links will optimize even more the process of downlinking data from satellites to the ground. In this case, the constraining connection times between satellite and ground stations in LEO will be mitigated by enabling the communication link during the longer time windows. In this sense, optical communication links might also have a powerful impact on the ability to quickly transfer data from space to earth.

Finally, in addition to the factors mentioned above, other transformations in the industry might happen due to the development of new technological capabilities.

6 Assessing Potential Disruption in the Earth Observation Market

6.1 Overview

The concept of disruptive innovation theory discussed in Chapter 4 and the Earth Observation industry context presented in Chapter 5 are significantly connected.

The Figure below tries to summarize the overall context based on the innovation theory diagrams. The EO industry started decades ago with the arrival of a few commercial players who are still in the market today. These established firms are currently addressing a mainstream market (Governmental customers from nations with space capabilities), but are constantly improving their technology to improve their margins and move towards a high-end and more profitable market (Defense customers). At the same time, the arrival of small satellites has enabled new companies to address a new portion of the market, where the performance requirements are lower but the expected margins and costs are also lower (emerging nations).

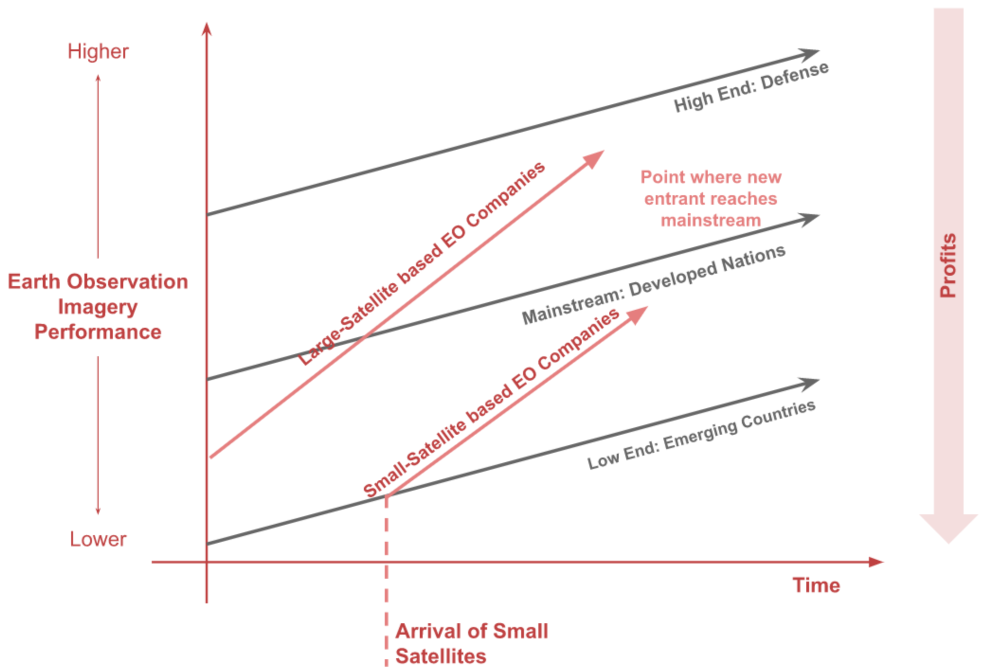


Figure 31 - Disruptive theory and the Earth Observation industry.

The model proposed in Section 4.4 will be used to analyze the potential disruptability of small satellites in the satellite-based Earth Observation sector. The analysis will be performed taking into account the market data presented throughout Chapter 5. In addition, the trends also presented in that Chapter will be used to estimate potential changes in performance metrics, new challenges or opportunities.

The study is based on three main parts. In the first part, the customer segments are presented along with their main valued performance metrics in the Earth Observation market. These metrics are based on the Table shown and discussed in Section 5.1.2. In the second part, the changes in the performance metrics introduced by small satellites and new entrants are compared with the performance indicators provided by established players. This comparison also takes into account cost as one of the main variables of the market. Finally, potential changes in the EO industry are assessed to identify possible variations in the customer segments or in their market preferences.

In order to conduct the final part of the study, a few future market scenarios are proposed by taking into account the trends presented in Section 5.4. The idea, in this case, is to try to predict how the market will react in the face of these new trends and how this will affect the performance metrics.

6.2 Customers and Performance Criteria

Based on the information provided in Section 5.1.3, the Table below depicts the main customer segments identified throughout this study. From a macro perspective, customers are split into three major segments: Governmental, Military and Commercial. The first two encompass all the contracts established with civil and military institutions (B2G), while the latter takes into account the private businesses that are using EO data as part of the line of products (B2B).

Table 8 - Customer Segments of the Earth Observation Industry

Segment	Category	Description
Military	-	Departments of Defense (DoD) and military customers, in general, are part of this customer segment.
Governmental	Established	Includes governmental institutions of nations that have an established space industry with strong satellite manufacturers and stable investment in space R&D activities. Large space agencies are also part of this category.
	Emerging	This category represents governmental institutions and agencies from countries that are starting to invest in space activities but do not yet dispose of a solid and fully developed space industry.
Commercial	-	Firms that use EO data to build their portfolio of products and solutions are part of this category of customers. They operate in the downstream part of the value chain. New Space startups and new entrants to the EO industry are also part of this segment. These are young and innovative companies that are starting to build their products using EO data. These companies are interested in an OPEX investment model like CaaS.

The military segment represents the largest portion of the current EO market share (Valenti, 2022). In particular, Departments of Defense (DoDs) are responsible for the largest demands in terms of EO data and value-added services. This class of customers, however, is pretty much attached to local satellite operators and manufacturers as the space infrastructure is critical for their military operations. This context creates an important barrier of entry for new companies who are starting to provide EO solutions and want to tackle this portion of the market.

The next important market segment is linked to contracts between private companies and civil public institutions. In the EO context, these contracts can be related to EO data provision (Downstream) or satellite manufacturing and deployment (Upstream). In this case, the segment can be further split into two main categories: established and emerging. The former includes nations that already have an established space industry to deploy EO missions and collect EO data. In this case, the contracts are frequently signed with established players in the space industry who have solid tracks of established contracts with their local government.

The latter category of the civil governmental segment is directly linked to one of the market trends presented in Section 5.4. Nowadays, emerging nations are more and more interested in investing in space technologies to improve their intelligence and monitoring capabilities (EUSPA, 2022). Although some of these applications might be related to military operations, there is a considerable portion of this market that is strictly related to the expansion of competencies in analyzing and processing Earth Observation data at the nation level. This market is still limited today, but market trends indicate that it is likely to grow fast in the upcoming years based on the democratization of space assets (Puteaux, 2022).

The third major segment of customers is composed of private companies which are basing their products and services on EO data. This category includes companies who are in the EO business (data processing, satellite operations, etc...) and usually establish contracts with established satellite manufacturers or data providers of the Earth Observation market.

In addition, commercial customers also include NewSpace players who are willing to enter the EO industry and need EO data or assets to start their operations. These are, in general, young companies who are implementing the NewSpace strategies presented in Section 5.3 to create attractive business offers to end users. Equivalently to the scenario of emerging economies in the governmental segment, newspace customers still represent a small portion of the EO market share. However, as space technologies become more accessible and the interest of end users becomes stronger, this segment has a high chance of representing an important part of the global EO industry.

The Table below summarizes the main economical and technical features valued by the customer segments listed in the previous sections. The performance metrics displayed in the table were extracted from the complete list of metrics provided in Section 5.1.2. The selection was based on the EO industry review presented in Chapter 5, including the expected trends of the market. The goal was to select metrics that are relevant to practically all segments of customers.

The first important performance axis that needs to be taken into account is the overall cost of the EO solutions acquired by customers. In this sense, Military and established governmental institutions are considered less price-sensitive than the other customer segments. These customers, in general, are looking for more reliable solutions due to the criticality of the applications that the data is intended for. In this case, these customers are willing to pay higher prices for EO data or infrastructure, while keeping a higher level of control over their suppliers (Denis et al., 2017).

On the other hand, customers that are part of emerging economies (governments) and newspace players do not require the same level of reliability as established nations and military customers. They are willing to compromise some of the reliability and safety levels in order to lower the total cost of the EO data and infrastructure. This happens because, as mentioned before, these customers are able to join the EO industry specifically due to the recent democratization of space technologies and lower costs than traditionally found in the market.

Finally, existing commercial players have a mixed approach when it comes to the prices of EO assets. In this case, the sensitivity to prices will be almost fully dependent on the targeted applications of their products. This is also true for the level of reliability that they aim for while purchasing EO data or assets in general. However, these private entities are interested in business relationships more based on operational expenses and are more inclined to become clients of CaaS platforms.

Table 9 - Performance Metric per Customer Segment

Segment	Performance Metrics				
	Economical		Technical		
	Willingness to pay	Business Model	Spatial Resolution	Revisit Time	Reliability
Military	5 - Budget to pay a premium amount for the product with additional extra features	CAPEX	5 - Ultra High Resolution	5 - Hourly	5 - Almost Fail proof
Governmental Established	4 - Budget to pay a premium for a high-quality product	CAPEX	4 - Very High Resolution	3 - Daily	4 - Very Reliable
Governmental Emerging	3 - Budget to pay slightly more than the basic cost	CAPEX / CaaS	4 - Very High Resolution	3 - Daily	3 - Reliable
Commercial	3 - Budget to pay slightly more than the basic cost	CaaS	3 - High Resolution	3 - Daily	3 - Reliable

The data displayed in the Table above can also be visualized in the plot below.

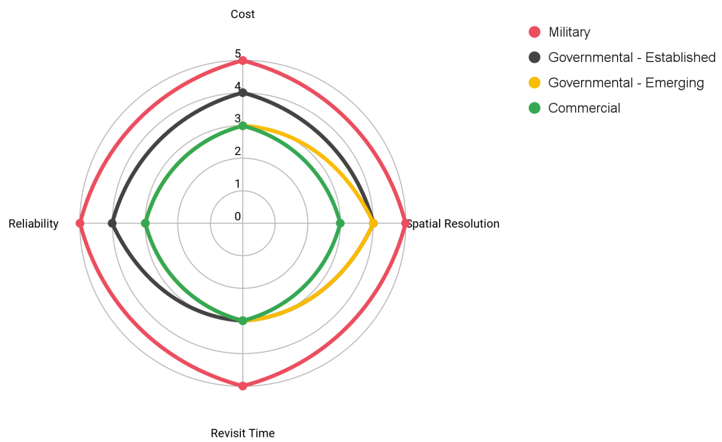


Figure 32 - Performance metrics for different types of customers.

When it comes to the technical features of the Earth Observation data, market trends show that there is a continuous and uniform demand for high-resolution images from almost every customer segment. Although this particular item is very dependent on targeted applications as discussed in Chapter 5, Figure 11 still shows that most of the applications are concentrated around high-resolution images (<1m). The exception, in this case, is military customers which demonstrate stricter requirements when it comes to spatial resolution (EUSPA, 2022). In their case, very and ultra-high resolutions are preferred.

This behavior can also be seen when looking at the requirements in terms of revisit time. Military customers are, in general, looking for imagery collected at shorter intervals than those envisaged by other customer segments. However, applications like Agriculture, Forestry, and Energy which compose almost 50% of expected revenues generated by EO data sales also demand imagery with a short revisit time. This indicates that commercial and governmental customers have similar requirements in terms of imagery time collection.

Finally, when it comes to reliability, based on the criteria provided in Section 5.1.2, defense customers require a higher level of overall reliability compared to other customers. In their case, they need a system that is operational 100% of the time and with a high level of flexibility and adaptability to their needs. This is also true for developed governments but on a lower scale. These high-reliability requirements also explain why these customers are willing to pay a premium price for their EO data and services. Emerging governments and commercial companies prefer to focus on lower costs for fairly reliable suppliers.

6.3 Comparing Performance Metrics

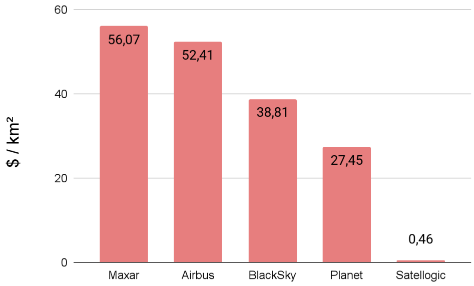
So far, the customer segments and the performance metrics valued by these segments have been identified. The next step in the analysis is to assess which performance metrics are addressed by established players and which ones are introduced or changed by new entrants.

As discussed in Section 5.2, large EO satellites are known to be highly reliable systems due to the strict design and manufacturing requirements adopted by established players in the industry. Because of this traditional approach, however, the cost of these large spacecraft tends to be significantly high. In this sense, the traditional EO industry is a very CAPEX-intensive sector and requires important investments to meet customer requirements.

Conversely, EO constellations based on small satellites tend to be less demanding in terms of initial investments (Satellogic, 2021). The reliability levels achieved by these constellations are also not similar to those found in large satellites because the focus, in the case of small satellites, is to have large numbers of spacecraft simultaneously in orbit and collecting data. The goal, in this case, is to be able to replace small satellites in orbit as time goes on in order to keep up with revisit-time constraints and technological requirements. The lower requirements in terms of investments and satellite performance, as a result, has a direct impact on the final cost of imagery collected using small satellites.

To illustrate the difference in costs between the traditional and newspace approach for Earth Observation data collection, the picture below depicts a comparison of the acquisition cost between traditional EO players (Maxar and Airbus DS) and small-satellite-based players (BlackSky, Planet and Satellogic). The acquisition costs of NewSpace companies are significantly lower than those proposed by established players. This, in turn, is directly connected to the amount of investments required to build and deploy these large and small satellite constellations.

The comparison between the prices proposed by established players and new entrants to the EO market shows that companies that are basing their space infrastructure on small satellites are pursuing a low-cost strategy. The technological innovations introduced by small satellites allow these new players to significantly reduce their costs when compared to incumbents of the industry.



	Maxar/Airbus DS	BlackSky	Planet	Satellogic
Platform Cost [M$]	835	10	10	1
Daily Capacity [km²]	680 000	29 040	26 667	300 000
Total CAPEX Required	$184 bn	$51 bn	$54 bn	$0.3 bn

Figure 33 - Imagery Acquisition cost of different EO players (Traditional and NewSpace) (Satellogic, 2021).

In terms of technical performance, established players still have a slight advantage especially when it comes to spatial resolution. As shown in Section 5.2, companies like Maxar and Airbus are currently offering image sets in the resolution range of 30 cm. Meanwhile, the majority of small satellite-based constellations are still in the range of 1-m resolution. Other technological innovations related to sensor design and constellation deployment might change this landscape but, as of now, small satellites are still not able to reach the same level of optical performance when compared to large satellites.

Although small satellites are still slightly behind in terms of resolution, the revisit times achieved by large constellations of these spacecraft are similar to the ones reached by large satellites. While large satellites need to rely on the "anywhere" approach and design very agile spacecraft that are able to change orientation to properly point their instruments, small satellites adopt the "everywhere" approach. In this case, by leveraging the high number of spacecraft in orbit, NewSpace companies are able to continuously capture images of any place on earth without being impacted by the simplicity of their spacecraft in orbit.

The picture below summarizes the comparison between the economical and technical features of Earth Observation based on large satellites versus small satellite constellations. To each performance metric, a score from 0 to 5 was given to each EO implementation. The scores were assigned based on the arguments provided throughout this section and on empirical analysis of the advantages and disadvantages of both classes of spacecraft to EO applications.

In a nutshell, small satellite constellations are a low-cost alternative to traditional EO satellites. The low cost achieved by these smaller spacecraft comes at the expense of spatial resolution performance and reliability. The revisit time achieved by smaller satellites is comparable to the ones achieved by high-cost traditional satellites.

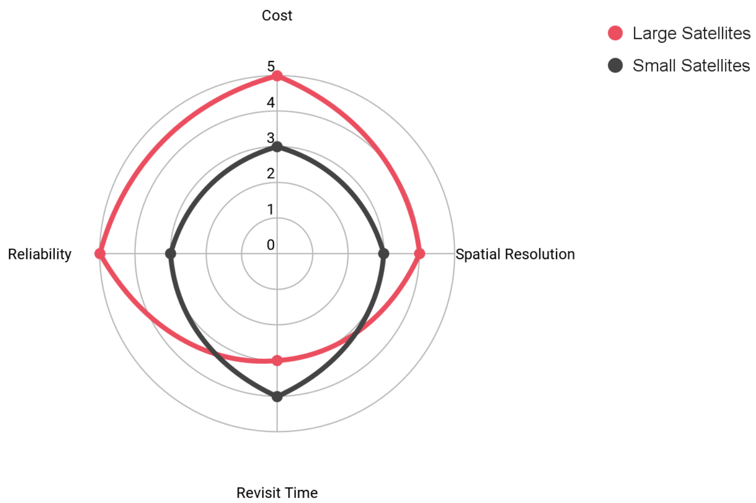


Figure 34 - Comparison between economical and technical performance metrics of large satellites and small satellite constellations for EO applications.

6.4 Potential Disruptions

In the last section, the performance metrics addressed by established players and new entrants have been quantified and discussed. When combining that result with the expectations of each customer segment found in the previous sections, it is possible to assess the disruptability of the Earth Observation industry due to the arrival of small satellites.

As discussed in Chapter 4, the analysis of the potential disruptability of the industry needs to take into account the different performance axes and how the customer requirements are distributed along these axes. In this sense, the first important point to consider is that small satellites are not, as of now, bringing new performance dimensions to the EO market.

As it has been discussed in the previous section, the different customers of the Earth Observation industry tend, in general, to take into account the same performance metrics. However, the level of requirements imposed on these metrics by each customer segment is significantly different. A good example to illustrate this analysis is the reliability level required by customers. All customer segments consider this an important metric, however military customers are willing to pay more for higher performance in this dimension.

Considering the market share, adoption timeline and overall requirements of the different customer segments, the military and government of established nations can be considered mainstream customers of the EO industry. The remaining customers are part of a fringe market, where the performance dimensions are almost identical to those of the mainstream market, but at a lower quality level. This information implies that the arrival of small satellites in the EO industry has the potential to create disruptions of **Type 1** and **Type 2**, following the definitions provided in Chapter 4. Each of these two types of disruptions will be discussed below.

6.4.1 Type 1: Immediate Disruption Assessment

In disruptions of type 1, by definition, the new entrants are directly competing with established players for mainstream customers. In this case, the performance criteria are exactly the same as the ones offered by established players, but the cost proposed by new entrants is significantly lower. As technology advances and performance levels increase over the required dimensions, mainstream customers slowly adopt the products of new entrants.

The plot below shows the performance achieved by small satellites and large satellites along the 4 performance criteria valued by mainstream customers (Military + Govt. Established). It also shows in lighter colors the performance requirements of these customers.

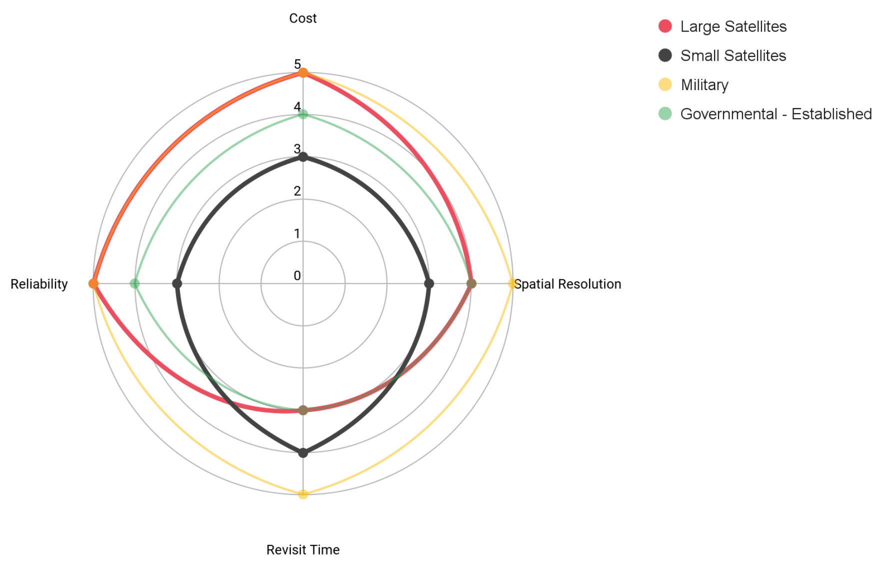


Figure 35 - Performance criteria of midstream customers compared to large-satellite-based and small-satellite-based EO companies.

The first important performance factor to assess is the cost of both solutions since this is one of the requirements for the Type 1 disruption to happen. Indeed, in this case, the prices proposed by new entrants (small satellites) are significantly lower than the ones proposed by established players. However, in the performance dimensions valued by mainstream customers, new entrants perform significantly worse than established players (Spatial Resolution and Reliability).

The combination of low-performance levels and low prices proposed by new entrants creates a relevant probability of Type 1 disruption. In this case, small satellites create a significant threat to incumbents by addressing the low-end portion of the market, which is composed of emerging nations who are willing to sacrifice part of their performance requirements to enable EO data or satellites to fit in their budget.

Although immediate disruptions (Type 1) have a destructive potential over the market shares of incumbents, it is important to notice that the growth in the market share of new entrants relies significantly on the technical improvement of their products. As can be seen in the performance comparison chart, the small satellite-based products demonstrate a significantly lower performance than the ones found in larger satellites. This is true for two important performance metrics required by mainstream customers: Reliability and Spatial Resolution.

Improvements in the reliability levels of small satellites depend on considerable improvements in the design, manufacturing, and testing procedures of this class of spacecraft. Although technology trends demonstrate that this is indeed possible, maintaining the balance between low-cost and high reliability might be a difficult challenge for new players to overcome.

The lower spatial resolution achieved by small constellations of satellites will also need to be addressed by incumbents in case they are interested in tackling the mainstream market. Because of limitations dictated by physics and by the limited payload volume available in these spacecraft, increasing the resolution of pictures collected might be a challenging issue to solve. Advances in sensor, data processing and propulsion technology might help in this sense.

6.4.2 Type 2: New Fringe Market Disruption

Based on the analysis presented, the remaining customer categories can be considered a new fringe market of the Earth Observation market. Commercial customers and also a share of public institutions of emerging nations are interested in quite similar performance metrics when compared to mainstream customers. However, in the case of commercial companies, they are also interested in more attractive commercialization models that are less CAPEX-intensive. This creates a small but important incremental performance dimension that new entrants offer to the low-end portion of the market.

Moreover, In terms of cost, these customers are not willing to pay for the additional performance levels that mainstream customers are currently paying for. Similarly to what happens in Type 1 disruption, customers of the fringe market are willing to compromise their performance levels to reduce the overall costs of using Earth Observation data and space infrastructure.

The performance comparison for these customers along with the performance achieved by small and large satellites is depicted in the Figure below. The price metric provided by small satellites is closer to the expectations of customers. For large satellites, the difference between the expected price and the proposed one is significantly large. This demonstrates a clear blocking point for the adoption of large EO satellites by these new customers.

In terms of technical features, the spatial resolution offered by small satellites is below the expected performance by customers, but this is compensated by the lower prices and the other technical features. For instance, the revisit time meets the customer's requirements. Finally, since reliability is not a critical performance metric from this fringe market point of view, the lower reliability rates of small satellites do not create a significant barrier to the diffusion of EO solutions based on small satellites.

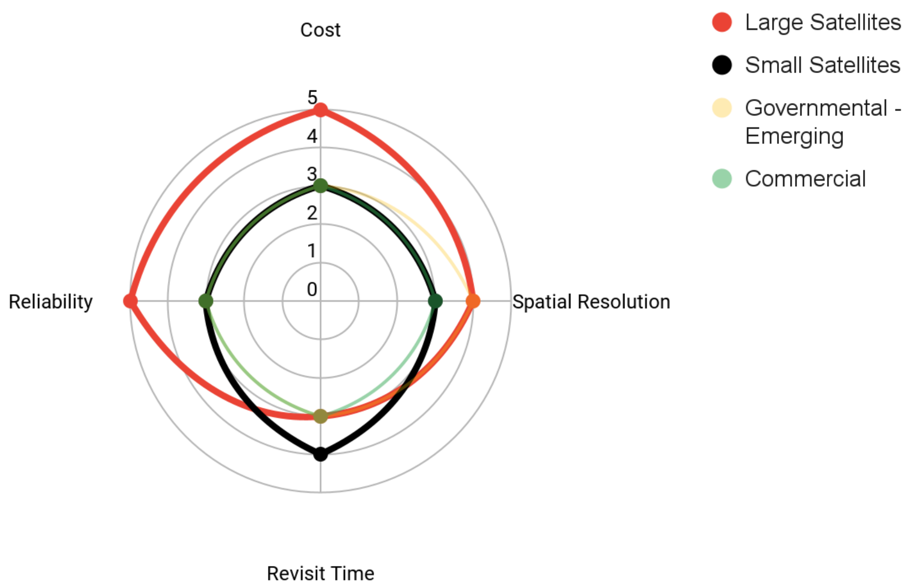


Figure 36 - Performance criteria of a fringe part of the EO market composed of commercial companies and part of emerging nations.

The comparison between the expected and delivered performance displayed in the Figure above indicates that there is a significant potential for type 2 disruption in the Earth Observation market due to the arrival of small satellites. A factor that might possibly slow down this process is related to the lower spatial resolution so far achieved by small satellites but, as mentioned before, technological advances might help overcome this technical barrier.

In this case, the opportunity for new entrants lies in the fact that the fringe market has the potential to grow and become larger than the current mainstream market. In this case, significant increases in the business activities of the EO commercial sector are paramount. In addition, the push from emerging countries to join the space sector might also play an important role in defining how big of an opportunity this fringe market really is.

6.5 Discussions and Recommendations

The analysis presented in the previous section demonstrates that there is a significant potential for disruption in the context of Type 1 and Type 2 disruptions. In this chapter, a special focus will be given to the conditions and context that might make this disruptive effect a real threat to established players. Also, a few scenarios will be used to discuss how these conditions might materialize taking into account the market trends presented in Section 5.4. The arguments presented in this chapter will also include a discussion about the advantages and limitations of applying the disruptive theory to the Earth Observation market.

The theory applied in the analysis presented in Section 4 is useful to identify and characterize the disruptive process in a given industry. Based on the results of this process, established players can adapt their strategies to possible challenges that might be created by the arrival of new players in their market. Nevertheless, it is important to notice that the fact that disruption has been identified does not necessarily mean that it imposes a threat to incumbents. Other factors like the technological and financial feasibility of new entrants' strategies need also to be considered.

For immediate disruptive innovations (type 1), the threat to established players is significantly high because the new proposed product is competing directly with current products on the market. In part, this is something that can already be seen in the Earth Observation market when companies like Planet manage to sign large service contracts with the U.S Government and with the German Government, or Satellogic's deal with the Albanian Government. However, even if the disruption process is already in place, it is important to notice that, according to the disruptive theory, one of the conditions for the mainstream market to be fully reached by new entrants is the equivalence in performance metrics between established and new players.

When considering the performance comparison presented in Section 6.3, it is clear that there is still a gap between the offers provided by small satellite companies and established players. These divergences are related to important features like spatial resolution or the overall reliability of their systems. In this case, NewSpace companies will need to find a proper R&D strategy to address these issues and match their performance metrics to the requirements of mainstream customers.

The industry trends presented in Section 5.4 might play an important role in the advancement of small satellite technologies. The incorporation of onboard processing techniques combined with better ground station infrastructure might help improve the refreshment rate of data collected in space while optimizing image resolution and filtering. The ability to quickly upgrade small spacecraft technologies as the space fleet is replaced might also be an important asset to keep up with the high-performance requirements of customers.

In this sense, for instance, Planet is already planning to deploy a more sophisticated constellation to acquire 30cm images (Pelican) and reach up to 30 revisits per day (Planet, 2021). Satellogic and Blacksky might also reach similar performance levels as they improve their onboard technologies and increase the number of satellites in orbit (BlackSky, 2021) (Satellogic, 2021). In all cases, however, these companies will need to beat established players who are also improving their current technology offerings, like Maxar with its Legion constellation, which promises very high resolutions (~30 cm) and very short revisit times (< 2 hours) (Maxar Technologies, 2021).

Another important factor in the diffusion of small satellites in the Earth Observation industry is related to the legal aspects presented in Section 5.4.1. As the number of satellites in orbit increases, the regulations to deploy new and larger constellations of small satellites might become even more challenging. Restrictions on the number of satellites in specific orbits, requirements on satellite subsystems such as propulsion and passivation mechanisms, and limitations on the frequency allocation spectrum might significantly slow down the proliferation of these technologies in the upcoming decades.

An equally important metric discussed throughout this report is the reliability of such systems. In this case, reliability refers to the resilience of the data collection systems to sustain the harsh space environment, but it also includes the overall safety and security of the complete data collection chain. Specifically, when looking at mainstream customers like DoDs and governments, the dependability of the systems plays a major role in the selection of data and satellite suppliers. This argument helps explain why traditionally most of the Earth Observation market is concentrated around two players from Europe and the US.

Finally, unlike other general-purpose industries, the EO and the space industry as a whole present a few key particularities that also need to be considered and that are out of the scope of the disruptive theory analysis. For instance, the EO industry is a critical market for countries' sovereignty and national interests. In this sense, performing a purely market and business analysis might create a wrong impression that the only rules that are applicable to this industry are related to supply-demand relationships. In fact, governments might play an important role to keep established players in business even if the customer requirements are fully met by new entrants. This might create distortions in the results expected from an industry going through technological disruption.

The arguments presented above are also valid for the second type of disruption identified for the Earth Observation industry. However, in this case, in addition to the technical development of the performance metrics provided by new entrants, the full conclusion of the disruptive process also depends on the expansion of the fringe market.

As shown in Section 5, the Earth Observation market is strongly reliant on governmental and military contracts to sustain its business activities. In this sense, the commercial part of the sector is still struggling to expand and become self-sustainable. New entrants relying on the results of the type 2 disruption are also, even if indirectly, relying on the development of the B2B relationships in the industry. The arrival of new end-user applications using EO data such as agriculture, insurance and finance might play an important role in this sense.

In this context, small-satellite-based companies are already projecting significant growth in their commercial share of customers. This can be seen in Planet's forecast for revenues by customer type shown below. The same approach can be seen in BlackSky's strategy presentation showing that a shift of market share from Government to commercial customers is expected in the next 5 years (BlackSky, 2022). These approaches show that these companies are also likely relying on the growth of this fringe market as part of their growth strategies.

From this perspective, an effective strategy to avoid being reliant on the quick expansion of the B2B segment in the EO industry is to adopt a hybrid approach. For example, companies like Satellogic and Planet have hybrid strategies where they focus on commercial businesses but also maintain a strong presence in the B2G domain through governmental contracts and data provision. This might be a wise approach to stay operational while the commercial and emerging markets are maturing.

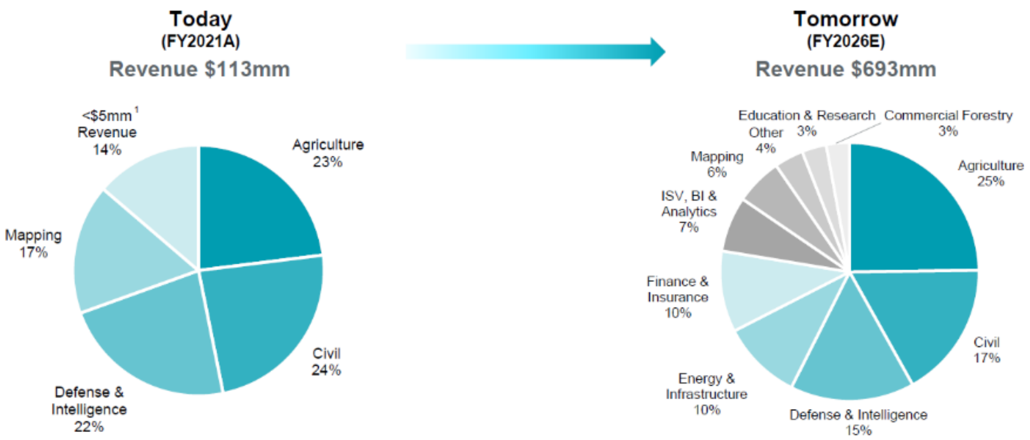


Figure 37 - Planet's current and expected revenue by customer type between 2021 and 2026 (Planet, 2021).

From the perspective of large companies and established players, it is important to maintain a closer look at what is happening in the EO industry and, as soon as possible, take action to mitigate possible impacts of the disruptive process in case it materializes. Although the disruptive theory itself does not incorporate a concise and complete set of actions to be taken in this sense, Christensen recommends creating a separate organization to handle innovation when facing disruptive technologies. This might be a safe first step to be taken by these companies to adapt themselves to competitive forces introduced by new entrants.

When looking at the large company's perspective, one of the key points of original Christensen's theory was to promote the idea that established players should focus on creating disruptive innovations instead of only focusing on sustainable innovations. This might be an important strategy to be considered by traditional space companies. Maybe a suitable strategy would be to devise mechanisms to boost even more the new space sector while leveraging their current capabilities.

Finally, these established firms can pursue different strategies that might help mitigate the impact of these new entrants in their market, such as (1) buying or investing in potential disruptors and (2) adopting similar technological approaches to EO imagery collection. The former involves a continuous scanning of the competitive landscape to incorporate companies that provide complementary skills and approaches to EO compared to those owned by established firms. The latter is related to the adoption of small satellites also by more established players in the industry. Both approaches can be constantly seen in the industry already and will likely be more common in the upcoming years (Airbus, 2021) (Maxar Technologies, 2022).

7 Conclusions

The goal of this report was to assess the potential threats that the arrival of small satellites brings to incumbents of the space-based Earth Observation industry. In order to do that, a combination of methods (Daneels, 2004) (Paulino & Le Hir, 2016) (Schmidt & Druehl, 2008) based on the concept of disruptive theory was employed. A step-by-step approach was proposed to perform a systematic analysis based on collected data from secondary sources like market reports and company investor presentations.

The analysis, which took into account the EO market context and the space industry value chain, concluded that small satellites indeed create a considerable threat to large-satellite-based EO companies. However, the discussions also showed that these threats depend on a number of technical and economical conditions to fully materialize. In this sense, future market dynamics and strategies adopted by new entrants might change the landscape explored in this report.

In summary, EO companies who are basing their space segments on small satellites have the potential to lower imagery data prices while offering new technical features like higher revisit time and new business models based on subscription plans and Constellation-as-a-service. These new factors enable customers in the low-end portion of the market to start using EO data in their products.

From one side, governmental institutions from emerging nations can be considered the low portion of the mainstream market which is currently being addressed by incumbents. These public entities are willing to start making use of EO imagery to improve their intelligence and internal analytics tools but do not dispose of the same level of investments required to close deals with established players in the EO industry. This scenario constitutes a very similar case when compared to other processes of adoption of disruptive technologies in other industries according to the disruptive theory. As such, it creates a significant threat to incumbents in case new entrants manage to improve their technologies to address the mainstream part of the market in the near future.

On the other hand, the continuous growth of the commercial customer segment also creates an important opportunity for new entrants in the EO industry. In this case, these customers are interested in simplified business models to build their products using EO imagery. Through the use of small satellites, new entrants are capable of providing affordable solutions based on subscription models to these companies. The threat to incumbents is not as elevated as in the previous case because new entrants are addressing a portion of the market which is slightly different from the current mainstream customers of established firms. The threat, in this case, is lower, but it can become more significant as the size of this adjacent commercial market grows as forecasted by most market reports.

The application of the disruptive innovation theory in the framework of this report provided a concise and systematic way to assess the disruptability of the EO industry in the face of small satellites. However, it is worth noting that a few information gaps were not fully addressed by this method. For instance, as mentioned by (Daneels, 2004), the theory does not provide a very clear way to identify a disruptive technology or a starting point for the disruptive process. Also, timewise, it is hard to define precisely whether the disruption process has already started or not. These two points are especially important for this report because there are already small-satellite-based companies operating in the market. In this sense, these points might be included in a further analysis of the topics of this report.

Another important missing point in this report is related to precise recommendations and strategies that incumbents might adopt to face disruptive innovations proposed by new entrants. The disruptive theory and its derivations do not fully cover the operational side of the disruption process. This tactical and operational analysis can also be addressed in other specific reports.

In terms of challenges, it is important to notice that collecting specific information about the earth observation industry imposes a considerable challenge to the analysis presented in this report. For instance, assessing the willingness to pay by customers in the EO market is problematic since it includes critical and sensitive information from customers like governments (civil and defense). In a way, this compromises the applicability of the disruptive theory models, which are very reliant on cost analysis. A more detailed review of this specific topic, including interviews and direct data collection, might be an interesting improvement to the analysis presented in this report.

The approaches and strategies that can be found in startup reports and investor presentations show that the movements described in this report are, in parts, already taking place. Companies like Planet, BlackSky and Satellogic are already focusing on new commercial customers to expand their revenues. Emerging nations are also one of the main focuses of these companies, as the revenue streams from governmental customers are still one of the largest sources of revenue in the EO markets.

At the same time, established players are also already taking steps to protect themselves against the impacts of these new entrants. In this sense, for instance, Maxar is heavily investing in its new generation of EO satellites (Legion) to boost its technical performance (Maxar Technologies, 2022). It remains to be seen at which level the global trends will impact the EO industry and how incumbents and new entrants will be able to leverage new opportunities to increase their market position.

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