Innovation as the threat? The evolution of the Earth observation industry within the era of new space

By

Songlin Hu

Supervised by: Prof. Victor DOS SANTOS PAULINO

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Abstract

Taking advantage of innovation theory, this paper discusses the new approach, addressing the influence of the innovation on the threat of new entrants in the Earth observation (EO) market. The discussion is divided into 2 steps. Step 1 summarizes the innovation propositions in EO market launched either by incumbents or by new players. Step 2 focus on discussing the threat of new entrants by using the innovation propositions.

I use four theories in this paper to help us establish the propositions and model in step 1. Firstly, an evolutionary model of technological change is proposed in which a technological breakthrough, or discontinuity, initiates an era of intense technical variation of EO industry. Secondly, the theory of disruptive innovation proposed by Christensen is used (1997), addressing the disruptive innovation always brought by the new entrants. Thirdly, the theory of product innovation and process innovation are applied in this paper to describe the activities of the incumbents. Finally, under Porter's five forces theory, I discuss the threat of new entrants from 3 aspects: capital requirements, access to distribution channels and differentiation in products.

The cases, as the arguments of the model, are summarized by two complementary perspectives: on one hand, the type of system (either single satellite or constellation) and its operational performance (either high revolution or high revisit) and, on the other hand, the related business strategy (either traditional strategy or new business strategy).

This paper not only makes the good interpretation of many classic theories in practical use but also uses new methods to deeply analyze the threat of new entrants. The result could be used as a reference when the space companies make their strategy.

Keywords: innovation, new entrants, threat, barrier, earth observation,

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1. Introduction

Technology improvement has been the central concept to space activities since the human's first step into space. Most of successful space activities conducted by governments from launching the first artificial satellite into space in 1957, the first man stepping the first footprint on the moon, to operating the stronger and bigger satellite in the orbit have demonstrated the innovation at technical and organizational levels.

It was more than that, the end of the Cold War led to profound changes in the space policies of the major Western countries, and also those of the former Soviet. Indeed, the focus of space missions has gradually moved away from military to civilian use, to open the commercial business market, such as scientific missions, telecommunications, meteorology, and other civil applications. It was marked by the launch of the first commercial telecommunications satellite placed in geosynchronous orbit took place on 06 April 1962, and was launched by the United States; The Intelsat 1 was nicknamed "Early Bird." [1]

Subsequently, with the evolution of the industry, Space innovation has frequently been observed in emerging commercial business market. On one side, the incumbents begin to distribute its business network over the world with the strong capability. On the other side, the new entrants with the private funding want to break the rules of the market, to find the foothold in the space industry. The new space actors or nontraditional space actors open the era of "new space".

The new space mainly based on America. In 1984, the U.S. announces a new space policy that includes a new Commercial Space Initiative to encourage U.S. commercial satellite launches to be privatized and limit NASA's involvement in commercial space operations.[2] It speeds the commercial business innovation. I also have to mention that the new space changed further in the early 2000s as Elon Musk formed SpaceX with significantly more private capital while he articulated a strong and consistent vision of the "colonization of space, beginning with Mars." The new entrants sprung up since then. These firms, mainly based in the Silicon Valley or near Seattle, bet on low-cost technology to provide more affordable space systems and services both for earth observation and for telecommunications.

As we can see, the new entrants use the space technology in a different way. They brought the disruptive innovation into the industry. They have had great influence on the legacy industry. They not speed the technical innovation in the space industry but change the space market structure. Within this context, the research focus of this paper is to investigate the threat brought by the new entrants' disruptive innovation.

I address this issue first by using the theory of disruptive innovation proposed by Christensen (1997). [3] A disruptive innovation brought by the new entrants firstly

appeal to low-end or unserved customers and then migrate to the mainstream market. When new entrants introduce the innovation, existing firms face a dilemma named the innovator's dilemma by Christensen (1997). Should existing firms cannibalize their existing product to invest in an innovation that does not ensure short term survival? Secondly, the theory I used is so called "sustaining innovation" which differentiates disruptive innovation. The latter make good products better in the eyes of an incumbents' existing customers. The improvements can be incremental or major breakthroughs, but they all enable firms to sell more products to their most profitable customers. Furthermore, an evolutionary model of technological change is proposed in which a technological breakthrough, or discontinuity, initiates an era of intense technical variation.

In addition, based on the innovation theory, I also will answer the question by using Porter's Five Forces theory. The threat of entry is one of Porter's Five Forces theory. Generally, the incumbent firms who want to obtain the excess profit in the market usually set up barriers to entry and deter potential entrants from starting a business in an industry. Answering "How to break or lower the barriers" is the core of the analyzing the threat of new entrants. There are many types of barriers including absolute cost advantage, product differentiation, economies of scale etc. I address this question from the capital requirement, access to distribute channel, and differentiation in products.

Therefore, in the second section I perform a literature review on some theory with respect to this paper, and specifically, it presents the results of the review. The third section will introduce the methodology adopted in order to reach my aim. And then the fourth section give the result of the innovation discipline in the space industry. Finally, I will discuss what the influence of the new entrants on the incumbents is. In the last section, I present the conclusions of my study.

2. Literature review

2.1.The threat of entry

The threat of entry is one of Porter's Five Forces (Michael E. Porter of Harvard University,1979). [4] I addressed this issue by using Porter's theory. How easy it is to enter the industry influences the degree of competition. The greater the threat of entry, the worse it is for incumbents in an industry. An attractive industry has high barriers to entry in order to reduce the threat of new competitors. Barriers to entry are the factors that need to be overcome by new entrants if they are to compete in an industry.

The first definition of barriers to entry was done by Bain (1956). [5] A barrier to entry is a factor that reduces the ability of new entrants to enter a new market although they know excess profits created by the incumbent firms in this market. Gable and others (1995: 211) [6] made another definition of barriers to entry by saying that they refer to deterrents or obstacles preventing new firms from engaging in production or sale of products or services. Various conflicting definitions of "barrier to entry" have been put

forth, and there has been no clear consensus on which definition should be used. Generally, that constitute entry barriers may be endogenous and exogenous barriers came from Bain(1956)'s study.

Exogenous barriers are those, which are borne by the structure of market conditions and cannot be controlled by incumbent firms. But endogenous barriers are created and maintained by incumbent firms (Gable and others, 1995: 211). According to this classification barriers, to entry are divided into two groups which are structural (technical) and behavioral (strategic).

The strategic barriers are intentionally created or enhanced by incumbent firms in the market, possibly for the purpose of deterring entry. It is more with respect to the strategy which the incumbents adopt. These barriers may arise from behavior such as exclusive dealing arrangements, [7] for example. It can be substantially more difficult to measure the difficulties that such behavior can impose on potential entrants than it is to measure the height of structural barriers. Some strategic behavior may be designed to thwart competition by raising entry barriers, which can help incumbent firms to maintain their market shares. In other instances, however, the strategic behavior may result in the retention of market share because it is efficient, even though it also happens to raise entry barriers.

The structural barriers came from Brain's (1956) study. It has more to do with respect to basic industry conditions such as cost and demand than with tactical actions taken by incumbent firms. Structural barriers may exist due to conditions such as economies of scale and network effects. Sometimes it is possible to quantify these kinds of barriers because it is known in advance how much it will cost to build an efficient plant or to purchase necessary inputs. [7] When we discuss some specific industry, some criteria need to be redefined. I select some criteria which are close to the space industry in this paper.

-*Capital requirements*

These are the financial resources required for infrastructure, machinery, R&D, and advertising. New entrants may get around capital requirements by outsourcing parts of the operation to companies that can leverage existing investments.

The space industry is one of the most typical examples of the high capital requirements, because of the complicated technical process and high risk and quality management, the cost of development of a satellite will cost a lot which private funding can't afford normally. For instance, the development of a remote sensing satellite cost more than 140 million dollars without launching service. The GEO telecommunication satellite will cost more than that. Furthermore, from design to launch to the orbit, at least 2 years are needed. The long payback period forces some new entrants to go out of the space business. If you were a manufacturer, it is harder to enter. The clean room and the

equipment of assembly, integration and testing have to be configured. It is more expensive than in other industries. In addition, the customized nature of satellites and their various purposes imply wide variability in their main characteristics. It increases the cost of spacecraft development.

-Access to distribution channels

In many industries, established competitors control the logical channels of distribution through long-standing relationships. In order to persuade distribution channels to accept a new product, new entrants often must provide incentives in the form of price discounts, promotions, and cooperative advertising. Such expenditures act as a barrier by reducing the profitability of new entrants. [9]

In Earth Observation (EO) industry, the network of distribution means the mode to distribute the data to the end-users. Data owners have several options to distribute the data, such as direct receiving stations, value-added service, and through web portals. Signing the agreement between data owners and local service sectors is a traditional way to distribute the data. It is reported by Euroconsult that approximated 550 active agreements signed among seven organization (private sector and government) commercializing data and local companies for data distribution and value-added resales. These agreements may vary, but essentially, they are classified into five types of distribution agreements: Date reseller, Value-added reseller, Exclusive distributor, Business partner, Direct receiving station. [10]

-Differentiation in products

Differentiation means providing a product or service with higher perceived value than the competition. Thanks to the technology development and new requirements continuously appeared, the space industry is a rich soil for feeding the products differentiation. Competitors may differentiate by type of satellites, service model, locations, and different business.

In conclusion, I will discuss the question toward the above interesting criteria, to see what influence is brought by innovation on the barrier to entry.

2.2.The disruptive innovation

"Disruption" describes a process whereby a smaller company with a fewer resource is able to successfully challenge established incumbents' business. Specifically, as incumbents focus on improving their products and services for the most demanding customers by incremental innovation, they exceed the needs of segments and ignore the needs of others. Entrants that prove to be disruptive begin by successfully targeting those overlooked segments, gaining a foothold by delivering suitable products often at a lower price. In the long term, thanks to the technology development, the performance of the disruptive innovation improves and it may attract mainstream customers. [11]

According to the theory, disruptive innovation originates in low-end or new-market footholds. Disruptive innovations are made possible because they get started in two types of markets that incumbents overlook. Low-end footholds exist because incumbents typically try to provide their most profitable and demanding customers with ever-improving products and services. In the case of new market footholds, disrupter creates a market where none existed before.

Compared with incremental innovation, disruptive innovation is always brought by the newcomers. Firms equipped with new, relevant knowledge and skills that are free from any vested interest in protecting the old technology. [12]

Disruptive innovation does not catch up with mainstream customers until quality catches up to their standards. Disruptive theory differentiates disruptive innovations from what are called "sustaining innovation". The latter make good products better in the eyes of an incumbents' existing customers: the fifth blade of the razor. The clearer TV picture, better mobile phone reception. These improvements could be incremental advances or major breakthrough, but they all enable firms to sell more products to their most profitable customers.

Disruptive innovation, on the other hand, is initially considered inferior by most of an incumbents' customers. Typically, customers are not willing to shift to the new offering merely because it is less expensive. Instead, they wait until its quality rises enough to satisfy them. Once it happened, they adapt the new product and happy to receive its lower price.

I use the disruptive innovation model to make it clearer (Fig.1). The diagram contrasts product performance trajectories (the red lines showing how products and services over time) with customer demand trajectories (the blue lines showing customers' willingness to pay for performance). As incumbent companies introduce higher-quality products or services (upper red line) to satisfy the high end of the market (where profitability is highest), they overshoot the needs of low-end customers and mainstream customers. This leaves an opening for entrants to find the footholds in the less-profitable segments that incumbents are neglecting. Entrants on a disruptive trajectory (lower red line) improve the performance of their offerings and move upmarket and challenge the dominance of the incumbents.

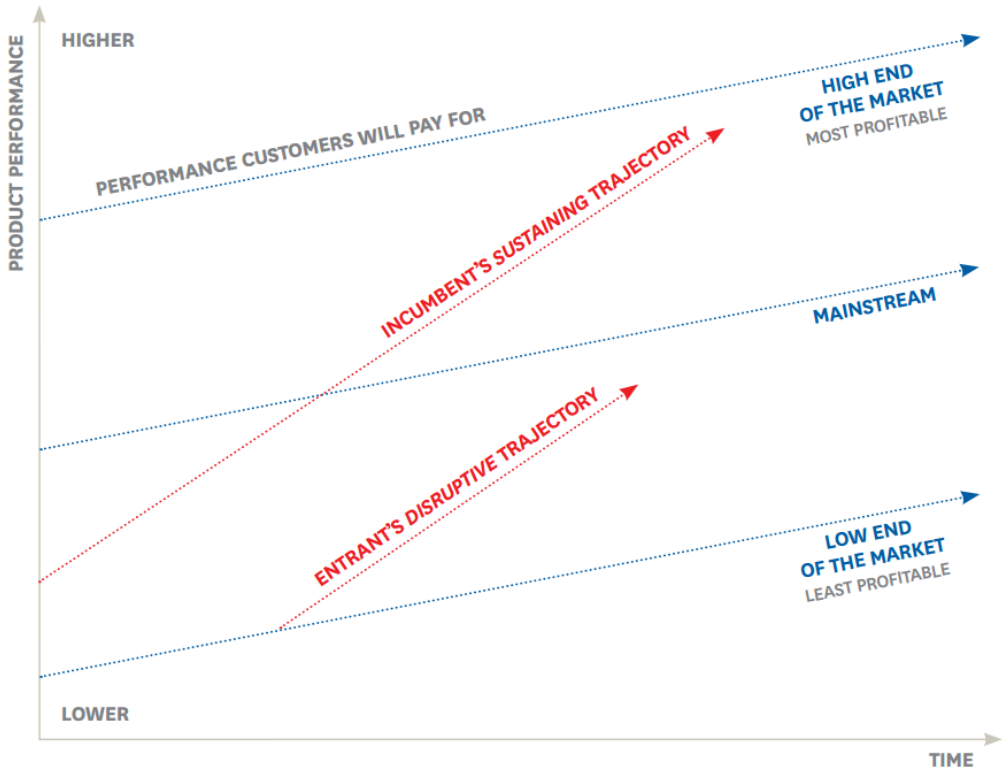

Figure 1 The disruptive innovation model [11]

2.3.The evolutionary model of technical change

Philip Anderon established a cyclical model of technical change which will be used in this paper [13]. It focuses on studying the industry evolution after technical discontinuous. It divides one cycle into two parts (Fig. 2). The first parts called Era of ferment defined from technological discontinuity to the dominant design. The second part is an era of incremental change defined from the dominant design to next technological discontinuity. The era of ferment is characterized by two distinct selection processes: competition between technical regimes and competition within the new technical regime. This period of substantial product-class variation and in turn, uncertainty ends with the emergence of a dominant design.

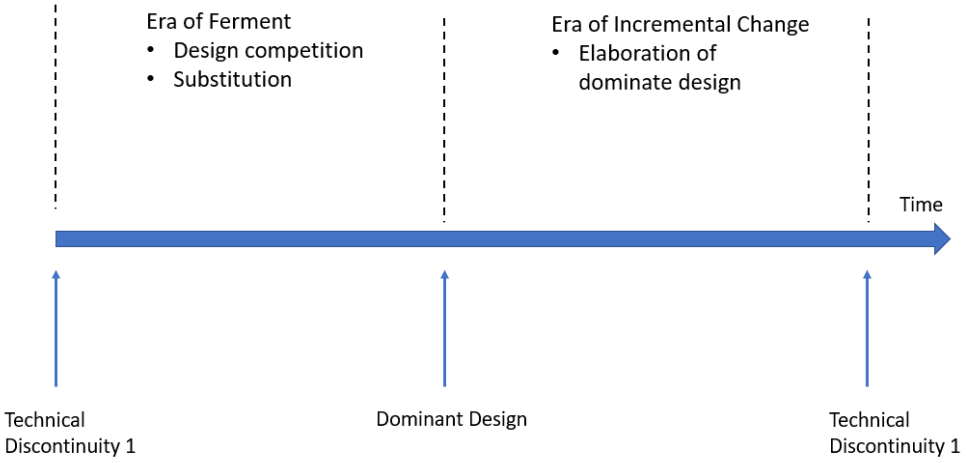

Figure 2 The evolutionary model of technical change [13]

Meanwhile, during the era of ferment, the old technology seldom vanishes quietly. The competitions between old and new technology are fierce. the incumbents must carefully assess whether the new technology may become a substitute for the existing technology or if the technical change is competence-enhancing while building on the existing technical order rather than making it obsolete.

2.4.Product innovation and process innovation

2.4.1. Product innovation

A product innovation is a new technology or combination of technologies introduced commercially to meet a user or a market need. The product will be developed over time in a predictable manner with the initial emphasis on product performance, then emphasis on product variety and later emphasis on product standardization and costs. The product innovation is divided into three stages: [14]

Performance-maximizing: In the early phases of the product lifecycle the rate of product change is expected to be rapid and margins to be large. A firm with a performance-maximizing strategy might be expected to emphasize unique product and product performance.

Sales-maximizing: As experience is gained by both producers and users of a product, market uncertainty will be correspondingly reduced. We might expect a greater degree of competition based on product differentiation with some product designs beginning to dominate. Sales-maximizing firms would tend to define needs based on their visibility to the customer. This stage of innovation roughly corresponds to the segmental stage of process evolution. Process changes will largely be stimulated by the demand for increased output and these may tend to be discontinuous process innovations that involve new methods of organization and product design as well as production.

Cost-minimizing: As the product lifecycle evolves product variety tend to be reduced and the product becomes standardized. Then as a progression, the basis of competition begins to shift to product price, margins are reduced, the industry often becomes an oligopoly, and efficiency and economies of scales are emphasized in production.

2.4.2. Process innovation

A production process is a system of process equipment, work force, task specifications, material inputs, work and information flows, etc. that are employed to produce a product or service. The basic idea of process innovation is that as a production process develops over time toward levels of improved output productivity. The productivity gains result from concurrent and often incremental changes in these factors. The process innovation is divided to three stages: [14]

Uncoordinated: Early in the life of process and product, the process itself is composed largely of unstandardized and manual operations, or operations that rely upon specific equipment. During this state, the process is fluid, with loose and unsettled relationships between process elements.

Segmental: during this period, the production system tends to become elaborated and tightly integrated through automation and process control. Some subprocess may be highly automated with process-specific technology while others may still be essentially manual or rely on specific equipment.

Systemic: The process becomes so well integrated that changes become very costly and difficult. Even a minor change may require changes in other elements of the process and in the product design. The process redesign typically comes more slowly at this stage.

The pattern of relationships between a segment's stage of development and innovation can be conceptualized as shown in Fig. 3. Changes in frequency of innovation are shown on the vertical axis and related to the stage of the process and product development on the horizontal axis.

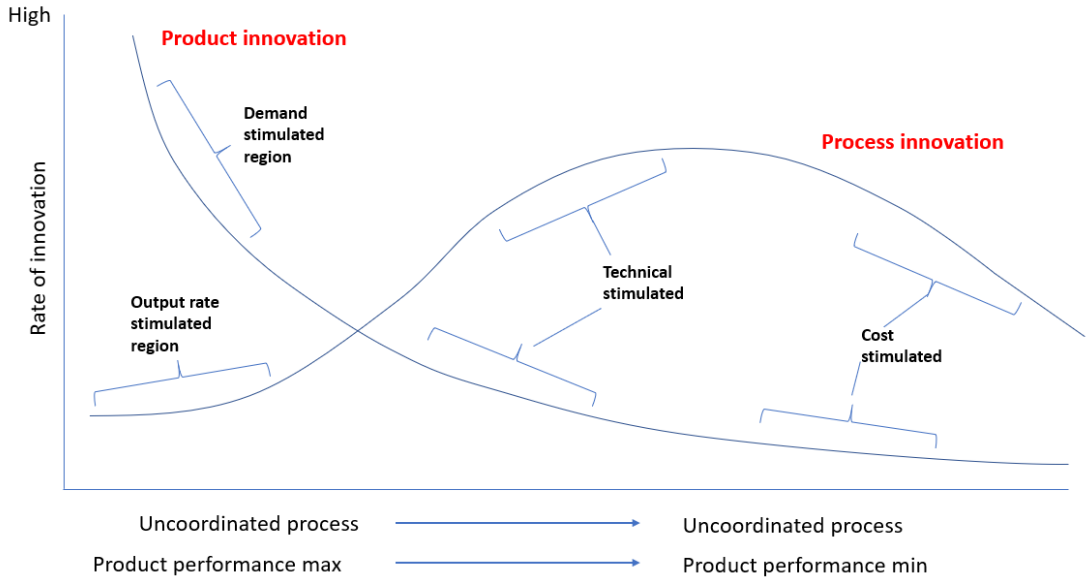

Figure 3 Innovation and stage of development [14]

2.5.Some research with respect to the space industry

Some literature take advantage of innovation theory to analyze the space industry. Leopold Summerer (2009) introduced the specifics of Innovation Mechanisms in the Space Sector. [15] The mechanisms developed for understanding disruptive innovation processes in the private sector, and two specific current developments in the space sector are analyzed. Victor Dos Santos Paulino(2016) analyze whether the new technology is a potential threat for existing firms by combined with three types of disruptive innovations. He highlighted the research on the threat of substitutes for the existing firms which is also the one dimension of Porter's five forces. [16]

Until now, I didn't observe that someone research on the threat of new entrants in the space industry. especially, under the innovation theory. This paper will see the theory gap in the space industry and propose some propositions by summarizing the historical cases. It also will discuss the barrier to entry in depth with regard to the position of the new entrants in the industry.

3. Model

I propose a method involving 2 steps to assess the threat induced by new entrants in EO value chain for existing incumbents. Normally, the descriptive methodology uses the typical cases directly under each criterion of barrier to entry to demonstrate if the barrier is high or low. It is difficult to see the relationship between innovation and the barrier to entry. So, I establish 3 innovation propositions, as the bridge between cases and barrier to entry. The propositions are the summary of the historical cases. I divide my work into 2 steps (Fig.4), Step 1, establishing 3 propositions, based on the theory of innovation. These propositions answer three questions aligned with innovation theory:

-What technical phase is the EO industry in?

-What are the incumbents doing?

-What are the new entrants doing?

The answer to these three questions clearly depicts the big picture in the space industry via the innovation theory.

Step 2, I will discuss their influence on each criterion of barriers to entry by using the propositions: Capital requirements, Access to supply or distribution channels, Differentiation in products. The bridge between innovation and barrier to entry was established.

Finally, the conclusion will be proposed.

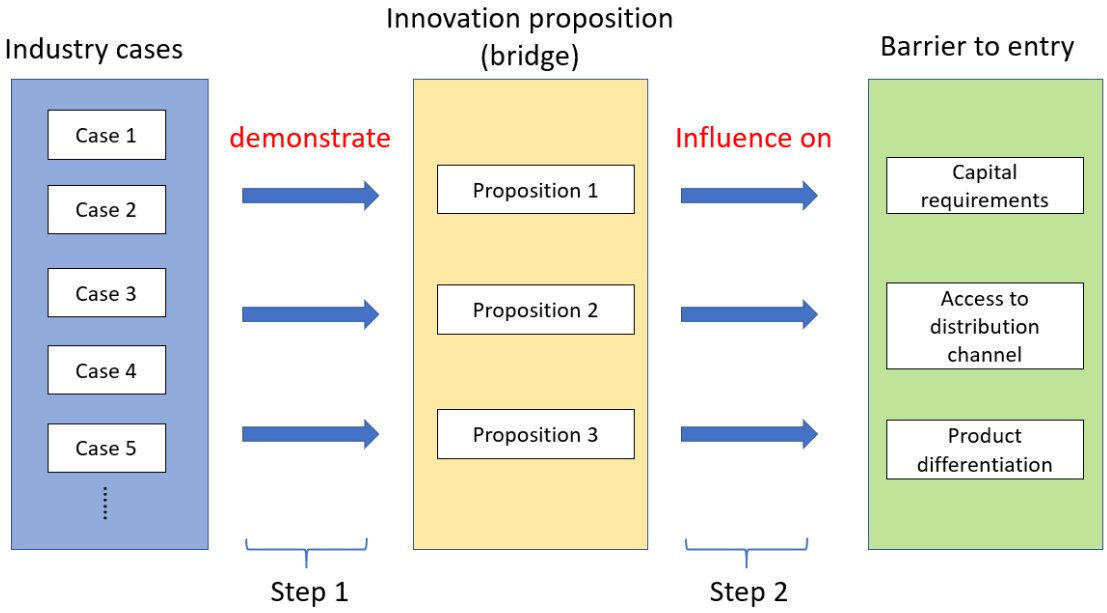

Figure 4 Analyzing model of this paper

4. Methodology

In this paper I apply a descriptive methodology to the earth observation (EO) satellite value chain. I chose this industry because its current situation fits with my research questions and my theoretical framework.

According to the State of the Satellite Industry Report 2017 from BRYCE [17], by the operation functions, telecommunication, navigation, and EO are the most commercial in the space industry. In 2016, the revenue of the telecommunication field reached US$149.2 billion, satellite operation and service contribute the most. The revenue of the navigation field reached US$95 billion which is dominated by the service and equipment development. The EO field only has US$5.8 billion. Some revenue of EO was contributed by the vertical missions.

I also observe that earth observation services revenues grew 11%. Continued growth

by established satellite remote sensing companies, with new entrants reporting revenue as they continue to roll out their services. And new entrants continued to raise capital, develop satellites, deploy orbital assets.

In EO industry, commercial space was not old or strong enough to dominate the industry, compared to the telecommunication or navigation. But the boom in the revenue is dependent on the transformation of business model, emerging new space, and emergence of new entrants. In EO field, the multiple factors help us understand the commercial space market and theoretical framework. It is dynamic both in the vertical and horizontal market. It involved radical and incremental innovation. It is filled with the conflicts between incumbents and new entrants. What's more important, the information of EO industry is easier to access.

I assess the threat for existing firms by using diverse secondary sources such as: (1) available reports (BRYCE, Euroconsult), (2) Journals (Space policy, Acta Astronautica), (3) the websites of space companies (Planet, Blacksky etc.), and (4) open-access information (WIKIMEDIA). I also interview a manager who works in the industry.

5. The current landscape of EO industry

5.1.The value chain

The value chain has been established with the products promotion and the new business model appearance. The typical pyramid can describe the value chain(Fig.5). [10]

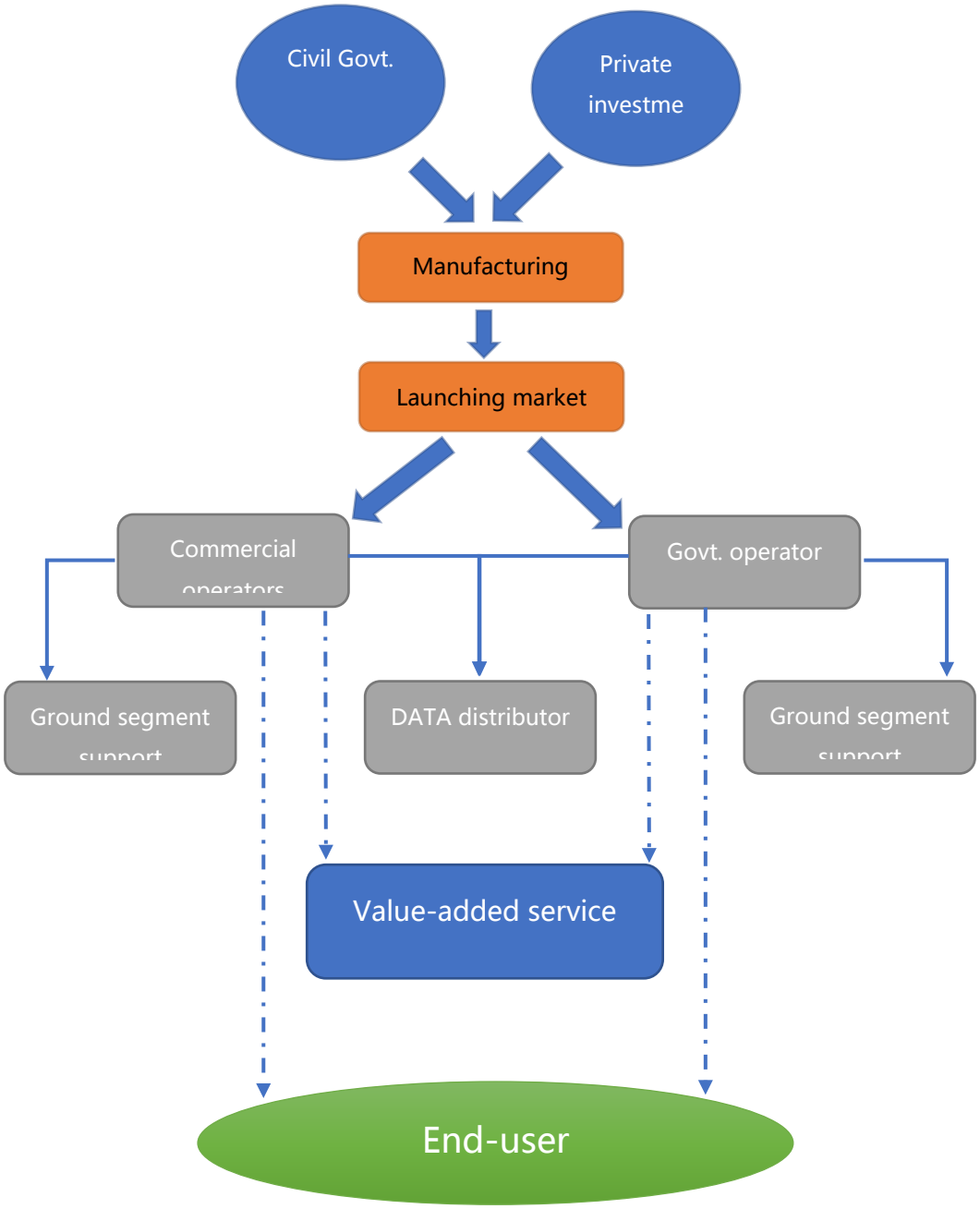

Figure 5 The structure of industry chain [10]

The starting point for the EO value-chain is the investment. Even though the private investment increase over the last few years. The government still supports much of the industry, especially, in some emerging countries who had strengthened their own presence in space.

Following the investment, the manufacturer and launch industry represent the core of space industrial base [17], even though they only occupied the small value in the whole chain. Based on the data from Euroconsult, a total of 181 satellites launched from 2007 to 2016. This is estimated to generate manufacturing revenue of over $33 billion.

Compared with that, the period from 2017 to 2026 maybe witness a significant increase, because of the emergence of new space constellation missions such as Blacksky, UrtheCast, and Planet. Nearly 340 satellites for such missions are expected to be launched in next decade.

Once the satellite is in the orbit, the data or images released varies by the purpose: Some are meteorology data, some are images to detect the disaster, agriculture or ocean condition etc. Some images only used for the military monitoring. The commercial data can be offered by the government or commercial operators (data owners) and distributed in different ways. Such as a direct supply from the company or through a data reseller.

These commercial operators will also offer additional value-added services, but will also partner with or sell to data to a value-added reseller, which will add its expertise to the data to build the dedicated services to various vertical markets.

What's more, it is reported by Euroconsult that in the upstream, most activities depend on the where the government investment is going. Though commercial enterprise is growing, it is still important to note that the majority of the space program are from the government. In the downstream, the government is still the first market. Policy drivers to support defense, resource monitoring, energy, and others all have a positive impact on the uptake of commercial data and service demand.

5.2.Customer groups

Since Public data released with Landsat in the US, different types of EO models have been developed over the last forty years bringing significant changes in paradigms. Until now, the images and data provided by earth observation satellite can be used in agriculture, climate change detection, disaster mitigation, meteorology etc. Normally, the requirements for satellites assets always come from the military or government departments which are classified as the institutional customers. Except for that, some players who are classified as the commercial customers who provide the image and data to the public via the acquisition and operation of satellite assets (e.g. Google Earth). In addition, the mixed customers (public-private partnerships) are also the main EO market segments.

5.3.Technique performance

The engineers are engaged in improving continuously the resolution of pictures released by the satellites all the time. There is no doubt that resolution is the most important criterion of the satellite. The resolution has been a significant advantage to drive the business within the last 30 years, it moved from 10 m (Spot 1) to 31 cm (Worldview-4) [18]. Depending on the difference of resolution, the Very high resolution (VHR, ≤1m) remains the most significant in the market sales. The high-medium resolution is challenged by the availability of free solution and low-cost systems. [10]. The SAR occupied 16% market sales, compared with 84% optical data, closely associated with

the defense and marine applications.

Other performance criteria are becoming more and more important for institutional and commercial operators on top of GSD: reactivity and revisit frequency, image freshness, video capability, multispectral capability, automatic processing, delivery mechanisms, etc. The new entrants target the revisit through constellation with medium or high-resolution sensors.

6. Results

6.1. What technical phase is the EO industry in?

Proposition1*: *The EO industry is in the Era of Ferment during the technology cycle from the start of EO development. It didn't converge to the dominant design. Technical uncertainty and market uncertainty exist in this phase.

Since Public data released with LANDSAT in the US, Different types of Earth observation models have been developed over the last forty years bringing significant changes in paradigms. When we looked back the history of EO industry, we witnessed the technology competition mainly between Europe and America, the duel-oriented target market (commercial and military), the ambitions of the emerging countries, and the appearance of a new business model.

In 1986, SPOT 1 launch and the objective of the French government and CNES is to use a commercial model for image distribution. [18] It demonstrated one of the main benefits of commercial remote sensing for intelligence missions: that it can be shared with anyone. Subsequently, the program called HELIOS launched in July 1995 and December 1999 respectively. It is operated by the French Ministry of Defence procurement agency DGA, can acquire high-resolution images of any point on the globe, with daily revisit capability. The Helios-1 satellites were based on the SPOT Mk.2 bus, based on the civilian SPOT series. [20] The success of SPOT fully shakes the domination of US in the EO industry.

Considering the threat, in 1999, IKONOS-2 was launched by the US, to be called" one of the most significant developments in the history of the space age" [19]. KONOS brought imagery rivaling that of military spy satellites to the commercial market. It was the first to collect publicly available high-resolution imagery at 1- and 4-meter resolution. The US took the lead of the race for higher resolution.

In 2011, the Pleiades which was designed by CNES was a constellation of two very-high-resolution satellites capable of acquiring imagery of any point on the globe in under 24 hours for civil and military users. [21].

For security concerns US Administrations for the two last decades have favored Commercial Services aimed at minimizing the proliferation or the uncontrolled dissemination of very high-resolution images. The US players, such as Digital Globe,

offer the best resolution to deter countries who could plan to acquire their own EO satellites.

At that time, the other countries gain the image mainly by the contract due to domestic technology limitation. But for the sake of enhancing national prestige, soft power and security issues, more and more nations are becoming active players in Earth Observation. This affects both the competition and the accessible market. China EO program is to ensure self-sustainability for data requirements with applications resource monitoring, environment monitoring and defense. The first two satellite Huanjing-1A, Huanjing-1B were launched in 2008 for disaster and environmental monitoring. ("huanjing" is Chinese for "environment"). Japan's EO program started from GCOM series (Japanese main contribution to global earth observation system) which was launched in 2010.

In parallel, development of the internet increased mass market interest for geo-information, this context was good for cross-fertilizing space EO industry with digital industry. Chasing the way to a new business model. At the end of 2010, Google unveiled its Google Earth Engine, a cloud computing platform for accessing and processing Landsat images of the planet going back about 40 years. With the digitization of a warehouse of information, scientific study of worldwide trends using Landsat data suddenly became possible [22].

Even though the private investment enters the industry before 1999. For instance, Landsat 4 and 5 had been operated by a private firm [22]. The small events can't change the main industry trend. The government obviously dominate the direction. I also can observe that: (1) The varied demand in military and commercial drives the EO satellite development to the diversity. (2) Chasing to the very high revolution is the prime target not only meeting the requirement but also showing the strongest capability. (3) Designing can't converge to the standard due to the security issues, technology protection and technical gap between nations. (4) the incubating of new technology tries to break the traditional game rules.

I review the theory of cyclical model of technological change, to be aligned with the historical cases. It can explain and conclude what happened in the traditional space.

Table 1 The alignment between theory and cases

Characteristics of the theory	Cases
Competition between technical regimes and competition within the new technical regimes.	The main competition between Europe and America in the EO industry represent the conflict between two technical regimes.
Concurrent with competition between technical orders is the process of design competition within a technological order	The American and French have the incentive to differentiate its variant from rivals. *American:* Landsat missions 1 through 5 carried the

	Landsat Multispectral Scanner (MSS), while missions 4 and 5 used the Landsat Thematic Mapper (TM) scanner. The United States develop LANDSAT at least five years ahead of the French SPOT, which first used CCD arrays to stare without the need for a scanner. IKONOS's primary instrument is the Optical Sensor Assembly (OSA), based on the LM-900 satellite bus. *French:* The SPOT 1, 2 and 3 is designed with two identical HRV (High-Resolution Visible) imaging instruments that were able to operate in two modes: panchromatic and multispectral. The Pleiades equipped with innovative latest-generation space technologies like fibre-optic gyros and control moment gyros.
During the era of ferment, variation and selection pressures are substantial due to both substitution and design competition. We, therefore, hypothesize that product-class ferment will be characterized by a high rate of variation, reflected in the number of variants of old and new technology competing in the market.	From the above technical features, I can observe that the American and French design the satellite with following each own knowledge system, to make the product varied from each other. The other countries who mainly target on self-sustainability for data requirements made each own satellite. This is consistent with product-class ferment.

6.2. What are the incumbents doing?

Proposition 2: During the era of ferment of EO industry, incremental innovation is always brought by the established players, working on the product innovation and process innovation.

The technological progress is identified when incremental innovation pushes forward the key performance of satellite based on an existing architecture. In EO industry, the incumbents always provide the sharpest image to the commercial or military market. It represents the state-of-the-art design. Digital Globe (US) and Airbus Defence and Space (Europe) were the strongest players in this field.

6.2.1. Product innovation

Digital Globe is today the worldwide leader. It offers today the sharpest imagery (30 cm GSD) with WorldView-3 and WorldView-4 (launched in November 2016). Its Worldview series technical trajectory express the development direction of traditional technology.

- WorldView-1, launched in 2007, was built by the Ball Aerospace. It included a panchromatic only camera with a 50 cm (20 in) maximum resolution.
- WorldView-2, launched in 2009, was built by the Ball Aerospace. The satellite includes a panchromatic sensor with a 46 cm (18 in) maximum resolution and a multispectral sensor of 184 cm (72 in).
- WorldView-3, launched in 2014, was built by the Ball Aerospace. It has a maximum resolution of 25 cm (9.8 in). Due to operating at an altitude of 617 km, it has an average revisit time of less than once per day.
- WorldView-4 satellite, launched in 2016, is designed to provide panchromatic images at the highest resolution of 0.31 meters per pixel (12.2 in/px), and multispectral images at 1.24 meters per pixel (48.8 in/px). The spacecraft was designed and built by Lockheed Martin.

Except for the WorldView series, EarlyBird-1(1997), IKONOS (1999), QuickBird (2001), and GeoEye-1 also represent the state-of-the-art in each period.

From above, I can see that Digital Globe incrementally improved their performance of satellite for 10 years. They take advantage of their existing high-end assets and advanced technology to dominate the market, i.e. in further increasing imagery resolution and targeting customers needing these new VHR data and acknowledging their value. The revenue mainly comes from the sales of EO image.

Airbus Defence and Space Intelligence division is the second biggest place and the oldest commercial operator in EO industry.

- Since the SPOT family of satellites has been orbiting the Earth and has already taken more than 10 million high-quality images. SPOT 1 was launched with the last Ariane 1 rocket on 1986. SPOT 2 joined SPOT 1 in orbit in 1990. SPOT 3 followed on September 26, 1993. The satellite includes two HRV (High Resolution) payload which can work in two modes, either simultaneously or individually. The two spectral modes are panchromatic and multispectral. The panchromatic band has a resolution of 10 meters, and the three multispectral bands (G, R, NIR) have resolutions of 20 meters.
- SPOT 4, launched in 1998, which can acquire time-lapse of images over 42 sites with 5 days revisit period.
- SPOT 5, Launched in 2002, has two high resolution geometrical (HRG) instruments that were deduced from the HRVIR of SPOT 4. They offer a higher resolution of 2.5 to 5 meters in panchromatic mode and 10 meters in multispectral mode.
- SPOT 6 and SPOT 7, launched in 2012 and 2014 respectively, formed a constellation of Earth-imaging satellites design to provide the continuity of

high-resolution, wide swath data up to 2024. They also can acquire the simultaneous panchromatic and multi-spectral data.

Except for SPOT series, the Pleiades-1A and Pleiades 1B also offered VHR. TerraSAR-X and TanDEM-X offered X-band radar imagery.

Same as Digital Globe, Airbus also incrementally improved their product for 18 years, and gain main revenue from the traditional market through providing the high-quality image to high-end customers.

-Performance maximizing phase

By using the model of product innovation and process innovation. I observe that the incumbents are in the *Performance-maximizing* phases. Because the incumbents might be expected to emphasize unique products and product performance. Improving their products performance and services tends to be driven or stimulated by the market demand. The products are nonstandard. Digital Global and Airbus take advantage of their existing technology to meet the requirements of the customer through promoting the performance of satellites continuously.

6.2.2. Process innovation

-Uncoordinated phase

Satellites are traditionally produced in very small batches, and it displays low levels of standardized and modularity because they are assembled for the specific customized demand, the process innovation never stopped in the space industry. The process innovation is considered the significant complementary of product innovation. As I observe by the process innovation model that the space industry is in the *uncoordinated phase*. The rates of product and process changes are high and there is great product diversity among competitors. Typically, the process itself is composed largely of unstandardized and manual operations. The satellite has to be assembly and test on the special equipment.

-Less flexible and more cost-oriented

But, the tendency we can't ignore is that the process of satellite development become less flexible and more cost-oriented due to the rich experience accumulated by producer and lead time required to be shorter, lower price required by the governments or major customers. I interviewed a manager Mr. Zhong who worked in CAST small satellite department for over ten years, He told me CAST are engaging in improve the satellite manufacturing process all the time. Some fixed and simplified process is the trend to contribute to lower the cost. For instance:

- Standardized design to some extent: The satellites in the same series are designed based on the same bus. The fixed model and process can be used in

the satellite to achieve the specific functions.

- The frequent application of commercial components in some satellite reduces the screen and test cost of the components.
- Limited need for redundancy in ensuring the reliability of satellites' function.
- The application of electric propulsion is a useful way to reduce the cost of launching service.

6.3.What are the new entrants doing?

Proposition 3: In the Era of Ferment, the new entrants bring the disruptive innovation marked by the constellations and new business model.

6.3.1. Technology change: single satellite to constellations

In terms of EO satellite specification, the revisit time is another important criterion of the EO satellite. For a given GSD, several solutions can reduce the revisit time and increase the acquisition capacity: steerable mirrors, agility of the platform, lower orbits, etc. in traditional way. With the increasing demand of high revisit rate, the new entrants (PLANET) use a disruptive solution: constellations of several small or medium and low-cost satellites. Their objective is to propose revolutionary operational and business models with cost effective services combining high resolution and high revisit.

- PLANET aims to image the entire earth every day and provide universal access to that imagery collected at a high frequency and at low cost to provide analytics based on the change detection. PLANET is in the process of building its constellation of 3 m resolution "Dove" satellites. A total number of 175 Cubesat.
- BlackSky Global is a wholly owned subsidiary of spacecraft industries based in Seattle in the U.S. The company plans to launch a 60-satellites constellation, aim to cover 95% of the earth' populated area at high resolution and hourly visit.
- HERA systems recently closed an initial Series A funding round. As demand grows, a constellation with up to 48 satellites is envisaged. This will aim to provide data with updates measured hourly.

Small satellite solutions are invariably less stable, simpler platforms that compromise accuracy (most solution do not carry advanced star tracker, gyros, etc.). However, the lower-cost approach, means operators can price data competitively, potentially disrupting the market.

A new value mindset for "low-cost satellite EO" is being developed by the new entrants. Subsequently, it extends to satellite and sensor manufacturer, integration and tests providers, communication systems and operator service providers.

6.3.2. Service-based strategy

The disruptive innovation is not only expressed by the technology change, but also by the service-based strategy. The development of the IT increased mass market interest

in geo-information. The new entrants could provide the added-value service for customers. They drive the value shifting from providing the satellite data to offering the added value service.

- The giant IT players bring the massive development of the Information technology (big data, analytics) with full private investment into the EO industry. Several new technologies, non-specific to EO, but are expected to utilize in EO industry. Cloud computing enables efficient storage and exploration of data. This technology leverages low-cost commercial cloud-based solutions such as Google Cloud and Amazon Cloud, facilitating the development of EO service.
- PLANET and UrtheCast extend their value chain to offer end-to-end data solutions to customers. The offerings include customizable, subscription-based monitoring data and cloud-based APIs
- Thanks to the IT technology development and cross-fertilizing, more and more value-added service companies have started to evolve in the recent years. They offered the research, service or product through analysis and image processing.

The "service-based strategy" of new entrants is not only the low-cost approach: it makes an assumption that the EO will become the commodity and that the value of the strategy will be the information services created from EO data and from other data sources.

Until now, I finished step 1 by demonstrating 3 propositions by elaborating a large number of cases. These propositions clearly depict the current landscape of the EO industry by innovation theory. The summery is expressed by the fig.6.

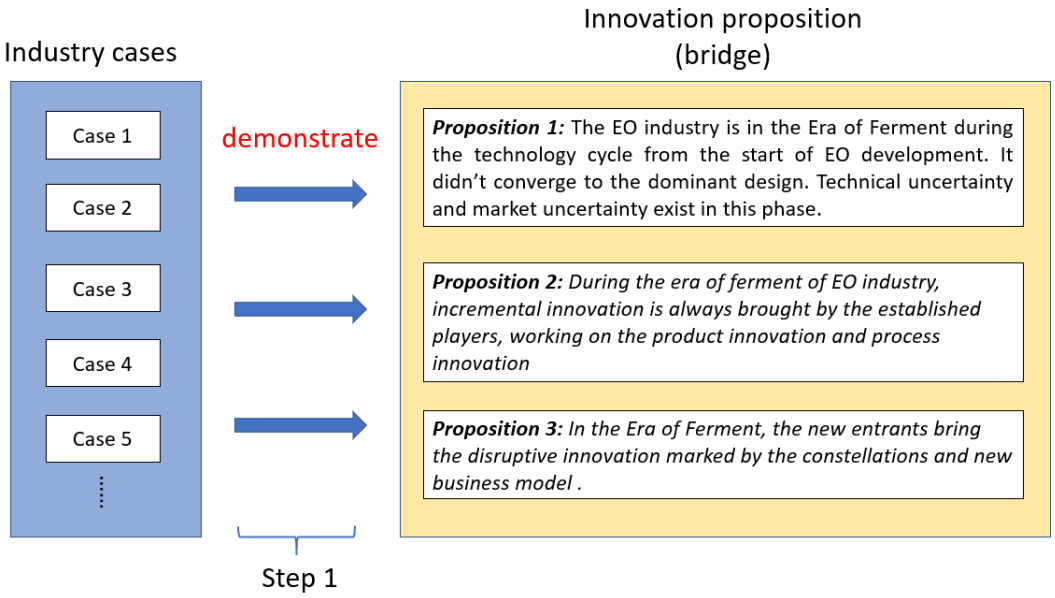

Figure 6 Result of demonstration

7. Discussion

From above, I can observe the 3 general disciplines of EO industry combined with innovation theory. Both the incumbents and new entrants did the good work toward each objective. but how they impact on each other? Step 2 will discuss the influence on the barrier of entry by taking advantage the propositions. I choose 3 factors to be discussed: capital requirements, access to the distribution channel, and product differentiation.

7.1. Capital requirements

Influence 1: The disruptive innovation performed by the new entrants aim at lowering the capital requirements.

As I said in the literature review, the space industry is one of the most obvious examples of the high capital requirements. The mass of satellite, the small batches manufacturing, the launching mass, and the customized demand play the important role in the price system of space missions. If some company want to enter the manufacturing field. The clean room, the costly test equipment must be needed. Reductions in mass and cost have made it possible to achieve the kind of small satellites listed below in Table 1 Classification of satellites

Table 2 the general relation between the price and mass

Class	Mass(kg)	Cost (US$million)
Large satellite	> 1000	> 140
Small satellite	500~1000	50~140
Mini-satellite	100~500	10~30
Micro-satellite	10~100	3~6
Nano-satellite	1~10	0.3~1.5
Pico-satellite	< 1	< 0.3

Source: KEYNOTE address Micro/Nano-satellites- The new world M.N. Sweeting, Surrey Space Center-University of Surrey, UK[23]

The disruptive innovation by the new entrants firstly bet on the “low-cost” strategy. The small satellite constellation is the popular solution in the space industry, not limited in EO field. The decrease of manufacturing cost benefit from reducing the mass of

satellite and the degree of complex, utilizing the commercial off-the-shelf technologies, and leaner industrial processes. As I observed in the innovation model, the performance of small satellite cannot achieve the level of reliability, high image, long-life etc., but the lower cost approach means operators can enter the market easier than before.

Advancements IT have further facilitated the development of new commercial EO solutions. Cloud-based computing enables efficient storage and exploration of data. This technology leverages low-cost commercial cloud-based solutions such as Google Cloud and Amazon Cloud, lower the barrier to entry.

A new market for EO-based services is created by the new entrants, such as Planet, BlackSky, UrtheCast etc. may offer the different services based on the environmental issues (adaptation to climate change, water, and food security, insurance etc.) or to the new commercial applications (geo-marketing, mapping, etc.)

Influence 2: The incremental innovation performed by the incumbents impacts on the barrier to entry on both sides, as a double-edge sword

There is no doubt that the VHR market is still the mainstream market in the EO industry. It is reported that VHR optical imagery totaled 83% of all commercial data sales in 2016 (Euroconsult) [10], again with defense being the first players. There is no doubt that the incumbents dominant the VHR market by their existing technology, DigitalGlobe and Airbus Defence and Space deliver high-quality VHR imagery, with focus on the acquisition capability and powerful distribution service, thanks to their satellite fleet and large telescopes. For the sake of dominating the market, they also never stop promoting the performance of satellite. The key performance of resolution has been improved from 10 m to 31cm in the last 30 years. The high-performance satellite also configured with star tracker, sun tracker CMG, etc. All these high specification means the larger platform to install large telescope and payloads, and the higher manufacturing cost. The high performance also means the higher price of the high-quality image. I can see from the figure that when the resolution below 1m, the price of optical data increase dramatically. This high-end market is not suitable for the "low-cost" business model.

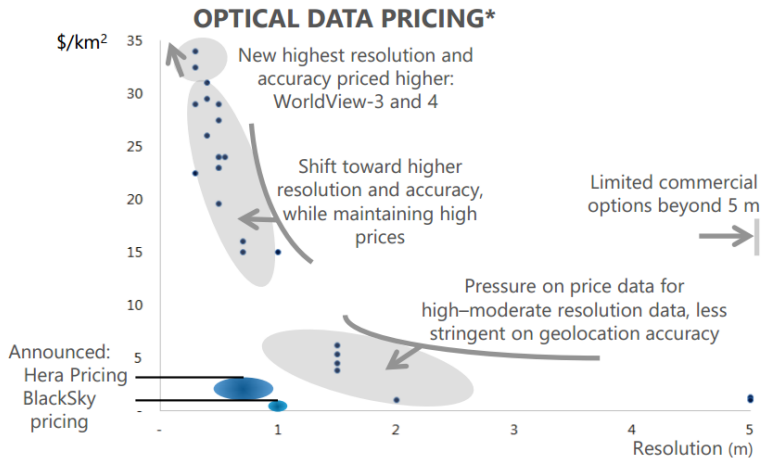

Figure 7 Optical data pricing (Euroconsult) [10]

But, on the other hand, an important role in improving performance and further reducing costs has been played by extensive process innovations as I described in chapter 4. This kind of process innovation has been conducted to the low-cost production: standardized design, commercial components application, and limited need for redundancy in ensuring the reliability of satellites' function. In addition, the process innovation usually draws considerable benefit from the circulation of technological innovations provided by its suppliers. It makes it clearer how the process of technology transfer follows the open innovation paradigm. Thus, the cost of access to new technology is not high, and even the investments in research and development have been modest.

In conclusion, the new entrants continuously lower the capital requirements of the space industry through each own new business model and new way to use the satellite. They created the new market based on "low-cost strategy". On the other hand, through the process and product innovation, the incumbents subjectively deter the new entrants entering the VHR field and retain the dominance over the other players, while at the same time facilitate the process and product progress in whole EO industry, objectively helping the new entrants lower the capital threshold to some extent.

7.2.Access to distribution channels

Influence 1: In the era of ferment of EO industry, establishing the traditional distribution channels is featured by region. The incumbents maintain the relationship well with local government and data reseller. It raises the barrier to entry the industry.

Establishing the traditional distribution channels is featured by regional. As I introduce at the beginning, in the era of ferment of EO industry, satellite design can't converge to the standard partly due to the security issues, technology protection and technical gap between nations. Similarly, during the data distributing process, in order to facilitate the local industry and protect the national confidence, the partnership with local service company sometimes is the mandatory option for incumbents penetrating local market when they explore the overseas market. These cooperation companies can be selected either as a result of Public-Private partnership or the authorized entity founded by the government. Until now, DigitalGlobe set the 140 partner agreements in North and Latin America. Airbus set the 116 partner agreements in Europe and Asia market [10]. They remain the long-term relationship with local government and local resellers. This naturally deters the new entrant into the traditional EO market.

Influence 2: The disruptive innovation facilitates the distribution channels to be refreshed. It becomes commonplace for commercial operators.

I can observe that some disruptive innovation changes the distribution channel when the IT technology enters the market. Firstly, the web portals became the popular way to distribute and sell the EO data. There is no doubt that it shortens the distribution channel.

- DigitalGlobe 's online portal image finder provided nearly 6 billion km^2 of archive images to its online ordering facility. The collection capability is approximately 1.2 million km^2 of imagery per year.
- Airbus's Geostore allows users to search for and purchase data online, including raw, mosaic and 3D maps. Additionally, it allows users to track the orders and place tasking orders.
- EyeFind of Planet offers online viewing of 6 billion km^2 images collected by the RapidEye constellation. In addition, Planet platform offers automated image processing and ortho-rectification.
- With the DMCII's online catalog, users have access more than 5 billion km^2 of archive imagery to view and order directly online.

Secondly, the cross-fertilizing with IT technology maximizes the value of the EO-based service. It drives the new entrant to find the opportunity to express their added value directly to the end-customer. It also opens the new market for new entrants.

For instance, Planet and UrtheCast provide end-to-end data solutions to customers. The product includes customizable, subscription-based monitoring programs and cloud-based APIs.

In a nutshell, Although the traditional distribution channel deters the new entrants from entering the market due to the strong regional feature, through the web portal to sell the product and service help the new entrant achieve their value. Based on the web, the feasibility of "horizontal market" have to be demonstrated. In this situation, the customer becomes a consumer. What's more, the end-to-end solutions maximize the EO-based service value, the new entrant could provide the high service directly with the end user.

7.3.Differentiation in products

Influence 1: Rely on the advanced space assets and incremental innovation, the incumbents remain the top performance of satellite, to provide the VHR to customers.

Differentiating operators themselves in the market more regarding the capabilities of their respective systems. Let us take an example of two champions in the industry.

Since the Worldview-1 launched in 2007, DigitalGlobe currently operates five satellites, including the last satellite from the Worldview series, The lasted Worldview-4 launched in 2016. Taking advantage of a fleet of agile satellites with the large telescope for VHR imagery, direct receiving stations, networks of distribution, and new relaxed regulation,

DigitalGlobe could deliver the global commercial with 31cm panchromatic and 124 cm multispectral images to customers. In addition, DigitalGlobe offers two types of achieve data: more than 90 days as the standard archive and less than 90 days as a fresh archive.

Airbus Defence & Space benefits from satellite funding by the government: commercialization of the French government dual-use program, Pleaides and its SAR satellites. The company has the most diverse data offering to the customer. It operates and distributes from more than 50 satellites, offering different capabilities and resolutions. SPOT 6-7 can provide the wide footprint 60km×60km, with Panchromatic 1.5 m. Pleiades-1A/1B can provide the resolution 50 km and 20km swath. TerraSAR-X can provide 3 main imaging mode, Spotlight(up to 1 m resolution, with swath 60km×60km), StripMap(up to 3 m resolution), and ScanSAR (up to 16 m resolution). In addition, Airbus has distribution rights for the 1m KazEOsat-1 belonging to Kazakhstan. Airbus has over 40 direct receiving station in the local place with customers.

I can observe from the cases, the incumbents have been engaging in improving the performance of product since they enter the EO industry. They continuously push their products reaching the customer demand through improving the resolution, establishing the local service network or receiving station. Inter-heritage can be obviously observed in the products series and service model. Meanwhile, although I witness an increasing of the private funding in the industry, especially when the large web actors enter the market, until recently, EO-based imagery and data more service for the government. Defense remains the largest demand in the market. The requirement for the VHR and SAR imagery and data from them drive the incumbents to promote the performance of products incrementally.

As I know, the key difference between the low-cost solution and high capability satellite is the resolution and data geolocation accuracy. Compared with the high-cost data stuck by the significant value, the low-cost data can’t gain the revenue without any postprocessing. Hence, Whether the new entrant can differentiate their product or narrow the gap with the incumbents ?

Influence 2: The disruptive innovation helps the new entrant built the different business strategy and product, initially targeting on the low-end market.

As I introduced above, the new entrants are emerging with a new approach that to use lower-cost constellations to collect data at a high revisit rate. It opens the new market requiring the high-frequency revisit to support change detection application. The examples include:

BlackSky Global plans to launch a 60 satellites constellation, aiming to cover 95% of the earth’s populated area at a high resolution and hourly revisit. It was more than that,

the companies like Hera (America), Capella Space (America), Iceye (Finland) etc. aim to provide the hourly revisit earth based on the constellation.

The new approach also drives the added-value service and open the EO data to the new customers who prefer the low-cost solutions across further sectors. In some parts, these potential customers are considered new or undeveloped, such as support to finance service, market intelligence etc. And on the other side, they also are considered existing, but serve by other solution (infrastructure monitoring, precision agriculture by UAV or smart sensor solutions).

Although the new entrants can differentiate their product and service, we can't ignore the VHR optical imagery is expected to remain the largest demand in terms of data sales. Is it possible to catch up with the high performance of satellites to meet the main demand?

It is reported that, any data can improve geolocation accuracy through the use of GCPs and DEMs[10], Postprocessing, as a new low-cost way, make the data more competitive. Bringing the geolocation accuracy into 10-20m CE90 range would make the data more suitable for applications at a lower price. (e.g. Blackbridge announced 10 m CE90 accuracy using Landsat GCP, suitable for some applications). If it is true, the incumbents will face the major challenge in VHR domain. This is aligned with the "disruptive innovation model"

In a nutshell, the incumbents are growing and replenishing their fleets to make sure that "high-end" solution could find its own niche, even is this market segment is mainly addressed by "low-cost" products. The new entrants bring the new service into the new market and bring high revisit indicator to attract new customer. In the short term, the products of new entrants can't shake the dominance of incumbents, but it is ambiguous in the long term.

The fig.8 could clearly describe the influence of innovation on the barrier to entry

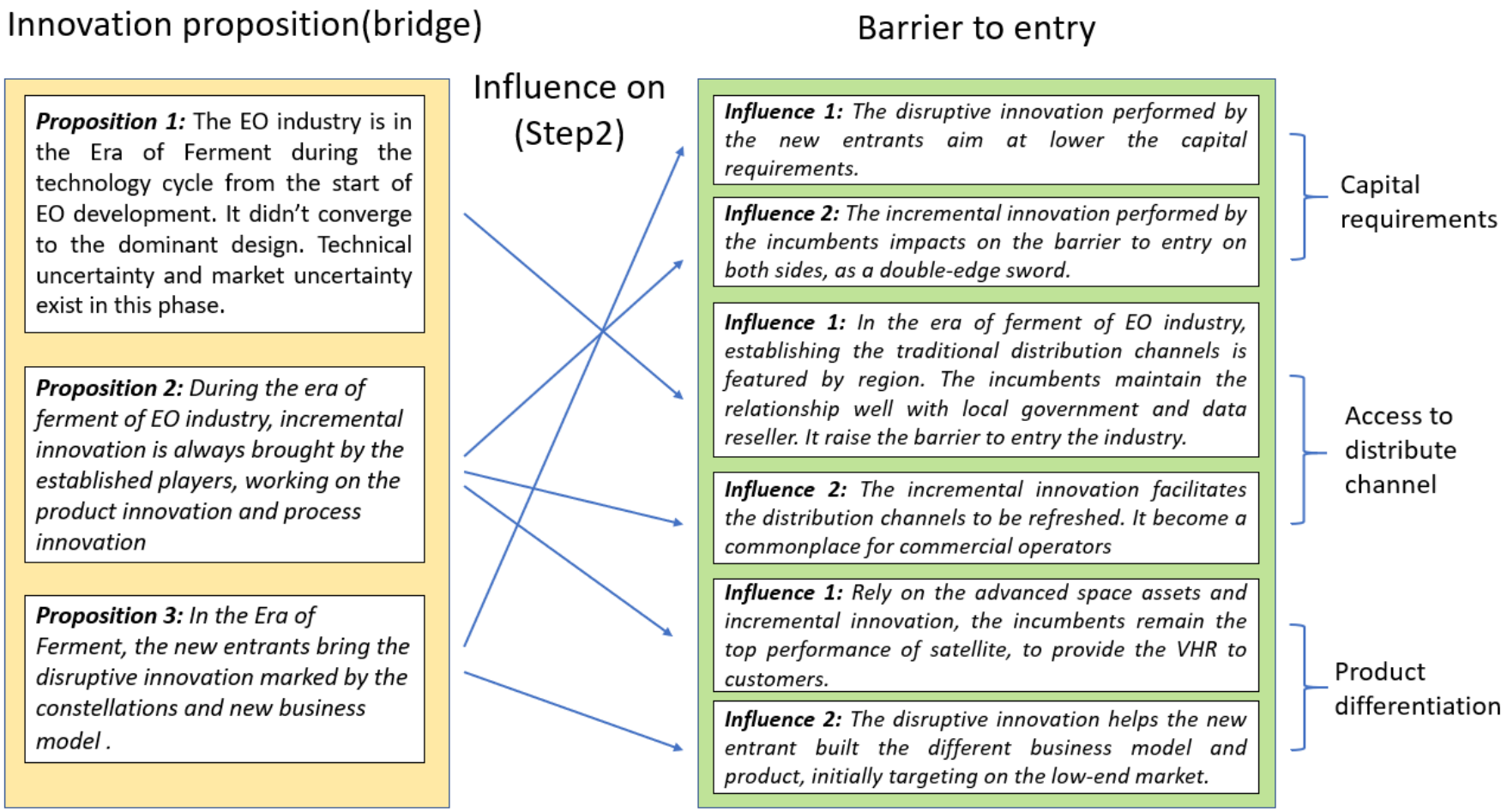

Figure 8 The influence of innovation on the barrier to entry

8. Conclusion

The first objective of this paper was to contribute to propose the innovation propositions in the EO industry by using the different innovation model. I define the innovation phases of EO industry by using the evolution model of technology change. The EO industry was in the era of ferment. It didn't converge to the dominant design. I also defined the incumbents' activities by using the product innovation and process innovation model. The product innovation of incumbents was in the Performance maximizing phase. The process innovation was in the uncoordinated phase. Finally, I defined the new entrants' activities by using the disruptive innovation model. The disruptive innovation always is brought by the new entrants aim at the "low-end" market. The new entrants want to find the foothold by using the "low-cost" strategy.

The second objective of this paper was to contribute to discuss the influence of the innovation on the barrier to entry. Generally, the influence was complicated. The new entrants want to lower the barrier by using the satellite in a different way. They focus on developing the constellation in order to lower the capital requirements. They provide the end-to-end service and online service in order to reach the customer directly. They opened the new market requiring high-frequency revisit and provided added-value service. At the same time, through the incremental innovation by the incumbents, they not only pushed the whole industry forward but also created own niche market by promoting the space asset.

This paper chooses some typical cases aiming at demonstrating the propositions. These cases, as the arguments of the model, are summarized by two complementary perspectives: on one hand, the type of system (either single satellite or constellation) and its operational performance (either high revolution or high revisit) and, on the other hand, the related business models (either traditional model or new business model).

Furthermore, the experts and managers in incumbents can benefit from this paper. Through position and analyzing the EO industry, they could see clearly where they are in the industry and how much threat they faced in theory level. The new entrants can also benefit from that. The summary of the historic cases and the analysis for the whole industry could be the reference when they design the specific strategy.

But, the real situation is more complicated than that. The president of ESSA said in Toulouse Space Show 2018, "there is no competition between new entrants and current players. They walk on the road hand in hand." I don't comment on that, but some are true that:

"Low-cost" is not the intellectual property of new entrants. The incumbents' plan focuses more on replenishment and adjustment to continue delivering operator services and adapt to new market conditions. Digital Globe, for instance, is aiming to add a

lower-cost satellite constellation to its portfolio to counter the probable impact of low-priced solutions entering the market. Meanwhile, consolidation between companies is ongoing to strengthen the competitiveness (Terra Bella being acquired by Planet, DigitalGlobe by MDA, OmniEarth by Eagle Vision). These issues beyond the range of this paper, but have a huge impact on barriers to entry. In the future, I propose to study what influence on the EO industry change by the acquisition and consolidation of the companies.

<End of dissertation>

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