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Downstream Space Activities in the New Space Era: Paradigm Shift and Evaluation Challenges

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Abstract

New Space refers to the recent opening-up of the space sector to private companies. The liberalization of space activities, which coincides with the digital evolution of the economy, is associated with the rapid expansion of the downstream space segment, i.e., space-related commercial applications and services. In this paper, we explore the role of commercial space, and more specifically downstream activities, in the change occurring in the space sector. We discuss the implications of this trend for the measurement of commercial space and space policy. After a literature review that points out the space sector evaluation challenges, we analyze New Space and the service-oriented growth of commercial space. We finally propose a theoretical reflection on New Space as a shift toward a demand-pull paradigm. We conclude by discussing the interest of the dynamic approach to understand and evaluate commercial space in this new context.

Keywords: New Space, space sector, downstream space, satellite-based services, demand-pull

JEL Codes: L1, L5, L8, O33

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1 Introduction

Over the last few years, the space sector has been experiencing renewed interest both from the political sphere and civil society. Formerly the preserve of a handful of major powers, an increasing number of countries are involved in space activities, creating their national space agency and operating their own satellites (OECD, 2019). Public budgets allocated to space programmes in the historical space-faring nations are also more substantial. The European Space Agency (ESA) Council[1] adopted in 2019 a record funding of 14.4 billion euros over three years, against 10.5 billion euros in 2016. Although exploration and science remain the primary focus of space policies, public investment in space is increasingly oriented towards innovation, economic performance and climate issues (Fioraso et al., 2016; European Commission, 2013; Lebeau, 2008).

In addition to the expressed ambitions in terms of space policy, the space industry is undergoing important changes commonly referred to as New Space. The latter describes the liberalization process of low Earth orbit activities and the reorientation of the space sector towards commercial purposes (Lafaye, 2017). New Space is associated with the emergence of new figures from private entrepreneurship intending to exploit space technologies and open new market opportunities, thereby reducing barriers to entry in the sector (Tortora, 2019).

A fundamental element of the current transformation of the space sector is its convergence with the digital industry (Nardon, 2017). Digital giants invested heavily in space in the early 2000s and developed their space systems with government support. This paved the way for new private investors and start-ups specialized in space technologies and applications to emerge, mainly in the United States. Space has become a valuable economic resource for data-intensive industries such as ICT. Satellite technologies are valuable assets that produce a wide variety of data (navigation and geolocation data, radar and optical images of the Earth, Internet, television signals, etc.) in large quantities and almost instantaneously. New Space is therefore characterized by the exploitation and improvement of space technologies by private actors from other industries and, to a greater extent, by the development of commercial applications.

The expansion of the so-called *downstream space sector*, i.e., all activities related to the production of value-added space-related goods and services, is generating significant economic value. The growth of commercial space is increasingly driven by the development of commercial uses in three traditional space application areas: communications, Earth observation, and satellite navigation. New Space is associated with

[1]ESA has 22 Member States including non-EU members such as Norway, Luxembourg, Switzerland and the United Kingdom.

significant changes in the space value chain, mainly in its downstream part where most of the sector's revenues are generated. By addressing a wide range of markets (e.g., agriculture, transportation, digital, finance, health, etc.), the space sector is seen as an important potential engine of economic growth (European Commission, 2013).

These considerations shed light on the importance of estimating the size of the space economy. The ability to assess the economic value generated by the use of space becomes critical for both institutions and the private sector. For the former, it would facilitate the definition and implementation of effective and well-targeted space policies. For the latter, it would help identify dynamic space markets and motivate investment decisions.

This paper examines the changes occurring in the space sector and their implications for economic assessment and space policy. More specifically, we discuss the role of downstream commercial space activities in New Space and provide theoretical insights for a better understanding and measurement of these growing activities.

The next section of the paper is devoted to the critical review of the literature dealing with commercial space evaluation, with a particular focus on the downstream segment. The third section aims to characterize New Space through the lens of economic theory. In the last section of the paper, we argue that New Space reflects a structural shift of the space sector toward a demand-pull paradigm. We conclude this article by proposing theoretical orientations to be taken into account to analyze the evolution of commercial space. We emphasize the interest in the dynamic approach to understand the logic of value creation within space activities.

2 Critical review of downstream commercial space assessment

2.1 Evaluation methods and downstream space key figures

Our review draws on thirty-one publicly available studies, surveys and reports spearheaded by space agencies, institutions or trade associations. Three categories of studies are identified, corresponding to the perimeter of activities they cover (see Table 1).

The first set of references includes studies estimating the size of specific downstream application segments. PwC France (2019), EARSC (2019, 2017, 2013), Lafaye (2017), and Ecorys (2008) are dedicated to estimating Earth observation (EO) commercial applications. European GNSS Agency (2017, 2015) deal with satellite navigation systems

Scope	References	Geographical area
Downstream applications	Lafaye (2017)	France
	EARSC (2019) PwC France (2019) Delponte et al. (2016)	Europe
	EARSC (2017, 2013)	Canada & Europe
	European GNSS Agency (2017, 2015)	World
Space economy	CSA (2019, 2018)	Canada
	ESPI (2020, 2019) Eurospace (2020)	Europe
	Bryce Space & Technology (2019b, 2018) Bryce Space & Technology (2017a, 2016) OECD (2019, 2014, 2011, 2007) OECD (2012)	World
Impact of the space economy	Know.space (2021) London Economics (2019, 2016) Oxford Economics (2009)	United Kingdom
	Highfill et al. (2020)	United States
	Booz & Company (2014) Technopolis group (2012)	Europe

Table 1: Publications by scope of evaluation and geographical area

markets, and Delponte et al. (2016) consider both EO and GNSS application markets. When defining the scope of activities considered, the reports essentially adopt the value chain approach. Delponte et al. (2016) identify three types of companies composing the GNSS market: components manufacturers producing navigation signal receivers (chipsets, antennas), system integrators delivering GNSS devices, and value-added service providers. As observed in Delponte et al. (2016) and EARSC (2019, 2017, 2013), the EO downstream value chain is longer and covers a wider range of activities than the GNSS value chain. It includes data suppliers (satellite and ground stations operators, data resellers), developers of value-added services and products (e.g., Geographic Information Systems companies), consulting firms and end-users. For most studies, the figures are obtained from surveys conducted with companies identified at each stage of the value chain. Both quantitative and qualitative data are collected (revenues, employment, application domain, number of receivers used for GNSS services).

The second set of references deals with the evaluation of the overall commercial space sector ("space economy" in 1). These reports provide an overview of the key trends in the space market from the upstream to the downstream sectors using a whole set of performance indicators (launch rates, upstream and downstream revenues, number of companies). The OECD studies use *input* or *readiness* indicators (e.g., space budgets, human capital), and *output* or *intensity* indicators (space systems manufacturing and launch services revenues, employment rate, downstream revenues, patents). Bryce's reports provide data on the global satellite industry such as revenues per market segment and the number of operating satellites. Finally, ESPI conducts annual surveys of space companies and organizations. It provides space market reports on the space economy to provide decision support to public institutions.

The last set of references evaluates the socio-economic impacts of space activities ("impact of the space economy" in Table 1). The publications mainly input/output analyses to assess the economic benefits associated with the development of the space sector. This approach consists of measuring the final GDP impact resulting from the injection of a certain amount of spending (e.g., public funding, R&D investment) into the economy (PwC France, 2019). Three types of economic effects are considered: direct effects (spending associated with space system's manufacturing), indirect effects (suppliers' expenditure for materials) and induced effects (salaries of space sector's employee spent on consumer goods and services).

The comparison between studies shows differences in terms of maturity degree and market structure between space application sectors. EO downstream services, although growing, is the less mature application segment. PwC France (2019) indicates that the global EO downstream market amounted 2.6 to 2.8 billion euros in 2017 (against 1.3 billion euros in 2005 (Ecorys, 2008)), against 94.8 billion euros for the GNSS downstream market, and 104.5 billion euros for the telecommunication services industry (ESPI, 2018; European GNSS Agency, 2017). Besides, EO downstream market is held by a relatively low number of companies compared to telecommunications and navigation. It is fragmented with on the one hand few very large space players (Maxar held 30% of the EO market in 2017, Airbus DS 12%) and non-space players (value-added resellers and big data analytics companies such as Atos represented 36% of the market in 2018), and on the other hand many small players (PwC France, 2019). More than 65% of EO downstream players are "micro-companies", i.e., companies with less than ten employees (PwC France, 2019; EARSC, 2017). When it comes to the demand for EO data and services, over 60% of the EO segment's revenues emanate from the public sector (national and European public bodies, international institutions, public research institutes) (EARSC, 2017).

The navigation market is the downstream segment that has enjoyed the most significant growth since the early 2000s, reaching 94.8 billion euros of global revenues in 2015 compared to 17.3 billion euros in 2005 (European GNSS Agency, 2017; Ecorys, 2008). Like the EO services market, the GNSS downstream industry is also composed of few large companies and an important number of SMEs. The sector is characterized by a growing trend of mergers and acquisitions, especially in navigation devices manufacturing where five companies account for 60% of income in 2015 (European GNSS Agency, 2017). Both studies on GNSS downstream activities suggest that road and location-based services are the applications that dominate the navigation market with respectively 50% and 43% of the total revenue over the period 2015-2025.

The global satellite communications market is the most important and mature segment of space applications, reaching 104.5 billion euros in 2017 (ESPI, 2018). It is made of two sub-segments: broadcast services (Direct-to-Home satellite television, radio) and broadband services (Internet access). Satellite television dominates the market even though it is experiencing stagnation in recent years. Satellite telecommunication operators revenues amounted $13 billion in 2015 (Fioraso et al., 2016). They are concentrated among few large historical players such as Intelsat, Eutelsat, SES and Inmarsat (OECD, 2014). The commercial telecommunications market is experiencing an important decline since 2015, with eight satellites orders in 2018 compared to twenty-five in 2014 partly due to the stagnation of the traditional telecommunications market and the rise of new market segments (Bondiou-Clergerie, 2019). Broadband is still at an early phase of development but is spurred by mega-constellation projects such as OneWeb, Starlink and Amazon's Kuiper.

2.2 Challenges in estimating the size of downstream space markets

The examination of the literature led us to identify some methodological difficulties in capturing the structural changes occurring within the space sector. As far as is known, there is currently no work that focuses exclusively on downstream space markets. The interest for such a study stems from the fact that downstream space dominates commercial space sector. In 2016, the global satellite services market was estimated at 230.8 billion dollars, or 67% of the overall space economy (Bryce Space & Technology, 2017c)

A major methodological challenge encountered in the studies relates to the proper definition of downstream space. The representation of the downstream space segment, and *a fortiori* the scope of actors considered, differs from one study to another. This makes it difficult to compare estimation results. Some reports adopt a shorter value chain representation in which downstream actors remain very close and linked to the upstream (Bryce Space & Technology, 2019a, 2018, 2017a, 2016; European GNSS Agency, 2017, 2015). Other studies, mostly impact evaluations, include a broader scope of players (PwC France, 2019; London Economics, 2019; Booz & Company, 2014; Oxford Economics, 2009).

The main issue encountered in the studies is the clear identification of the value chain downstream limit. To what level of exploitation of space data and/or signal is an organization considered as belonging to the downstream space segment? How can this level be measured? The evolution of the perimeter of downstream activities considered to estimate the size of the sector is in fact closely linked to the question of commercial uses of space and their fast development in New Space. Space-based products and services are expanding both in terms of volume and variety, as they are spreading to a wider scope of economic sectors. A direct consequence of this trend is the extension of the space sector's value chain: the creation of added value from space data involves a longer process of data and signal transformation and the potential recombination of space assets with other data sources. Therefore, some references considered in this paper underline that the identification of downstream players is challenging. It encompasses increasingly heterogeneous business segments and it may even include companies and organizations whose activities' portfolio is not entirely integrated into the traditional space value chain (ESPI, 2019).

Finally, the space value chain as presented in most the studies, in which space systems manufacturing and launch necessarily predate the economic exploitation, relies on the assumption that space technologies evolves independently of its application markets. The downstream sector mainly includes satellite services operators and suppliers of consumer ground equipment. These two players are closely linked to the upstream segment since they act as intermediaries of in-orbit activities and space-based terrestrial applications. However, restricting the downstream space sector to these actors suggests that the level of their activity evolves independently of market signals. We believe recent space programmes and technological innovations that occurred in the space sector can no longer be analyzed without taking into consideration the role of space application markets. Satellite miniaturization, mega-constellations projects, launch rates increase result from a growing demand for space-based services. The representation of the space sector in the context of New Space must necessarily include activities that use space data and signal, even to a lesser extent than satellite operators, since the same actors influence the configuration of the space value chain in the long run.

3 The New Space paradigm and service-oriented space activities

Over the past two decades, commercial space applications have been enjoying extensive growth. The fast development of space-based products and services is part of a more general transformation: the entry of new players - mostly arriving from the digital industry - introducing new business models where the economic value stems from downstream activities. This section aims at characterizing downstream applications by depicting the overall context in which they are conducted.

3.1 Characteristics of new space entrants

The fast spread of digital technologies occurring since the late 1990s has disrupted most of the economic and industrial sectors, lowering barriers to entry, increasing business dynamics and introducing new business models (Calvino and Criscuolo, 2019). The space sector is no exception to this trend. The move into the New Space era is associated with the progressive liberalization of space activities and the entry of new players for which the convergence between the digital industry and satellite technologies is a significant growth opportunity. These new entrants are of two types: already existing private companies - mostly coming from the ICT sector - and new space start-ups (ESPI, 2019). The first category of entrants consists mainly of large companies operating in information technologies, big data, or the Internet industry. They are embodied by entrepreneurs coming from Silicon Valley with substantial investment capacities due to their dominant market position in their core market area (Pasco, 2017). Although their core business is not *a priori* linked with space, these digital champions follow a diversification strategy and meet specific characteristics that may explain their incentive to invest in a high-tech, high risk and capital intensive industry such as space (European Commission, 2013). Most of them are high-tech multinationals with a highly skilled workforce, well established in their sector and generating significant revenues. These companies introduce an innovation culture based on an entrepreneurial logic, reinvesting a large share of their income to R&D activities for both technological and industrial improvements (Nardon, 2017). The economic growth of these firms is driven by the production, processing and dissemination of information. Satellite technologies, whose basic principle is to receive and transmit information (Lebeau, 2008), are a huge source of competitive advantage as they become one of the biggest providers of big data (Fioraso et al., 2016).

The second category of entrants is new space start-ups. From 2000 to 2018, more than two hundred space companies were created worldwide, corresponding to approximately twenty-two billion dollars invested in space start-ups (Bryce Space & Technology, 2019b). In the early 2000s, the number of new ventures created was steady and relatively low (around four new space ventures per year) but increased by 55% in 2009-2010. The substantial growth in the number of new entrants coincides with the first successful launch of SpaceX, the space manufacturer and launch services company belonging to the first category of new entrants defined above. The success story of SpaceX sent a positive signal to private U.S. investors. More generally, the first private entrants have democratized access to space and demonstrated the potential associated with its commercial exploitation. The second wave of new entrants subsequently benefited from this weakening of barriers to entry to space.

Another defining element of New Space, in line with the entry of private actors, is the use of new funding streams (Bryce Space & Technology, 2019b; ESPI, 2019; Fioraso et al., 2016). The demand for space systems came primarily from institutional organizations and public project owners and thus relied heavily on public funds (Lebeau, 2008). While this is still the case, particularly in Europe with over 60% of industry activity funded by institutional programs (Eurospace, 2020), the space sector is increasingly attracting private investors such as venture capitalists, private equity firms, angel investors, and commercial banks (Bryce Space & Technology, 2019b). Diversifying funding sources reflects private investors' confidence in the space sector's ability to generate returns and be highly profitable. This trend is not observable in all countries, as 80% of privately funded startups are located in the United States. However, it is gradually gaining ground in Europe (e.g., the United Kingdom) and other new space nations such as China.

The segment that benefits most from private capital is the upstream segment, with more than two-thirds of global investment (ESPI, 2019; Fioraso et al., 2016). This suggests that most new entrants are specialized in activities such as launch operations and satellite system manufacturing. However, this observation must be qualified. First, most existing studies on space markets indicate the existence of a statistical bias regarding the measurement of downstream activities and the difficulty of precisely identifying the companies that belong to this segment (ESPI, 2019; PwC France, 2019). This aspect will be discussed in more detail in the next sections of the paper. The second objection refers to an additional and perhaps more fundamental feature of New Space for our research area: the shift to vertical integration of space activities initiated by new entrants and the concentration of economic value in the downstream part of the space value chain (Robinson and Mazzucato, 2019; Nardon, 2017; Delponte et al., 2016; OECD, 2014).

3.2 The emergence of new business models

Before New Space, the prevailing industrial model was based on high technological complexity and long development cycles to ensure the reliability of space launch systems (Robinson and Mazzucato, 2019). As with large network infrastructures, the development costs of space technologies were massive and could only be supported by national governments (OECD, 2012; Lebeau, 2008). The production rate of space infrastructure was relatively low with around ten satellites and launch vehicles produced per year. The commercial launch services market operated on business-to-government and business-to-business models, where institutional and government acted as contractors to a handful of large manufacturers in a narrow oligopolistic position. New entrants intend to drastically reduce manufacturing costs by introducing new business models that transform the economic dynamics of the sector(Nardon, 2017).

The innovation strategy adopted in New Space encompasses three interrelated objectives: increasing the profitability of space activities, introducing new business models, and providing new space-based market solutions (ESPI, 2019; Fioraso et al., 2016). To achieve the first objective, the industry concentrates its innovation efforts to substantially diminish the development and production costs of launch and satellite infrastructures. This translates into the miniaturization of satellite platforms and payloads, the adoption of mass-production models with standardized components, and increased production rates. In addition, test and decision times are significantly reduced, generating a higher risk of failure that is now more equally shared between institutional and private investors.

These disruptive innovations[2] brought to the upstream sector are part of a broader shift in space companies' business models toward vertical integration. The big players that recently entered the sector are positioning themselves in downstream markets, creating close relationships with end-users to identify their needs and move up the value chain. New entrants tend to cover all activities, from satellite manufacturing to data processing to the supply of space-based products and services (ESPI, 2019; PwC France, 2019). The example of mega-constellations in the communication industry is quite striking. The Starlink satellite constellation project led by SpaceX seeks to launch around 12,000 small satellites into low Earth orbit to provide global Internet access. The company is involved in all project phases, from satellite development to launch on the Falcon 9 rocket and in-orbit operations. This case of extreme integration is not

[2]Disruptive innovation refers to a type of innovation that offers a new value proposition to the market (Christensen, 2013). It first appears to be less performant than existing technologies due to its newness and lack of refinement, and therefore only addresses a limited fringe of new consumers in the short run.

common to all New Space players. In the same segment, OneWeb relies on a less integrated business model. The company collaborates with incumbent firms, such as Airbus Defense and Space Intelligence for small satellites manufacturing and Arianespace for launch operations and constellation deployment. Two distinct economic models are emerging in New Space. On the one hand, a few large companies rapidly acquire technical know-how and adopt vertically integrated industrial models. On the other hand, new space ventures rely massively on the traditional manufacturing industry. The latter model often leads to partnerships between companies or mergers and acquisitions (e.g., Thales Alenia Space and Telespazio groups partnership with SpaceFlight Industries on BlackSky constellation).

A third feature characterizing the innovation strategy of New Space companies is the concentration of economic value at the end of the space value chain. The economic efficiency of the model mentioned above relies on the idea that increasing space systems production and launch rates necessarily lead to the disruption of existing markets and the creation of new mass markets (ESPI, 2019). Moreover, the development of space applications is not only driven by technological progress but also by potential users (Fioraso et al., 2016). This market-driven logic has at least two consequences for downstream activities. The first is the increasing heterogeneity of downstream space value chains and diversified space-based applications and services (Robinson and Mazzucato, 2019). New downstream markets related to the digital sector emerge such as global connectivity, geo-information systems, Internet of Things, and Machine to Machine networks. The second consequence is the extension of the space value chain to the end-user with the development of business-to-consumer services (Robinson and Mazzucato, 2019; Nardon, 2017). While space infrastructure becomes standardized, space-based services are increasingly customized and therefore diversified. The current growth of downstream activities reflects a shift towards a demand-pull paradigm supported by governments and institutions.

3.3 The role of public agencies in the development of downstream space markets

In addition to the entry of private players, the New Space dynamic is also driven by a transformation in the objectives of space agencies and institutional bodies (Pasco, 2017). The changing political context, the economic difficulties faced by space nations with the weakening of their industrial system in the 1990s, and the need to tighten public spending have forced agencies to legitimize government efforts for space. Until now, space programmes have been developed following a technology-push approach to address institutional policy needs. For that reason, government and institution bodies largely dominated upstream activities and their funding. This has led to the emergence of spacefaring nations with efficient and competitive space infrastructures (launchers, Earth observation satellites, etc.) used to strengthen their sovereignty. However, the link between the space industry and potential space civilian applications was weak for at least two reasons. First, the needs of non-space users were not sufficiently taken into account in the upstream. Second, technology barriers were so high that downstream players needed a certain level of knowledge to access, use and exploit satellite data (Secara and Bruston, 2016). In this context, the legitimacy of public-funded space activities was questioned, as was the ability of space technologies to address economic challenges.

Space programmes, considering these aspects, have been developed with the imperative to address civilian concerns and needs (Sartorius, 2012; Lebeau, 2008). Policy briefs from institutions (e.g. (European Commission, 2013)) and policy reports commissioned by space agencies, governments, or institutions (e.g. PwC France (2019); Fioraso et al. (2016); ESA (2016)) promote the idea that public actors should encourage the development of downstream space applications. These are described as being able to provide rapid and efficient solutions to problems of public interest such as enhanced climate change monitoring, services for mobility, urban surveillance, borders monitoring. In addition, countries that were not initially involved in space affairs (e.g., the UK, Australia, India) decided to invest in space, expecting significant leverage for economic, societal development and employment (Bryce Space & Technology, 2017b; Fioraso et al., 2016; Oxford Economics, 2009). From the 1960s to the late 2000s, the number of countries with at least one registered satellite in orbit has steadily increased. Over the past decade, this trend has accelerated. Eighty-two countries had at least one satellite in orbit in 2018, up from fifty in 2008 (OECD, 2019).

4 Toward a demand-pull model in the space sector

Thus far, we have identified trends that suggest a paradigm shift in the way technological and industrial activities are pursued. We assume that since New Space, the space sector is moving toward a demand-pull model. Technological advances, as well as industrial processes, are increasingly driven by market signals. To our knowledge, this change of paradigm in the space sector has not yet been observed. Our aim is to provide arguments in favor of this vision.

Existing literature on the subject affirms that the space industry has been a demand-driven industry from its inception (Barbaroux, 2016; Barbaroux and dos Santos Paulino, 2013). Space technologies and applications emerged in the post-1945 period during which governments made massive investments in military R&D (Mowery, 2010). At that time, it is true that space assets were developed in mission-oriented R&D programmes and were primarily motivated by defense purposes and political prestige (Robinson and Mazzucato, 2019). States and defense organizations were prime investors and purchasers, shaping space technologies with well-defined technical requirements and supervising the industry (Heracleous et al., 2019).

However, we believe that a change has occurred between the early stages of development of space activities and New Space and that the latter period better describes the demand-pull paradigm as defined in the literature. This theory analyses the causal relationship between economic growth and innovation activities. Space technologies first evolved independently of market constraints, with a single buyer, the State, controlling the entire value chain of a few sellers. Economic considerations, such as productivity gains due to the introduction of the new technology, entered into account only when space infrastructures opened to civil use in the form of indirect benefits (Mowery, 2010).

We presume that the transition towards a demand-pull model historically corresponds to the end of the Cold War and has been confirmed by the first achievements of big private players. In the first stage of space liberalization in the late 1980s, public authorities intended to convert space resources formerly used for military purposes into economic assets. This resulted in the rapid growth of the satellite telecommunications sector. However, it is the convergence with the Internet economy that has challenged the prevailing industry models. Space industry no longer evolves independently of sectors of activity; digital entrepreneurs perceive and exploit it as an economic asset, a technological instrument to develop their activity such as information systems. In this demand-pull vision, value creation in the space sector does no longer rely on the technology itself, but on the commercial goods and services produced from the technology.

In the market-pull approach, technological progress is not an exogenous variable but is shaped by economic factors and changes in market conditions (Schmookler, 2013; Rosenberg, 1974). In this respect, market signals, i.e., changing demand characteristics, are determinant factors of innovation. The recent innovative activities within the space sector focus on three areas: launchers, satellite miniaturization, and electric propulsion of satellites[3]. Faced with aggressive competition from new models of low-orbit constellations of small satellites, the traditional market for geostationary telecommunications satellites is in decline. To boost sales and withstand the downward pressure on prices

[3]These advances can be described as incremental innovations in that they did not lead to the disruption of the technological trajectory of the space sector.

for access to space, the Franco-Italian manufacturer Thales Alenia Space is launching in 2023 the "Space Inspire" line of digital, in-flight reconfigurable geostationary satellites[4]. This technological innovation enables commercial operators to change the service provided by the satellite directly in orbit and thus adapt to shifts in demand. For instance, a satellite dedicated to direct-to-home television (a shrinking market) could be reconfigured into a broadband connectivity satellite (a fast-growing market). The case of reconfigurable satellites illustrates the innovation model that is currently prevailing in the space sector. Technical progress is the result of adaptation to growing downstream markets.

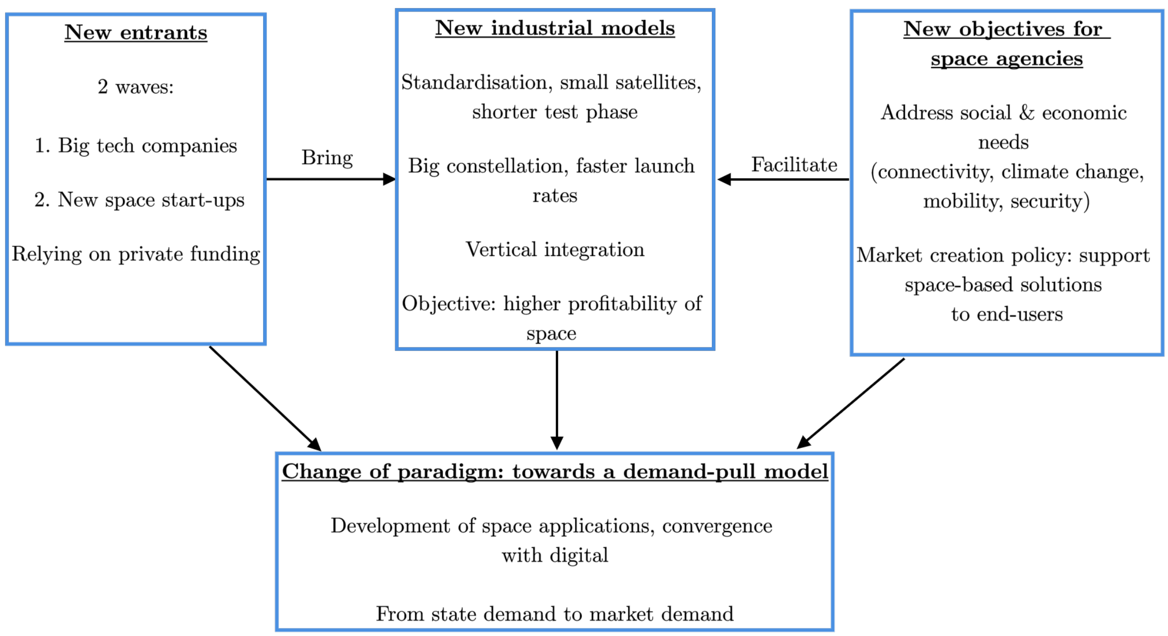

Figure 1: New Space paradigm

In this section, we attempted to identify and articulate contextual elements that may explain why the current transformation of the space sectors is associated with a market-driven model of growth, and ultimately, to the expansion of downstream space activities. Figure 1 summarizes our analysis.

The digital transformation undergoing in a wide range of high technology sectors, the space sector included, leads to the transfer of the economic value from technological assets such as space infrastructures and systems to intangible assets such as satellite data and space-based services. In this context, the measure of the downstream space segment, which encompasses activities of space-based products and services development, is of particular importance.

[4]Thales Alenia Space is also active in the low-orbit constellations market, notably with BlackSky, Iridium NEXT, Kinéis, and Omnispace projects.

5 Concluding remarks

This paper aimed to analyze the ongoing structural shift in the space sector and to highlight the importance of downstream space activities in this context.

Existing evaluation reports commissioned by institutions or space trade associations have several limitations when estimating the size of downstream space. First, this set of activities is poorly covered in the existing literature even though it generates the largest share of commercial space revenues and is expanding rapidly. Secondly, studies have difficulty defining a downstream value chain that integrates the evolution of this segment of activity and the growth of space-related services. More importantly, the variety of methodological tools used and the differences in estimation results reveal a lack of theoretical reflection before any statistical evaluation. To our knowledge, there is no conceptual framework on which to rely for understanding and measuring the recent evolution of commercial space activities.

We have defined New Space as a transition phase of the space sector characterized by convergence with the digital sector, the creation of private-funded space start-ups, and, more generally, expanded access to space for service-oriented commercial purposes. These trends are disrupting the way space activities were conducted in the previous phases of development of the sector. We assumed that they reflect a paradigm shift, in which space activities are increasingly spurred by market demand emanating from end-users.

To conclude, we suggest considering the evolution of commercial space activities from a dynamic perspective. More specifically, we assume that the industrial shift in the space sector is closely linked to an evolution in the nature of space data. Downstream space activities consist basically of using satellite data to generate value-added services and equipment to end-users. The incursion of the digital sector into the space sector has changed the dynamics of satellite data production and use. Commercial satellite launches are ramping up, pointing out an evolution in the demand for large volume, fast frequency, easier and real-time access to data. As data flows increase, downstream players adopt digital technologies such as AI and cloud computing to facilitate mass data collection and processing. Another evolution regarding space data in New Space is the trend, admittedly marginal and limited but observable, towards open data. In navigation, satellite positioning systems developed by States are based on the principle of open access to signals and free exploitation. In Earth observation, several platforms of institutional and, to a lesser extent, private initiatives have been developed. They offer free or low-cost access to satellite images to all potential users. A rather telling example in Europe is the Copernicus Open Access Hub of the European Union's Earth observation programme. It includes a set of platforms providing free access to Sentinel images, but also to more sophisticated services and indicators for land, sea, and climate monitoring.

Besides, data are by nature non-rival goods: they can be consumed at the same time and as many times as desired without being diminished (Jones and Tonetti, 2020; Romer, 1990). In the case of the space sector, once EO satellites are in orbit and the first set of images is created, it can be used simultaneously by several downstream companies and duplicated with zero or almost zero additional cost. These fundamental attributes of data, which make them akin to public goods if considered imperfectly appropriable, differentiate them from conventional physical goods. They imply that data are a source of considerable economic value, but make the assessment of this value complex. For instance, a given Earth observation image may be perceived as having little utility at a certain time but may have a considerable value afterward when a natural disaster occurs. Similarly, space data can gain or lose value depending on its combination with other data sources, such as end-user data.

This last feature has several implications in terms of economic and space policy. It highlights the increasing importance of downstream commercial services in the growth of the space sector. Developing evaluation tools will help in understanding that commercial space is a major economic interest for states. The convergence with the digital sector reinforces this interest. In addition, space actors must take into consideration the interaction of the space sector with other sectors. Space activities are diffused not only through technology transfer but although through the use of data. Finally, the open access to satellite data initiated by institutions challenges existing industrial models. A large part of the revenues of commercial satellite operators depends on the sale of images. The trend towards open access to satellite data, if confirmed, suggests a shift in the value from data production to the commercial services that integrate this data.

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