The impact of digital technologies on business models. Insights from the space industry

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Abstract

Purpose – *In the past decade, in the space industry, many initiatives intended at offering open access to big data from space multiplied. Therefore, firms started adopting business models (BMs) which lever on digital technologies (e.g. cloud computing, high-performance computing and artificial intelligence), to seize these opportunities. Within this scenario, this article aims at answering the following research question: which digital technologies do impact which components the BM is made of?*

Design/methodology/approach – *An exploratory multiple case study approach was used. Three cases operating in the space industry that lever on digital technologies to implement their business were analyzed. Despite concerns regarding reliability and validity, multiple case studies allow greater understanding of causality, and show superiority respect to quantitative studies for theory building.*

Findings – *Big data, system integration (artificial intelligence, high-performance computing) and cloud computing seem to be pivotal in the space industry. It emerges that digital technologies involve all the different areas and components of the BM.*

Originality/value – *This paper sheds light on the impact that digital technologies have on the different BM components. It is only understanding which technologies can support the value proposition, which technologies make the infrastructural part able to support this proposition, which technologies may be helpful for delivering and communicating this value to customers and which technologies may help firms to appropriate the value that it is possible to seize the impact of digital technologies on BM.*

Keywords *Artificial intelligence, High-performance computing, Cloud computing, Big data, European Space Agency, Copernicus Programme, Case study*

Paper type *Research paper*

1. Introduction

In the past decade, the space industry has seen the multiplication of initiatives offering open access to big data from space and hence the possibility for firms to exploit the huge quantity of data made available at an ever increasing rate. This is, for instance, the case of downloaded data from Earth Observation (EO) satellites that in the past were mainly sold to service providers, which on their turn made a profit by selling them to end-users such as, for instance, consultant companies, cost guards and fisheries. Indeed, since 2014, the Copernicus Programme, with over 12 terabytes of EO data generated daily (the third largest data provider globally), has established a full, free and open data policy which allows anyone anywhere in the world to access and use the data and geo-spatial information.

The Copernicus Programme is the European Union’s EO programme coordinated and managed by the European Commission in partnership with the European Space Agency (ESA), the EU member states and EU agencies, aiming at providing world monitoring for use by governments and private firms. Through the Copernicus Programme, ESA started what can be defined a “sensing revolution” which, while allowing the development of an

Received 1 December 2020
Revised 30 December 2020
Accepted 10 February 2021

ever-increasing number of downstream services, offers firms opportunities for competing in new ways.

To fully grasp these opportunities connected with these very large amount of data, digital technologies – also known as 4.0 technologies – such as cloud computing, high-performance computing (HPC) and artificial intelligence (AI), play a pivotal role: by "pushing the frontier of what machines are capable of doing to unlock the secrets of space data" (NSR, 2019), digital technologies allow firms to reconsider their business models (BMs) (Foss and Saebi, 2017) to fully tap into the opportunities opened by the new scenario.

Building on the fact that, whatever its theoretical conceptualization (Rayna and Striukova, 2016; Osterwalder and Pigneur, 2010), a BM is to be interpreted as made up of different components (Foss and Saebi, 2017) aiming at creating, delivering and capturing value (Teece, 2010; Bocken *et al.*, 2014; Chesbrough, 2007; Saebi *et al.*, 2016; Müller *et al.*, 2018), the point is: which digital technologies do impact which components the BM is made of? More exactly, given that recurring components in the BM frameworks put forward in the scientific literature are the value proposition, the customer segments, the infrastructure resources/activities/partners required for realizing the value proposition and the financial structure (Chesbrough and Rosenbloom, 2002; Morris *et al.*, 2005; Osterwalder and Pigneur, 2010), which digital technologies do impact each of these constituting elements?

Indeed, understanding the impact of a set of digital technologies on the different BM components is important because of two main reasons. First, the experiences and the practices which characterize a high-technology environment such as the Space Industry, where firms are at the forefront of edge technologies, could be inspirational for firms operating in more traditional industries. These firms indeed can be inspired by possible uses, application and potentialities of digital technologies. Second, understanding the impact of a set of digital technologies on the different BM allows achieving a comprehensive picture of the overall reach of a set of digital technologies on BM, this way overcoming the limit of an analysis which investigates them separately. This, on its turn, and from a theoretical point of view, represents a first step for further analyses aiming at investigating, on the one hand, the "mix" and "balance" of digital technologies that best improve BM performance, and, on the other hand, if it is possible to identifying a developmental path of digital technologies that best impact BM's performance in terms of competitiveness and sustainability.

To achieve this purpose, we propose an explorative methodological approach based on multiple case studies in the space industry, where, as anticipated, digital technologies are deeply impacting the constituents of business models.

The article is structured as follows. Section 2 presents a general overview of the space industry, the literature on BM and digital technologies; Section 3 outlines the methodology, whereas the Section 4 puts forward the results. Sections 5 and 6 present the discussion and the conclusions.

2. Theoretical background

2.1 Business models

BM is a concept of high importance on business practices, strategic management and economics (Carayannis *et al.*, 2015), that is increasingly gaining attention from both practitioners and scholars (Schneider and Spieth, 2013; Spieth *et al.*, 2014; Zott and Amit, 2010).

The BM concept started gaining popularity during the internet boom of the late 90s. Originally, the BM concept was used to communicate complex business ideas to potential investors within a short period of time (Zott and Amit, 2010). Since then, a broad research activity has been developed and the BM concept has been analysed according to different perspectives. Three main perspectives indeed can be pointed out: the strategic perspective, the activity-based perspective and the architectural perspective which deals with the architecture of the mechanisms and components that are to be leveraged to create value.

According to a strategic perspective, some researchers suggest that BM has become a tool to systematically analyze, plan and communicate strategic choices (Lambert and Davidson, 2013). Others point out that the BM is increasingly seen as a strategic asset for competitive advantage and firm performance (Chesbrough, 2007).

According to an activity-based perspective, a company's BM is defined as a system of interconnected and interdependent activities that determines the way the company does business with its customers, vendors and other partners (Amit and Zott, 2012). In a similar vein, Wirtz *et al.* (2016) define the BM concept in an integrated manner, i.e. "a simplified and aggregated representation of the relevant activities of a company".

A third perspective can be connected to the stream of the literature that focuses on the architecture of the firm's mechanisms for creating, delivering and capturing value (Teece, 2010). According to this perspective, Foss and Saebi (2017) suggest that the "mechanisms for creating, delivering, and capturing value reflect BM components". This introduces to that part of the literature which aims at identifying BM components and at providing an overview of them (Zott and Amit, 2010; Lambert and Davidson, 2013). Among others, Demil and Lecocq (2010) suggest that BMs can be described according to three main components: resources and competencies, organizational structure and proposals for value delivery. Johnson *et al.* (2008) believe that a successful BM should have four interlocking components: a customer value proposition, a profit formula, as well as key resources and processes. Osterwalder and Pigneur (2010) put forward four areas, each encompassing different components, as named in brackets: offer (value proposition), customers (customer segments, customer relationship and channels), infrastructure (key resources, key activities and key partners) and financial viability (revenue stream and cost structure). These authors propose that BM includes both the main elements of a firm's activity and their integration. A BM can, hence, be described as a configuration of interdependent BM components.

Despite differences between the proposed components of which the BM is made of, the more frequently mentioned BM components in the literature (Abdelkafi *et al.*, 2013) are value creation (known as the mechanism by which goods and services acquire value that can then be captured and shared), value proposition (known as the mechanism through which the value created is offered to the market), value capture (known as the ability of a firm to benefit from the value created, including the revenue model used to generate cash flow as well as the cost structure), value delivery (which describes how the value created is delivered to customers through distribution channels) and value communication (referred to how companies communicate with customers and partners about their products and the value they create). Following that line, scholars commonly accept that value proposition, defined by Osterwalder and Pigneur (2010) as "the bundle of products and services that create value for a specific customer segment" (p. 22), stands at the core of the BM framework. Thus, aspects such as value creation, delivery, capture and communication emerge from the value proposition (Abdelkafi *et al.*, 2013).

This third perspective seems particularly interesting because it is suitable to fully grasp the potential digital technologies offer and hence put in evidence the fundamental link existing between business models and technologies. It is only by understanding which technologies can support the value proposition offered to the market, which technologies make the infrastructural part able to support this proposition, which technologies may be helpful for delivering and communicating this value to customers and which technologies may help firms to appropriate the value that we have the full picture of the impact of a bundle of digital technologies on BM. In addition, it is very important to assume a more comprehensive approach which enlarges to encompass a set of digital technologies. Indeed, not only very seldom a given technology operates in isolation from other technologies to create, deliver and capture value, but also the issue of interoperability between technologies is becoming more intense, dynamic and uncertain, because of the arrival of sophisticated information technologies (Baden-Fuller and Haefliger, 2013).

In the following, we present a list of digital technologies which may impact the different components of the BM.

2.2 Space industry

For decades, the space industry activities have been driven by governmental needs and priorities, with private industries acting as contractors for public programs and massively relying on public funding coming from the European/National Space Agencies, National Governments and the European Union. The goals of space activities were mainly driven by scientific needs and not by service-oriented commercial interests (with the exception of the Telecommunications sector).

Until the early 2000s, the space industry did not present the proper conditions in which private actors could invest and create added value for a series of reasons. First, space activities mainly addressed public institutions, governments and service providers which indeed were the most important customers, making the market a kind of "governmental monopsony" (a single or dominant buyer dealing with multiple sellers) (Smyrlakis *et al.*, 2011). Second, because of the long time needed to contract, procure and deliver (Sheffer *et al.*, 2000), space business was too expensive for new incumbents. Third, space was a niche market where actors, while operating as isolated entities, were unable to exploit the potential of an harmonized network of relationships. Finally, while dividing the space value chain into the upstream segment (i.e. business activities/infrastructures related to the development, production, deployment and operation of space systems) and the downstream segment (i.e. exploitation of space systems' capabilities and data analysis to deliver space-enabled products and services to end-users), the core competencies across the entire sector were mainly based on upstream activities, not featuring yet the growth of downstream utility of Space technologies and services.

These characteristics were particularly visible in the EO's upstream satellite imagery market where government space agencies were historically the only prominent players providing images from their satellites. And still today government agencies such as ESA are providing free satellite imagery data through the Copernicus Programme.

However, the past two decades have seen the privatization of space applications (Vecchi and Brennan, 2015) in countries such as the USA, China and Europe, with private firms playing an important role in developing EO services. This has enabled the development of a large downstream market which yields more commercial results because of its wide variety of applications for various industrial verticals such as agriculture, disaster management, weather forecasting and national security. All this translated into BM configurations connected with data licensing and data selling.

Today the new space paradigm and in particular the use of EO satellite imageries to extract meaningful data and develop tailored services is favoring the introduction of new BM types.

2.3 4.0 Technologies and business models

The relationship between technology and BMs is widely recognized in the literature (Baden-Fuller and Haefliger, 2013): technology development can facilitate new business models. In such perspective, Industry 4.0 (I4.0) is widely considered as a new industrial phase in which emerging 4.0 technologies are integrated to provide digital solutions to traditional and novel business issues. Similarly, Space 4.0 reflects the concept of Industry 4.0 in space industry (Beer) where it remarks such revolution in space activities, enhancing the participation of a huge number of actors, from governments to private investors. Definitely, 4.0 technologies are recognized to allow cheaper and faster access to space, even for smaller nations and developing countries or players (Bohlmann and Petrovici, 2019). Indeed, the development of small satellites and the recent advancements resulting from Industry 4.0 paradigm have enabled more nations and business players to grasp the new opportunities of space business.

As Industry 4.0, Space 4.0 makes use of contemporary information, automation, manufacturing technologies and big data to inspire innovation of business activities. In doing so, new BMs can emerge exploiting technological advancements such as smart integrated services and digital technologies. Literature shows that a large number of both consolidated and emerging technologies are adopted for implementing Industry and Space 4.0 paradigms.

AI and 3D printing are just two examples that currently find their use on board the International Space Station (ISS). Not only is a 3D printer installed on the ISS, where it is used for scientific experiment (Bohlmann and Petrovici, 2019; ESA, 2018a), but ESA has also considered using 3D printing technology in the frame of the Moon Village (Bohlmann and Petrovici, 2019; ESA, 2018b).

In this context, authors have suggested different frameworks and classification models trying to systematize such technologies. However, the picture of the Industry/Space 4.0 technological foundation is still partial and not fully exhaustive (Frank *et al.*, 2019). Indeed, 4.0 paradigm includes a huge amount of specific and very heterogeneous technologies, for example, cyber-physical system (CPS), Internet of Things (IoT), cloud computing and blockchain systems, for information integration (see for instance, Wang *et al.*, 2016; Jeschke *et al.*, 2017; Lee *et al.*, 2015; Gilchrist, 2016). Here in the following, we report 4.0 technologies that are particularly significant for space business, accordingly to the nine technology pillars considered as building blocks of I4.0 (BCG report, 2015).

- *Big data and analytics* are based on large data sets and are emerging in the both manufacturing (Wang *et al.*, 2016) and service operations, also in the space context, to enable optimization of service/product quality, energy saving and service level. The collection and comprehensive evaluation of data from many different sources – geo-spatial data, environmental data as well as enterprise data – can enable a huge potential to support decision-making and drive the development of new business models in space business.
- *Autonomous robots* can enable building innovative cyber-physical system and support space operations to tackle complex assignments in more autonomous, flexible and cooperative ways (Wang *et al.*, 2015). Also, robots can interact with one another and work safely side by side with humans and learn from them.
- *Simulation* of service, products, materials and production processes is already used in manufacturing and business simulation; nevertheless, in 4.0 paradigm, they can leverage data availability and system integration to support real-time decision-making also in space cyber-physical system, which includes machines, products and humans (Jeschke *et al.*, 2017). This might allow machine and operators to test and optimize choices in terms of operation setting to setup times and increasing safety and service quality.
- *Horizontal and vertical system integration* refers to IT systems integration of departments, functions and capabilities within and outside the company borders (Jeschke *et al.*, 2017; Gilchrist, 2016), as a cohesive cross-company effort to provide universal data-integration networks and enable automated value chains (Angeles, 2009). Santos *et al.* (2017) affirm that this revolution is characterized by AI. Indeed, AI

has a central role in realizing system integration and enabling effective cyber-physical systems, connecting automation and communication technologies to achieve high levels of performance, reliability, efficiency and robustness (Goossens and Richard, 2017). Such integration can include also space system and the related operations.

- *Industrial Internet of Things* includes networked sensors, actuators, programmable logic controller, machines with increasing embedded computing and intelligence, typically connected and able to communicate and interact with each other and with centralized controllers (Jeschke *et al.*, 2017; Lee *et al.*, 2015; Gilchrist, 2016). Such decentralized paradigm for system analytics and decision-making can dramatically affect the decision-making processes, thus inspiring new business models also in the space industry.
- *Cybersecurity*, the increased connectivity which characterizes I4.0 paradigm, boosts the need to protect critical industrial systems from cybersecurity threats. In the space industry, secure and reliable communications, as well as sophisticated identity and access management of machines and users, were already critical. However, increasing the number of connected systems, devices and business players makes such requirements become essential and opens new challenges to companies, governments and space agencies (cyber security and space-based services | ESA Business Applications; Manulis *et al.*, 2020).
- *The cloud* technologies have extremely improved their performance, achieving reaction times of just several milliseconds and enabling more data-driven services for production systems, as well as monitor and control processes (Zheng *et al.*, 2014; Mourtzis and Vlachou, 2016). In the space industry, where a huge amount of geo-spatial data becomes available and can be integrated across sites and company boundaries with other sources, such technologies can enable new services and value propositions.
- *Additive manufacturing*, such as 3D printing, can be used to prototype and produce individual components or to produce small batches of customized products, reducing transport distances and stock on hand (Weller *et al.*, 2015; D'Aveni, 2015). This also applies to specific optimization needs of space companies and missions.
- *Augmented reality*-based systems support a variety of services, such as selecting parts in a warehouse and sending instructions (by mobile device, or augmented-reality glasses) which can provide people with real-time information to improve decision-making and work procedures also in space activities (Elia *et al.*, 2016; Gorecky *et al.*, 2017). Another application is virtual training that is already largely used in space to provide a realistic, data-based 3-D environment, and also to interact with machines, operators and retrieve operational data.

Despite the potential of such technologies for inspiring and driving business innovation in the space activities is widely accepted and recognized from both scholars and practitioners, very little is known about how digital technologies can impact the different components of the BM. Based on these premises, considering the paucity of research on the role of a set of digital technologies supporting BM in the space industry, the aim of this article is to empirically explore the technological component(s) of BM.

3. Methodology

According to an exploratory multiple case study approach, we analyzed three cases operating in the space industry and that lever on digital technologies to implement their business. Although, according to Ginsberg and Abrahamson (1991) and Yin (2003), we are aware of the reliability and validity limitations connected with case studies, we relied on them not only because they provide the possibility of illuminating specific factors which may allow greater understanding of causality (McClintock *et al.*, 1979), but also because of their superiority with respect to quantitative studies in terms of theory building (theoretical generalization and falsification) and theory testing.

Despite the impossibility to develop a new theory from three case studies, theoretical implications for further development can be generated (Tsang, 2014), as in the Discussion section.

According to Barczak (2015), six steps were developed to conduct the three case studies: case selection and identification of the unit of analysis, definition of the reference research framework, data collection, elaboration and analysis.

As regards case selection and the identification of the unit of analysis, case sampling was performed theoretically (Eisenhardt, 1989): as case studies, we selected three small firms – A, B and C – operating in the space industry, which use digital technologies for doing business (their main characteristics are reported in Table 1). BM was identified as unit of analysis.

As regards the definition of the reference research framework, to conduct interviews, we specified the potentially important variables at play, but, according to our exploratory aim, we strived to maintain a neutral position, hence avoiding thinking about specific relationships between the variables.

Specifically, we addressed the BM components and the digital technologies which could impact them. As far as the BM, we built on Osterwalder and Pigneur's (2010) BM canvas with its four areas, each encompassing a number of components: offer (value proposition), customers (customer segments, customer relationship and channels), infrastructure (key resources, key activities and key partners) and financial viability (revenue stream and cost structure). Within the plethora of possible BM frameworks (see above), the high knowledgeability of Osterwalder and Pigneur's (2010) BM within firms (as we could verify ourselves) allowed sharing with interviewees a common language, so limiting possible biases or misunderstandings with them.

As far as digital technologies, we asked the firms which digital technologies have affected each BM component.

Data, collected in a four-month period, included several primary and secondary information sources (Eisenhardt, 1989) to improve information validity and reliability and better substantiate the relationships among variables.

As regards primary sources, we carried out six face-to-face semi-structured interviews, whose duration ranged from 45 to 120 min (Table 2).

During the interviews, we used a protocol made up of semi-open questions based on the BM conceptualization put forward by Osterwalder and Pigneur (2010). Specifically, questions were articulated according to the four areas of the BM, to investigate which digital technologies affected them. The use of semi-open questions allowed gathering all the necessary data, at the same time leaving interviewees the opportunity to enrich the context description and to enlarge the set of variables investigated.

We also relied on secondary sources, both internal and external. As regards internal sources, before the interviews were conducted, we analyzed the firms' websites. Firm B also provided slides presented at international conferences and company presentations.

Table 1 Main characteristics of the firms

Firm	*Founded*	*Country*	*Size (n. employees)*	*Industry*	*Funding*	*Type*
A	2014	IT	~10, spin-off and start-up	Computer hardware (mainly aerospace)	Private and Public	Privately held
B	1994	IT	~50, SME	Defense and space	Private and public	Privately held
C	2008	SL	~65, start-up	Computer software (mainly aerospace)	Private and public	Privately held

Table 2 Interviews – number, duration and interviewees				
		Interview 1	*Interview 2*	*Interview 3*
Firm A	Duration	90	60	60
	Interviewee	Chief Executive Officer (CEO)	Space Business Manager	Senior Advisor
Firm B	Duration	120	60	–
	Interviewee	Chief Executive Officer (CEO)	Chief Marketing Officer (CMO) and Head of Design Lab	–
Firm C	Duration	120	45	–
	Interviewee	General Manager	General Manager	

As regards secondary external sources, we used the following repositories to find articles and news about the firms (Table 3):

- the Nexis Uni® database (only newspapers and Web-based publications section narrowed by "Defense & Aerospace");
- GEOmedia database; and
- GIM international magazine[1].

As regards data elaboration, two or three researchers were present during all the interviews that were recorded and transcribed my means of a software tool (Dragon Professional v.15). Collaboration among researchers allowed achieving consensus for interpreting data.

We elaborated all the gathered information – both from primary and internal/external secondary sources – with data categorization. Categories/variables in terms of BM components and digital technologies were used (Campbell, 1975). Firms were newly contacted in case of unclear or incomplete information.

As regards data elaboration, we carried out a within-case and a cross-case analysis to generate the necessary insights to answer the research question.

As regards the within-case analysis, for each case, considered as a stand-alone entity, we codified the transcribed interviews and the documents through the analysis of the text with the aim of analyzing how digital technologies have been used in each of the nine components of the Osterwalder and Pigneur's (2010) model. To facilitate the emergence of evidences from the cases, we used Osterwalder and Pigneur's (2010) BM canvas as scheme. A couple of tools were implemented to improve the confidence on our findings. On the one hand, by building a widely known tool as the BM canvas is, we prevented possible misunderstandings or misrepresentations that instead can arise when the interviewers and the interviewees do not share the same meaning of the investigated variables. On the other hand, we shared with the CEOs/General Managers the within-case analysis results to have their follow-up review and amend possible biases.

Table 3 Secondary external sources			
	Nexis Uni	*Geo media[1]*	*GIM international magazine*
Firm A	8	–	–
Firm B	5	5	6
Firm C	8	–	3

Notes: [1]Geo media is the reference Italian magazine for advanced technologies in the field of geographic information, land and satellite navigation systems for the new smart geography and information technology. Published bi-monthly in Italy since 1996, and has the main objective in the dissemination at the reasonable level of information produced by scientific and academic research for the specific applications in the fields of the environment, territory and culture

Afterwards, a cross-case analysis was carried out for comparing how digital technologies impacted the different BM components in the three different case-studies. Specifically, we looked for within-group similarities coupled with intergroup differences, with the aim of generalizing patterns across cases, according to a replication logic (Eisenhardt, 1989).

4. Results and discussion

4.1 Firm A

Firm A is a small and medium enterprise specialized in intellectual property (IP) cores, test equipment and design services for various sectors such as aerospace field, telemedicine gateways and services for healthcare field, and automotive. Firm A's business is divided in two main categories: products and services. Products are divided into electrical ground support equipment (EGSE) and IP cores:

- (*A.i*) EGSEs;
- (*A.ii*) products related to testing;
- (*A.iii*) products related to flight area; and
- (*A.iv*) IP cores.

As for the services, Firm A follows specialized projects to cater to the need and detailed specification of the different customers, mainly field-programmable gate array designs and HW/SW-embedded solutions. Another service of Firm A regards the application of AI to hyperspectral and thermal sensing from space.

Firm A's BM is strongly impacted by AI. Indeed, Firm A designs electronic systems endowed with AI algorithms which can work on board of satellites for selecting images directly on board, so optimizing resources. This computational use of AI, mainly intended to ESA, is supported by CEO's words:

> to improve the quality of downlinked data. Such algorithms are tuned/trained on ground using reference satellite data (from Copernicus for example) with the final ambitious goal to implement them on board and provide high quality data directly from the satellite.

For being at the forefront of AI technologies, Firm A, on the one hand, taps into digital technological knowledge of both universities' (by means of project collaborations and contracts with academics) and ESA Labs, and, on the other, trains its personnel on AI algorithms. This activity is simplified because of the possibility to build on human resources who are well prepared on digital technologies. In the CEO's words:

> being spin-off of University is key to get access and attract the most promising talents. With a strong tutorship since the beginning they grow very fast and give an important contribution to the value creation of the company. They bring also a very modern mentality as they are grown in the era of digital transformation.

The participation to a pilot project funded by ESA, intended to provide an in-orbit demonstration of AI algorithms on a CubeSat, and workshops/conferences organized by ESA on AI have been used to strengthen the relationship with ESA.

Figure 1 depicts which 4.0 technologies have been used for which BM components of Firm A.

4.2 Firm B

Firm B provides solutions to exploit the value of geo-spatial data through all phases of data life cycle from acquisition, storage, management up to analysis and sharing.

Figure 1 4.0 Technologies used in Firm A's BM

			4.0 technologies	
			Big data and analytics	System integration (Artificial Intelligence)
Areas	Offer	Value proposition	Selection of images from Copernicus by means of AI	
	Customer	Customer segments		
		Channels		
		Customer Relationship		- Workshops and Conferences on AI - Pilot Projects for in-orbit demonstration of AI algorithms on a CubeSat
	Infrastructure	Key Resources	Copernicus Data	- AI algorithms - AI expertise of HR
		Key Activities		- Design of innovative AI algorithms - Training on AI Space applications
		Key Partners	ESA providing large data by means of the Copernicus Programme	Partners providing digital technological knowledge (ESA Labs and Universities)
	Financial viability	Cost Structure	Copernicus Programme has also led the initiative of allowing EO data to be free and easily accessible to any	
		Revenue Stream		

The company operates in many application areas ranging from environmental and land monitoring to open-government and smart cities, and including defence and security, as well as space exploration and EO satellite missions.

Firm C's main activity areas are:

- (*B.i*) satellite, aerial and drone data processing for cartography and geo-information production;
- (*B.ii*) continuous monitoring with satellite data of Earth's surface, infrastructures, work sites, urban dynamics or marine coastal areas in support of decision-making and operational activities;
- (*B.iii*) design and development of spatial data infrastructures for geo-spatial data archive, management and sharing;
- (*B.iv*) design and development of real-time geo-location-based solutions, through positioning; and
- (*B.v*) development of software for the satellite on-board data and image processing and for ground segment infrastructures.

Firm B levers on the cloud, big data and analytics to provide its customers (firms in the transportation/oil & gas industries and public administrations) with geo-analytics as info-as-a-service software that is scalable in both time and space (value proposition). Indeed, customers are offered ready-to-use knowledge obtained by joining together many diverse data sources (e.g. social media, satellite imagery, mobile phone telemetry and weather sensors) into a single, unified model able to expose the relationships between apparently unrelated data elements.

Cloud technology offers the customers the possibility not only to continuously access knowledge, but also to adapt their cost structure, shifting from an investment in an on-premise software to an operating cost for subscriptions to info-as-a-service. Conversely, for Firm B, this shift impacted its revenue stream: from software sales to revenues from service subscriptions.

A set of digital technologies is used to keep costs affordable: on the one hand, the big data, i.e. the large volume of EO daily data, unleashed for free by ESA through the Copernicus Programme, and, on the other hand, the cloud computing that allows distributing scalable software-based services to customers via a single server, the HPC and the AI. Specifically, info-as-a-service, as one of the main applications of cloud computing, is used by Firm B to distribute software-based services to customers via a single server, owned by an external partner. In fact, concentrating the provision of software on a dedicated server saves time and money, and helps addressing the problems of scalability. AI, used with a computational intent, is pivotal to automatize directly on board of satellites the interpretation of satellites images, avoiding to transmit unnecessary data.

Figure 2 depicts which 4.0 technologies have been used for which BM components of Firm B.

4.3 Firm C

Firm C develops advanced geo-spatial information systems products and services based on Web technology operating in various markets such as agriculture and real estate. Firm C’s solutions consist of:

- a service for archival, processing and distribution of satellite imagery data and similar spatial, multi-spectral and temporal raster data archives in real-time, developed to scale to tens of PBs of data and tens of thousands of requests per second;
- an open-source Python package for machine learning in EO, bridging the gap between satellite imagery and machine learning technologies;
- a cloud-based crowd-sourcing GIS tool, used by more than 1 million users annually, which contributed more than 20,000 datasets combining more than 20 million records;
- 2D and 3D mapping engine, which uses WebGL and HTML5 technologies to perform efficient visualization of spatial data; and
- a combination of these solutions makes it possible for Firm C to build Web-based applications managing extremely large spatial datasets to be accessed by tens of thousands of people at the same time.

Firm C has a large and varied customer base which comprises governmental institutions (such as Ministries of Housing/Lands, Agriculture, Forestry and Food, Environment and Spatial Planning and other administration bodies), at which smaller non-governmental organizations have been added later on, such as, for instance, private companies and even many individual users of its Web-based systems. Firm C serves clients from all over the world, including Central and Western Europe and Africa.

Case C is using computational AI for its services and specifically for *C.i*, which, while being

Figure 2 4.0 Technologies used in Firm B’s BM

			4.0 technologies		
			Big data and analytics	System Integration (Artificial Intelligence and HPC)	Cloud
Areas	Offer	Value proposition	Cloud computing to offer geo-analytics by means of info-as-a-service software		
	Customer	Customer segments			
		Channels			Cloud for distributing scalable software-based services to customers
		Customer Relationship			
	Infrastructure	Key Resources	Copernicus data	- AI algorithms - HPC for Data processing	Cloud computing
		Key Activities		- Processing algorithms - Data integration	
		Key Partners	ESA providing large data by means of the Copernicus Programme		Suppliers of the server enabling cloud computing to distribute software-based services to customers
	Financial viability	Cost Structure	Copernicus Programme has also led the initiative of allowing EO data to be free and easily accessible to any	AI for automating the interpretation of satellite images (avoids enrolling the services of a multitude of image interpreters and optimize the use of data transmission channels)	Geo-analytics offered by means of info-as-a-service software saves money and addresses the problem of scalability
		Revenue Stream			Cloud computing allows shifting from software sales revenues to service subscription revenues

distributed as a Web service, can be used by hundreds of (non-expert) application developers worldwide to build remote sensing applications for land cover/crop classification, and global water-level monitoring. Specifically, AI allowed standardizing the service, so that customers are provided with readily available, scalable, self-serving products, rather than custom applications.

To effectively build on AI, Firm C, on the one hand, has created a new organizational unit to introduce AI machine learning in the company's services and, on the other hand, worked on open-source software for machine learning that allows "to start somewhere and then proceed from there on" (CEO).

The use of cloud technologies helps both in charging the customer in proportion to the number of requests they do per month and to pay only for the capacity Firm C needs (Figure 3).

5. Discussion

What emerges from this analysis is that to create, deliver and capture value, 4.0 technologies do not operate in isolation the one from the other. This draws attention to the issue of interoperability between 4.0 technologies, which indeed is becoming more intense, dynamic and uncertain (Baden-Fuller and Haefliger, 2013). In addition, it emerges that, despite differences, digital technologies involve all the different areas and components of the BM.

Going to a greater detail, three digital technologies seem to be pivotal in the space industry, namely, big data, here connected with the Copernicus Programme, system integration and the cloud.

As regards big data, it is important to underline that, in our analysis, we refer to large data sets that are open and free. Indeed, the Copernicus Programme, while democratizing EO data, has made large volumes and variety of data available with ongoing continuity to all possible subjects – citizens, as well as firms of any size. To put it in other words, the open data policy of the Copernicus Programme has a critical impact on the uptake of EO by users in general and firms in particular, so fostering the creation of different BMs able to exploit data.

Big data, in all the three cases, have specifically impacted four components of the BM

Figure 3 4.0 Technologies used in Firm C's BM

			4.0 technologies		
			Big data and analytics	System integration (Artificial Intelligence)	Cloud
Areas	Offer	Value proposition	AI machine learning allowed offering a new standardized service (an open source framework consisting of an open source Python library integrated with the service for archival, processing and distribution of satellite imagery data)		
	Customer	Customer segments		While standardizing the service, AI allows the product to make EO data easily and intuitively accessible (for browsing, visualizing and analyzing) also to non-experts. This way, the product caters at a new Customer Segment composed of hundreds of (non-expert) application developers worldwide, who can make EO data requests when needed	
		Channels			
		Customer Relationship		AI, while standardizing the service, allowed self-service	
	Infrastructure	Key Resources	Copernicus Data	- Open source software for machine learning - Machine learning R&D Team	Cloud Infrastructure
		Key Activities		Development of open software for machine learning	
		Key Partners	ESA providing large data by means of the Copernicus Programme	Providers of open source software for machine learning	
	Financial viability	Cost Structure	Copernicus Programme has also led the initiative of allowing EO data to be free and easily accessible to any		Payment for the needed capacity
		Revenue Stream			Revenue per volume of service request/month

Canvas, i.e. the key partners, the cost structure, the key resources and the value proposition. This means that ESA, identified as one of the main key partners of the three firms, while unleashing each day a dozen of terabytes of EO data for free, allows firms to build with no costs (cost structure) one of the fundamental key resources, upon which firms can offer their value proposition.

However, the possibility for the three firms to offer their value proposition builds not only on big data – the Copernicus Programme – as a key resource, but also on a bundle of system integration technologies, composed of computational AI together with HPC. The use of AI in the three cases is mainly computational, i.e. connected with the need of standardizing the offered service (Case C), or related to the technical constraints that data transmission has and hence to the need of interpreting images, with the final aim of transmitting on Earth only useful data (Case A and Case B). The possibility to lever also on another system integration technology – HPC – is particularly important for Firm B. Indeed, Firm B aims at offering its customers the possibility to derive additional insights by integrating geo-spatial data, selected by means of AI, with multiple data sources and types. As a matter of fact, by processing, analyzing and fusing multiple satellite images and other data sources, Firm B offers its customers the chance to achieve intelligence which was not previously available.

Together with big data and system integration technologies, there is another 4.0 technology which allows the viability of the investigated BMs, especially for Firms B and C. It is the case of cloud computing that enables new and easier ways to access data, and facilitates large volume storage. With cloud computing, indeed, customers of Firms B and C do not need to download and store the data they need on their own computer. This way the offered value proposition is more appealing in that the cloud not only reduces the cost of access, but also gives customers the access to a wide range of different sources of data with a unique entry point. In addition, the fierce competition among cloud providers (e.g. Amazon Web Services, Google, Microsoft, Oracle or IBM) boosts the reduction of storage costs. In addition, beyond simply accessing and storing the data, cloud computing allows the on-demand delivery of computing power, servers, databases, networking, software, analytics and other resources that greatly support the development of new applications and solutions.

6. Conclusion

This paper aims to contribute to the growing debate about which 4.0 technologies can effectively impact on emergent business models in space industry.

Indeed, space industry offers a unique opportunity to explore this phenomenon because of the very peculiar context which is characterized by a high market dynamism and a new emergent stage of the industry life cycle, enabled by 4.0 digital technologies (namely, Space 4.0).

While the role of digital technologies as enabler of BM innovation is quite well recognized in Industry 4.0 and most emerging technologies of I4.0 are well consolidated and mature technologies in space applications, the peculiar characteristics of the space activities – such as extreme working conditions, features of geo-spatial data, limited computational resources, high security requirements, high risk of operations – suggest that technologies being more interesting for ground applications, as happens in Industry 4.0, could not get the same opportunities in space application.

Nevertheless, it is recognized that a hybridization of space and ground applications is occurring, with many space services and activities being directed to common citizen and traditional firms. This condition is upgrading and transforming business models of many firms in space economy.

In this context, the paper investigates which technologies among the Industry 4.0 pillars are impacting BMs particularly in space applications. In other words, while recognizing the impact of 4.0 technologies on the BMs of firms playing in the space economy context, this research shows which BM components are specifically impacted by these technologies.

The first contribution emerging by the case studies confirms the central value of big data in fostering and enabling new services to support governments, firms and citizens ranging from space activities to more traditional service/manufacturing processes.

However, to take full advantage of such data, companies need to optimize data processing and transfer. In doing so, AI and HPC have a pivotal role to enable efficient data elaboration. Similarly, network infrastructure becomes essential, and particularly the cloud, which appears central both to provide a way to connect distributed data coming from different services/applications and to provide the customers with computational resources directly on demand, as needed.

As for practical implications, this research provides empirical evidence to both public and private players about some really interesting 4.0 technologies that are transforming the business of space companies and may significantly impact in redesigning BMs of other firms in future. Thus, firms are required to build a bundle of related resources and competencies, to enable such potential, investing on internal resources to acquire appropriate expertise opening up to emerging technologies such as big data, cloud and AI, as well as being opened to collaborations with external partners.

Clearly, this work has also important limitations that offer interesting directions for future developments. Limitations are both theoretical and methodological. From a theoretical point of view, we built on Osterwalder and Pigneur's (2010) BM canvas to address the BM components and hence analyze the impact of digital technologies on them. This waves caution flags about possible effects on results, which indeed may be affected by the above choice. The point is: may results have changed with another BM framework, different than Osterwalder–Pigneur's? This reflection suggests to address in the future developments of the research, the exploration of the research question with respect to other BM frameworks.

From a methodological point of view, the most important limitations are related to its explorative nature. Drawing on a limited number of case studies, results might be affected by specific factors. More in particular, the three cases are not enough to extend the evidence to the whole industry. Other cases are desirable because they could open the way to other interesting perspectives about the value of 4.0 technologies in space.

Finally, despite the space industry is an extremely interesting empirical domain to investigate, its specific characteristics might have influenced how the role of 4.0 technologies has been assessed.

Note

1. GIM International was launched 35 years ago and since then has firmly established itself as the leading global magazine for geomatics. Bi-monthly, a new issue is produced and distributed in print to thousands of professionals in 170 countries worldwide. GIM International is the independent and high-quality information online source for everything the global geomatics industry has to offer: news, articles, vacancies, company profiles, educators and an event calendar. It provides a wide variety of information about all the major topics in the business, such as mapping and surveying, geodesy, cartography, GIS, photogrammetry and remote sensing.

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Further reading

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