The Space Economy

The Space Economy:

From Science to Market

Edited by

Giorgio Petroni and Barbara Bigliardi

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INTRODUCTION

GIORGIO PETRONI

From its inception, the modern conquest of space has been characterised by an important economic dimension. The first phase of this conquest, intended as a set of objectives, tools and actions going beyond traditional aeronautical activities, is conventionally said to have begun when Sputnik 1 was launched on 4 October 1957. Essentially arising from political and military objectives, the conquest of space was financed by huge public investment. The "Space Race", as it is commonly referred to, marked a confrontation between two superpowers, namely the US and the USSR, who both sought to impose worldwide political supremacy. The cost of this competition was enormous, given the huge stakes at hand.

It was envisaged that in obtaining dominance of space, the winner of the Space Race would be able to extend its political, social and economic systems to most other countries. Moreover, victory indirectly implied decline of the defeated super-power. Fortunately, remarkable progress in military technology interrupted the Space Race. The availability of intercontinental ballistic missiles capable of carrying devastating nuclear devices eventually gave rise to the common belief, on both sides of the conflict, that nuclear war would lead to no winners. Controlled disarmament of military arsenals thus begun, marking the beginning of a second phase of space conquest characterised by international collaboration and development of space activities. The episode most symbolic of collaboration in space during this period was the docking of the Russian Soyuz 19 and American Apollo command module in July 1975, with emblematic exchange of the two crews.

From the early 1980's onwards, collaborations between large space agencies such as NASA, the Russian Roscosmos and the European Space Agency (ESA) developed along two lines:

- exploration of space, involving the main scientific structures of all major countries, and
- development of access to space in many other countries, in particular in large Asian countries such as Japan, India and China.

In later times, these collaborations stimulated the transfer of technology from countries with an established presence in space to others, many of which were developing countries. The gradual increase and extent of space activities, marked by intense collaboration and exchange between many countries, has brought with it development of a market for space tools such as launch vehicles, infrastructure and, above all, satellites. This market has progressively expanded with the development of satellite technologies that have allowed the growth of widespread services such as telecommunications and applications exploiting Geographic Positioning Systems (GPS).

It is therefore possible to observe how space activities have developed over the past 60 years along a trajectory that was initially inspired by political and military objectives but ended up being nurtured by a large space tools and services market. This trajectory is the common thread that binds the contents of this book, which aims to provide basic elements for interpreting the economic dimension of the space sector, comprising public investments, creation and evolution of goods and services, production systems, innovation, and generation of the resulting value chain. This dimension unfolds across a complex reality resulting from interactions between various political, military, scientific and industrial factors, as well as various institutional players and private businesses. This subject will be discussed within the various chapters of this book, which cover different areas of space activities and the related economy. Attention will be given to the main space agencies and their roles as institutional bodies for the promotion of space activities. Space science will be discussed, together with generation and evolution of demand for space-related products and services. Military space activities will also be presented, as well as international collaborations, the dynamics of industrial systems and the roles of international supervisory structures in regulating space activities and enforcing the rule of law.

In dealing with these issues, major changes that have occurred over the past sixty years of space activities will obviously be taken into consideration. These changes concern various elements within the political and economic landscape, including collapse of the former Soviet Union at the end of the last century, expansion of countries considered leaders in space to include major Asian markets such as Japan, India and China, a tendency towards direct management of space activities by the governments of individual countries, and growing attention towards Earth observation programs dedicated to the "living planet" paradigm. This last aspect, as will be shown, calls on players in space to address serious problems relating to the planet, including climate change, environmental disasters and natural resource depletion. Finally, the question of what economic returns are actually expected from significant investments in space will be addressed with two approaches. The first will attempt to quantify the return on investments over time based on an econometric approach that has been put forward by various scholars. The second will consider a more robust approach comparing costs incurred with significant economic benefits in terms of produced income, generated employment, growth in the production system of various countries, the level of innovation introduced, and goods and services generated to the benefit of the community.

CHAPTER ONE

SPACE ECONOMY OVERVIEW

GIORGIO PETRONI

Introduction

An adequate representation of the economic dimension of space activities must necessarily take into account the strong connection of this sector with defence or, more generally, domestic and international political affairs. As will be discussed in this chapter, an increased impetus for development of space activities led to the so-called "Space Race" between the US and USSR, which began in the 1950s and was essentially generated by the will of political and military leadership.

During the sixty years that have passed since the beginning of the Space Race, there has been a gradual maturation of the collaborative attitude between countries most engaged in the development of this sector. It can be said that, with abandonment of the dominant political-military logic over recent decades, space has essentially become a field of scientific collaboration and peaceful industrial and commercial competition. Interactions between the space economy (public and private investments, development and use of new technologies, dynamics of new satellite service markets, etc.) and the political and military needs of various countries, however, have not disappeared. Some examples may be given to demonstrate this point. For instance, access to space by some large Asian countries (e.g., China, India and Japan), and the significant investment that this requires, is legitimised based on considerations that go beyond the social and commercial benefits expected from new satellite technologies (navigation, telecommunications, Earth observations etc.). Planned interplanetary missions by these countries, currently in preparatory phases, legitimise their aspirations of belonging to the small number of countries that are highly respected in terms of political and military power (Petroni and Bianchi, 2015). These missions, such as a new planned Moon landing, as well as exploration (unmanned, for the time being) of Mars and Venus, require knowledge and technologies of avantgarde, or at least significant upgrades. These capabilities are quite contiguous to most modern defence instruments such as launching abilities, the availability of transport vehicles in non-traditional space, the availability of a reliable Geographic Positioning System (GPS), the development of a reliable soft-landing system, the effectiveness of communication and image detection systems, and so on.

As has been recently observed (Lee and Steele, 2014), the latest applications of satellite technologies such as high definition imagery, GPS localisation, assessment of water availability, etc., were originally developed for military applications. Other elements also indicate a connection between space activities and political and defence interests. Firstly, the 2015 US space asset balance sheet (Space Report 2015) indicates that of the 44.5 billion dollars allocated by the US Government and Congress, 18 billion were assigned to NASA, intended for civil space use, and 23.5 billion were destined for the Department of Defense (DOD). This means that the availability of particularly advanced space technologies within the US Government strategy constitutes not only an essential safeguard for defence of the country, but also a premise for preservation of its leadership and therefore power of its political influence. Secondly, over the last two decades, "dual use" satellites, or satellites that collect data and information for both civil and military use, have seen significant developed. The adoption of this approach, typically reserved for Earth observation satellites, is also due to production cost savings resulting from strong functional proximity.

The abovementioned interactions make the separation and description of the economic dimension of space activities generally rather complex, thus suggesting the adoption of various points of view to achieve an effective representation of the economic structure of the sector. The main perspectives regarding this matter are detailed in this chapter.

The 2015 balance sheet

A first perspective from which it is possible to grasp the global economic dimension of space activities is the amount of resources that are generated or made available, and the sources from which they are generated. In this respect, the total value of these resources was 323 billion dollars in 2015 against 329 billion dollars in 2014. This decline in overall budget is partly due to strengthening of the US dollar compared to other main currencies (including the Euro) and partly due to a decrease in the overall volume of activities carried out. In 2015, in fact, 86 orbital vehicle launches were carried out against 92 in the previous year. Contractions in the number of

Russian (32 in 2014 vs. 26 in 2015) and Chinese (19 in 2014 vs. 15 in 2015) launches was significant in this respect. Table 1-1 summarises the resources made available in 2015 from public sources (governments) and those generated by the market for satellite products and services.

Revenue from commercial activities	126.33 B
Revenue from infrastructure and support industries	120.09 B
US Government space budget	44.57 B
Non-US Government space budget	31.95 B
Total	*322.94 B*

Table 1-1: Global space activities, 2015 (B = billions of dollars) (Source: derived from Space Report 2015).

Transactions deriving from the development of satellite technologies in the global market of goods and services are the largest source of revenue, amounting to 126.33 billion dollars (39% of the total). The main commercialised products and services relate, in particular, to applications in the telecommunications sector, navigation systems (GPS) and Earth observations. Users of these applications can be private companies or citizen communities, public organisations (i.e. central government bodies or local governments), public agencies or other public administration bodies. Revenue from production activities (design and manufacturing) of space tools, as well as launch infrastructure and services, reached a value of 120.09 billion dollars at the end of 2015, representing 37% of the total. Included in this figure are not only the design and construction of aircraft, but also the design and construction of rockets. US Government allocations for space activities (44.57 billion dollars, or 14% of the total) exceeded government allocations from all the other countries involved in space (including European countries, Russia, China, India and Japan).

The market under consideration is booming and, according to forecasts, there will be a significant increase in space activities over the coming years (Space Report 2015). Figure 1-1 shows only a few examples of these applications that will be detailed in terms of their nature and the dynamics of relevant markets in subsequent chapters of this book.

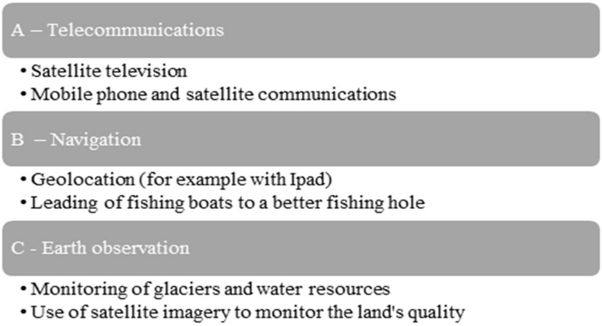

Fig. 1-1: Some examples of satellite technology applications.

Areas of resource use

Another perspective from which the economic dimension of space can be considered is the sectors of resource use: military, civil and science. Interactions and operational mixtures between these different sectors prevent, except in specific cases, analytical detection of the quantity of resources allocated to each of them. As mentioned above, the value of resources allocated to each sector in 2015 for the US appear in official documents. In the remaining countries, however, the quantity of resources dedicated to science, in particular, is often not contained in official documents. For this reason, we have turned to some contributions in the literature for estimates. The data shown in Table 1-2, below, is a comparative analysis of the sectoral destinations of space resources in the US and in non-US countries.

	US	*% total*	*Non-US countries*	*% total*
Military space spending	23.57 B	55.3%	10.5 B	32.9
Civil space spending	13.75	32.4%	18.2B	56.8%
Science space spending *(Earth science, planetary science)*	*5.2*	*12.3%*	*3.2 B*[1]	*10.3%*
Total space spending	42.52 B	100%	31.9 B	100%

Table 1-2: Division of 2015 US and non-US space budget by sector (B = billions of dollars) (Source: derived from Space Report 2016).

[1] P. Barbaroux (2016) indications have been used to check estimates for production of this data, which express assessments deriving from examination of the 1495 spacecraft (including scientific) launched worldwide over a period of fifteen years.

These data confirm the pre-eminent position of the US in space policy, characterised by a very high level of resource allocation. While retaining overall leadership, the US has tended to reduce emphasis on civil space development, as indicated by NASA budget data over the past two decades (see Figure 1-2, below).

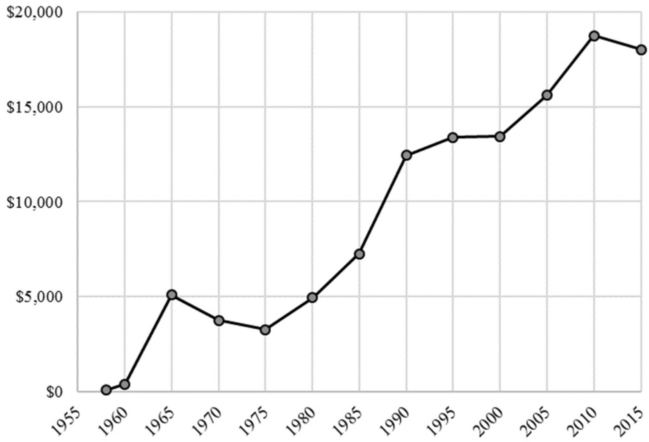

Fig. 1-2: NASA budget over the period 1958-2015 (nominal values in millions of dollars) (Source: derived from IPFS.IO: NASA budget).

It is also interesting to note the share of resources dedicated to development of military technologies compared to all other countries. The probable reason for this situation must be sought not only in the defence program but also in the expectation of important industrial implications. The choice to finance projects with public money in technology-intensive sectors and thus promote significant industrial developments (Stewart and Springs, 2015)[2] is a constant feature of American policy for innovation. Space is one of these sectors, as are biotechnology, robotics, computer science, nanotechnologies, new energy sources, etc.

Two recent examples of projects funded by the Defence Advanced Research Projects Agency (DARPA), part of the DOD, are:

[2] Along the same line of innovation policy, actions taken by the US Government after the Stevenson Act entered into force in 1980 facilitated access to federal lab patents by private companies.

- "Project X", aimed at reconstructing a map of actors and opportunities in cyberspace, considered one of the most interesting areas for management of security and organisation of defence by the government; and
- The development of autonomous military road vehicles (now undergoing advanced testing), conducted by the DOD in collaboration with Carnegie Mellon University and the Department of Computer Engineering at the University of Parma.

A project of great importance, under management for some years within NASA and recently arousing the interest of the DOD, is the SPS (Solar Power Satellite), which involves the construction and launch of a constellation of geo-stationary mega-satellites to be used for the capture of large amounts of solar energy to transfer to Earth and transform into electricity.

It is reasonable to think that the possible development of these projects may have consequences in industrial terms. This has already been the case on several occasions for other important technologies that were initially developed in the military sector and were subsequently subject to significant upgrading for use in space. In this regard, we can cite the example of radar technology used today in super-fast satellite communications. Finally, the fact that major construction companies are engaged both in the business of military space tools and civilian satellites should be considered. These also operate in other sectors such as aeronautics, which is often dominant in the structure of their business. This is the case for Lockheed Martin and Boeing in the US, as well as Thales Alenia Space-Aerospace in Europe. This greatly facilitates the transfer of technological innovations from one sector to another. Moreover, this process is not only horizontal (i.e., inter-sectorial) but also develops vertically following the supply chain. In this respect, in particular, a bidirectional innovation transfer path is activated. This phenomenon has acquired increasing importance with the entry of large Asian countries into the sector. Their commitment has widened supply chain dimensions by increasing competition in the industry (Space Safety Magazine).

Leading countries in space activities

Amongst the many countries participating in the development of space activities, a group of protagonists has emerged for some time now. Strong commitment allows them to exercise a leading role in the sector and to derive significant economic and political-military advantages from it. Such countries can be identified based on the resources they invest in space, the advanced technology they have available to them and their production facilities. To give substance to these observations, it should be noted that the ability to launch and the availability of an autonomous navigation system (Geographic Positioning System - GPS) are essential to carrying out astrophysical exploration programs and Earth observations while, at the same time, constituting the basis for organising an effective defence system. Moreover, the availability of advanced satellite technologies is the premise of a production system capable of feeding the products and services sector (telecommunications, territory monitoring, etc.) where the market is booming. Table 1-3 shows a ranking of countries based on expenditure allocated to space activities in 2015. Table 1-4, further to presenting the quantity of resources dedicated to space activities (expressed as %GDP), provides a list of countries owning rockets (column "C"), having an autonomous GPS system (column "D") and having individually constructed over 10% of launched aircraft (column “E”) over the period 2012-2015.

Country	*Spending*	*Country*	*Spending*
US	44.94	South Korea	0.55
	4.94	Italy	0.54
Europe			
China	4.21	Canada	0.36
Russia	2.99	Spain	0.15
Japan	2.65	UK	0.13
France	1.37	Brazil	0.10
India	0.91	Israel	0.04
Germany	0.59		

Table 1-3: Space spending by country in 2015 (billions of dollars) (Source: derived from Space Report 2016).

Country (A)	*Spending as %GDP (B)*	*Owning rockets (C)*	*With autonomous GPS system (D)*	*Satellites manufacturing (E)*
US	0.248	USSR	US	US
Russia	0.222	US	Russia	Europe
France	0.098	Europe	China	Russia
Japan	0.095	Japan	Japan	China
Germany	0.047	Israel	India	Japan
India	0.041	India	Europe	India
South Korea	0.040	China		
Italy	0.039	South Korea		
Canada	0.023	Iran		
UK	0.017			
Israel	0.016			
Brazil	0.006			

Table 1-4: The characteristics of leading countries in the development of space activities (Source: derived from Space Report 2016).[3]

The first countries to conquer space, including the US, Russia and European countries, still maintain a dominant position based on the data presented above. Japan should be added to these countries, as it had already made considerable progress in the sixties from both scientific and technological-operational points of view with the assistance of the US. Amongst European countries, an important position must be reserved for France, which devotes a considerable amount of economic and human resources to space. Its CNES space agency, employing over three thousand employees, has developed high levels of skill and knowledge over 50 years of work in the field. The most important aspect within the sector relates to development of space access by large Asian countries such as China and India over the last three decades. These, in turn, have achieved a high level of skill, which can be observed by their commitment to interplanetary missions, amongst other things. India, which already uses satellite technology extensively for internal public services (teleducation, telemedicine, monitoring of water resources, rotation of agricultural crops, etc.), presents strong growth

[3] The decision to present resource use in space by country in two different tables (monetary value of expenditure and share of expenditure as %GDP) derives from the fact that values attributed to individual countries in the first case, relating to European countries, include a participation fee required by ESA (European space Agency), while in the second case they do not contain this quota.

potential in space, as does China. South Korea must also be added to this list of countries due to their rather important production facilities connected to space technology. The same can be said for Brazil, which has recently been troubled by serious economic problems but nonetheless has a solid tradition in the aerospace sector. Ukraine and South Africa are amongst countries not listed in the previous tables that have nonetheless increased their presence in the international space sector over recent years. Other countries such as Iran and North Korea, which have recently acquired launch capacity, seem to be predominantly driven by military needs. Finally, it should be noted that Israel has also attained high levels of scientific and technological knowledge and skills relating to space.

The production system

To grasp the structure of industrial space tool production facilities, even if only at a basic level, it is useful to provide some context relating to developments that have taken place at the beginning of this century. These have contributed significantly to the economic profile evolution of the sector. As previously mentioned, technological innovations allowing extensive development of satellite services were accompanied by the appearance of small satellites on the market (satellites with a weight ranging from 5 to 50 kilograms). Production of the latter involved relatively modest costs and the use of unsophisticated technologies. This made production and use possible in countries that did not have access to advanced technology. Small satellites are typically placed in geo-stationary orbits used for telecommunications, mobile phone services and, in some specific segments, Earth observations. The dissemination of these tools has generated the following effects:

- The number of countries that build satellites has significantly increased. The latest findings indicate 57 countries in which companies are engaged in this segment of the space market.
- The qualitative and structural difference between satellites from prime-companies and those from companies dedicated to the sole production of small satellites has widened. The former are necessarily involved in research and development programs. Unlike the latter, they also possess a high level of knowledge and technological skills. A prime-company is typically engaged in very complex missions and is responsible for the design, construction and assembly of payloads and main satellite subsystems. These relate to the physical-mechanical structure, propulsion subsystem, launch

subsystem, ground satellite governance subsystem, control systems, etc. (Space Safety Magazine).

- Companies first present in the nineties from the US and Europe were subject to an intense concentration process over subsequent years with the dual purpose of strengthening the supply of particularly complex space tools and acquiring a significant share in the consumer-satellite market (small satellites). This is how oligopolistic formation has the potential to significantly orientate the global space tools market. The main members of this group are:

  - AIRBUS Defence and Space (EU);
  - OHB (EU);
  - Thales Alenia Space (EU);
  - Boeing Defense, Space & Security (US);
  - Lockheed Martin (US);
  - Orbital ATK (US);
  - Systems Loreal (US);
  - JSC Information, Satellite Systems (Russia).

Production facilities within the Indian space agency ISRO and the Chinese space agency CNSA must now also be added to this list of large players.
Production of a space system can be divided into the following three segments: aircraft manufacturing, launch industry (including production of launch vehicles and equipment for launch services) and ground equipment. The latter includes a vast array of instruments ranging from control stations to very small aperture terminals (VSATS), gateways and network equipment. In addition to this type of instrumentation dedicated to aircraft ground handling, there is another large series of tools needed to manage various satellite services. These include satellite TV dishes, satellite radio equipment, satellite broadband dishes, satellite phones, mobile satellite terminals and standalone satellite navigation hardware. To grasp the economic dimension of these productions, data shown in the following graph (Figure 1-3) can be examined, noting that they refer to satellites produced over the period 2009-2014 (Satellite Industry Association). Global turnover of the three aforementioned production segments was 80.1 billion dollars in 2014, an increase of 7% compared to 2013, broken down as shown in Table 1-5.

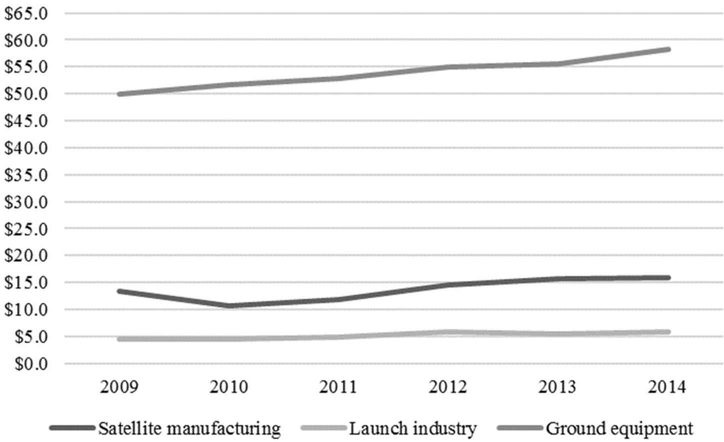

Fig. 1-3: 2009-2014 Space industry revenue (billions of dollars), excluding satellite services (Source: derived from Satellite Industry Association Report 2015).

Satellite manufacturing	15.9 B
Launch industry	5.9 B
Ground equipment	58.3 B

Table 1-5: 2014 revenue for the industrial production segment (B = billions of dollars) (Source: derived from Satellite Industry Association data).

In the context of growth achieved in all three segments, the particular weight of ground equipment (57% of the total) is due to the continuous diffusion of satellite services. In the construction of satellites, US industry still holds a prominent position. The US share of the 15.9 billion euros total revenue from satellite manufacturing in 2014 was 63%, against 69% in 2013. In the launch systems segment, the largest share of revenue lies with countries outside the US. Finally, in the ground equipment segment, US companies achieved a 41% share of global revenue in 2014.

Space workforce

There has been an overall tendency for growth in the global space workforce, which has been particularly accentuated over the last two decades. This trend, however, appears to be inverted in the US, based on data given in Figure 1-4 and Table 1-7. The tendency for growth reduction in the US civil space workforce obviously also involves NASA, who had 17316 employees at the end of 2016 (Satellite Industry Association) after recording a contraction of 4.6% over the period 2013-2016. In the military space segment (including the DOD), there was the same tendency towards contraction of staff in US Airforce space activities but a slight increase in US Army space activities over the period 2013-2015. This situation is a result of various factors. Firstly, the progressive contraction of resources allocated by the US Government for space activities over the last three decades, as outlined at the beginning of this chapter, must be emphasised. Despite this contraction, the US remains the country with by far the greatest presence in the various segments of the space sector. On the other hand, strong development of global activities related to space was registered over the same period, especially in large Asian countries such as China, India and Japan.

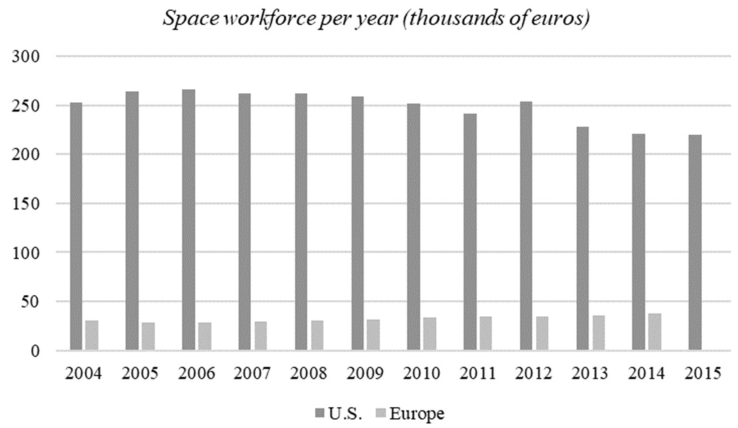

Fig. 1-4: Comparison of US and European space industry workforces from 2004 to 2015 (Source: derived from Space Report 2016).

Country	*2015 space workforce*
Russia	250,000[4]
China	270,000
India (ISRO)	15,900[5]
Japan	8,232

Table 1-7: 2015 space workforce for selected Countries. (Source: derived from OECD data).

This development partly stemmed from initiation and progressive growth of the satellite services market, which mainly involved development due to demand for telecommunications and navigation instruments (TV and mobile telephone services). There were 57 countries able to launch geostationary or suborbital satellites at the end of 2016. Another factor that has promoted the aforementioned contraction of the workforce is the delocalisation of production adopted by large US construction companies. In many countries that have entered space over the last twenty years, subsidiaries have been developed to decentralise the production of spacecraft parts. This is still the case, with significant savings in terms of labour costs. The choice to decentralise part of production away from large companies allows more attention to be paid to the construction of products incorporating greater technological value on US soil. The difference between the production quota and percentage revenue in the satellite segment for US construction companies in 2014 appears to be significant. In fact, excluding the production of microsatellites (CubeSats), US companies built 29% of satellites launched worldwide while obtaining 62% of total revenue (Satellite Industry Association). For other important countries involved in space, there is no historical data relating to workforce dynamics, but only that from recent years. These data indicate, however, steady growth that will probably become increasingly intense over the next few years. To grasp the quality of human resources required for the development of space activities (type of professional knowledge and skills), reference should be made to the developmental goals of individual countries. In India and China, for example, one of the main objectives is development of satellite applications for social purposes (communications

[4] The quoted number (referring to China) concerns the sum of employees of 98 industrial companies and those engaged in military and other public structures in the sector.

[5] In the absence of other official data for India, significant insight can be gained from the number of ISRO staff, which is the country's space agency where the main space manufacturing activities are carried out.

networks, telemedicine, teleducation, prevention and management of natural disasters). This objective has led to demand for technicians with basic knowledge and skills relating to the maintenance and repair of mechanical and electronic systems and equipment, development of software for communications, etc. (Sanjai, 2015). In other cases, such as the US and European countries, human resources are required for development and management of technologies that are currently only in a research phase, such as laser communication devices, electric propulsion, multistage launches, etc. It is no coincidence that while the space industry contracts in the US, production staff numbers do not decrease but tend to grow, with the work force engaged in research and development.

Distinctive features of the sector

From an economic point of view, the space sector has some significant differences compared to other scientific and industrial sectors. Firstly, resources feeding its development are still predominantly public. This is due to the fact that many space activities have a clear public purpose. These include scientific missions for astrophysical exploration and other basic research such as the study of human, animal or plant life in conditions of microgravity. Space activities developed for defence, intelligence and security have objectives that are also essentially public, as do programs aimed at studying environmental and land protection. Structures responsible for the orientation of space policies within various countries are government organisations (space agencies). A second peculiar characteristic of the sector is its very broad and deep value chain, which derives from space tool manufacturers (launch and space transport vehicles, satellites, probes and ground segments). In particular, the value chain is linked to prime manufacturers that present a "system specialist structure". They are responsible for the design, assembly and testing of technology-intensive sub-systems. Satellite sub-systems (excluding small or microsatellites) typically include those relating to energy supply, thermal regulation, navigation, control and communications management (to and from Earth). The prime company therefore intercepts and coordinates a wide range of technologies (mechanics, optics, electronics, power, materials, robotics) incorporated in instruments and apparatuses whose production is entrusted to a plurality of specialised supplier companies.

This range of technologies is further extended with the construction and monitoring of ground stations that "project" functions to end users (satellite data and images for TV networks, mobile telephone networks, navigation equipment, etc.). The importance of the aforementioned "system specialist structure" that fosters the development of innovation flows along the supply chain will be further outlined within this volume. Finally, the configuration of investment opportunities is another unique feature of the sector. Private capital can essentially be invested at four different points in the production chain to obtain economic value:

- private capital can firstly be injected at the early manufacturing level or in technological sub-system supply. This is an opportunity that requires a lot of capital and solid technological preparation, for which it is usually reserved for large players;
- a second investment opportunity, which has seen strong worldwide expansion over the last two decades, exists for small or micro-satellite producers for whom there is now an increasing demand;
- significant investment opportunities now also exist for producers of satellite services (networks for data and image transmission related to Earth observations). There is a growing market for social purposes such as education and health;
- finally, market dynamics have for some years envisaged the opportunity to develop new specialised services through computer processing of satellite data (software for transport and logistics management, sea analysis and organisation of fishing, agricultural land analysis for crop rotation, relocation of power stations for the production of biomass power, etc.).

Risk factors

It is useful to remember that the primary actions for access to, and exploitation of, space such as launching a vehicle, ensuring its correct placement in orbit and possible return are still subject to high levels of risk. This is another feature specific to space activities that is also reflected in related economic activity. The history of space conquests is punctuated by accidents, some of which have been very serious. These include the loss of two shuttle spacecraft and crew (1986 and 2004), the death of Russian astronauts Komarov, Dobrovolski, Patsayev and Volkov, and the terrible accident that provoked 21 deaths following the 2003 explosion of the Brazilian Pitcher N VLS -1. As is known, these accidents led to the suspension of human spaceflights all over the world for several years. Without evoking other serious losses, an estimate made on an historical basis indicates the margin of failure to be between 5-10% of satellite launches. It has already been noted that three of the 96 worldwide satellites launched in 2015 failed. Very recently, the first of the European satellites for the GALILEO constellation (perhaps the most important project promoted by ESA over the last ten years) did not reach its programmed orbit. To confirm the persistence of elevated risks associated with primary space activities, it is useful to note that over the period 2011-2015, the worldwide ratio of premiums to claims for insurance companies in the space sector gradually reduced to a value of 1, basically eliminating the expected profit margin (Space Foundation). On the other hand, risk factors relating to space activities are well-known, to the point that a reliability index has been drawn up for each type of launcher amongst those most commonly used in the commercial sector. The situation has tended to improve with the entry of new launchers into the international market, developed by space agencies from large Asian countries. Table 1-7 presents a ranking of countries providing launchers for orbital placement of satellites in 2015 (% of total).

Country	*% of rockets*
Russia	30%
US	23%
China	22%
Europe	13%
India	6%
Japan	5%
Iran	1%

Table 1-7: Percentage of rockets used by different countries for orbital launches in 2015 (Source: derived from Space Report 2016).

Amongst these countries, China and India, in particular, have progressively increased their presence in the sector since 2012.

Overview of institutional structures within the sector

For the sake of completeness, and in the context of an overall presentation of the economics of space, it is useful to briefly recall the basic profile and purposes of some government and regulatory structures within the sector.

Space agencies

In each country, the guidance and organisation of resources assigned to space are entrusted to space agencies. As a rule, these structures are placed under the control of a minister or a committee of ministers in the government. Often, the minister responsible for guidance of the agency oversees universities, research and other educational activities in the country. Very frequently, this figure works in collaboration with the Minister of Defence or the Minister of Industry. An analysis of strategies adopted by the various agencies is presented in Chapter 3. Within the present discussion, however, analysis will be limited to identifying the structures and their role in some of the main countries involved in space activities. Space agencies, in addition to directing civil activities, maintain intense functional collaboration with military authorities in each country. This collaboration concerns, above all, planning and management of projects relating to Earth observations. This is the case for ESA, individual agencies of European countries and the JAXA Japanese Agency. In other cases (China, India and Russia), the structural and organisational bond with the military is very tight because the agencies of these countries oversee both civil and military space activities. In countries that invest most in the sector, their respective agencies have research and technological development centres that guide the manufacturing processes for tool commissioning by issuing technical standards for construction companies. They therefore also lead technology transfer programs. In other countries, where space agencies operate with fewer staff, their roles are limited to the development of strategies and programs for space activities, together with finding and distributing funds.

The role of regional governments in space

With the Lisbon Treaty (Passoni, 2015), the European Union (EU) expanded its expertise in promoting industrial innovation, with extension to include space technologies (Article 189 of the EU Reform Treaty, signed on 13 December 2007). These expertise automatically increased the role of EU member states within the sector who are called on to translate the Union's goals into operational programs. This circumstance has led to the signing of an important agreement between the European Space Agency (ESA) and the EU from which various collaborative projects have been derived. Amongst these, the Galileo project must be mentioned, which involves putting a constellation of 29 satellites into orbit from which a modern European navigation system will emerge. The agreement with ESA has also generated the Copernicus project, which aims to develop a global monitoring system for the environment and security. Finally, the Nereus Network has been added to these projects, which is a network of European regions that develops advanced satellite technology applications aimed at monitoring water resources, land modification, sea health, the state of biodiversity in forests, and organisation and distribution of solar energy etc. In subsequent chapters, some examples of such applications that have already been implemented will be presented and analysed. At the basis of the collaboration between the EU and ESA is the belief that the development of space technologies can increasingly and necessarily meet the social needs of local populations. In this regard, it is useful to recall the abovementioned projects financed by the EU. These projects are therefore connection points between the technological value expressed by the space sector and the socio-economic value coming from the EU and, in particular, its territorial regions. It is interesting to note that, in this case, the political structure (i.e. the EU) did not generate ESA, which historically preceded the former, overturning the traditional organisational paradigm. The EU nonetheless turned to it when economic and social needs arose. ESA was in fact founded in 1975, long before the signing of the Treaty of Maastricht (1992), giving a first unified political structure between Western European countries. Considering the strong push given to ESA by the scientific community at the time, it can be said that the underlying collaborative nature of researchers once again (as had already happened during the Cold War) anticipated political dynamics. Regarding the participation of regional governments in space activities, it should be noted that the Landers were active in Germany within the German space agency DLR from its founding. This enabled them to carry out numerous programs aimed, in particular, at industrial development of satellite technologies.

UNOOSA: An international authority

The United Nations Office for Outer Space Affairs (UNOOSA) in Vienna is a structure based on the principles and values on which the United Nations was founded, with the endeavour to conserve and peacefully use outer space. By convention, outer space includes space and the celestial bodies that populate it, including the Moon, extending beyond 1000 kilometres above sea level. The office is essentially a structure for study, promotion and collaboration between the UN member states with the objective of developing shared rules and behaviour that, on one hand, preserve outer space and, on the other, facilitate access to outer space for the social and economic benefit of the entire international community. The operational purpose of UNOOSA concerns promotion and organisation of consensus regarding the principles and rules of conduct to be adopted and signed within the UN, together with treaties or conventions amongst member countries, or those subject to protection or supervision by the United Nations. In this context, the activities of UNOOSA contribute significantly to the creation and development of Space Law. As an example, some