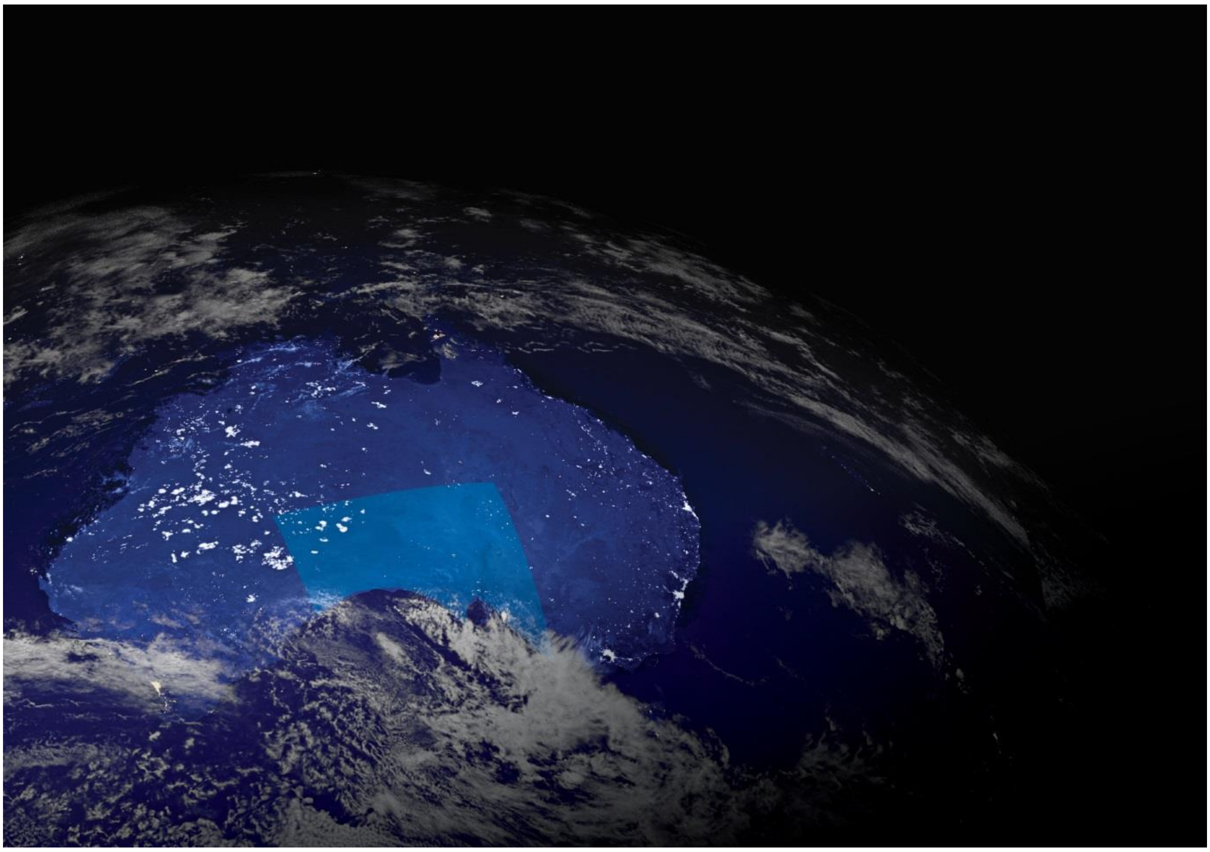
An International Comparison of Space History, Policy and Industrial Capability



Gabriele Lania
Intern – Universita' Commerciale Luigi Bocconi

Supervisor: Nicola Sasanelli AM
Director – Space Industry and R&D Collaboration
DefenceSA
Government of South Australia

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CONTENTS

SYNOPSIS

This paper will focus on Space and Space-related activities, and is linked with a wider plan for the development of a Space strategy in South Australia. Focusing on the South Australian space economy, the study uses internationally recognised categories and applies them to the Australian case.

The first chapter provides overview data and outlines the characteristics of the space economy by applying categories used by the Asian Pacific Aerospace Consultant (APAC) and by the Australian and New Zealand Standard Industrial Classification (ANZSIC). These categorisations will be useful both for future studies and as benchmarks of the State's space environment.

The second chapter provides information and statistical data on world leading space economies. For each country analysed, the twofold objective is to provide international benchmarking and to understand each country's space framework (and the process that led to it). This provides insight into the countries historical involvement in space, present policies pursued by the governing bodies as well as the industrial composition of each national space economy.

It is worth noting that different policies implemented by the national space agencies examined led to some incongruences in the data available. For example, the United Kingdom Space Agency has, by mandate, a large focus on the downstream application of the space industry, and its studies tend to include a very broad range of downstream applications, resulting in data bias. On the other hand, countries such as France or Italy tend to have a stricter vision of the space industry, focusing on the upper stream of the value chain, resulting in an underestimation of the economy. As for China and India, the intense evolution of their space economy (policy, industry and research and development activities) qualifies them as key international actors where the establishment of profitable partnerships may be possible.

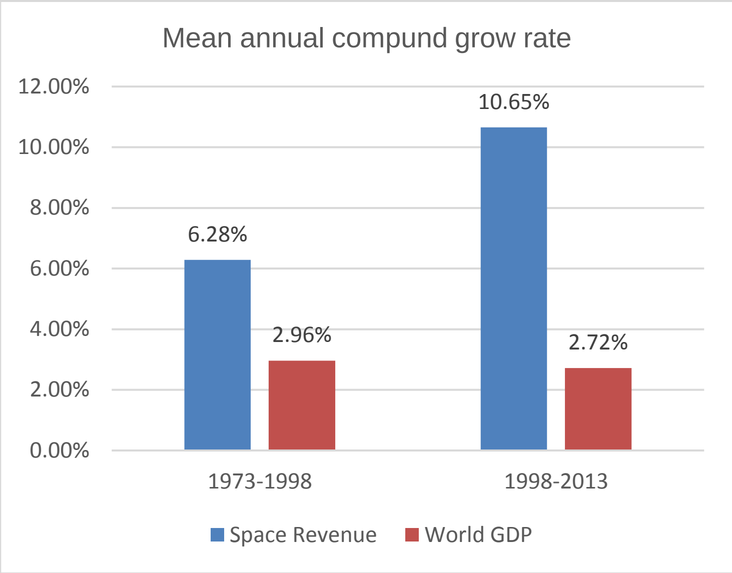
The last chapter briefly highlights Australian space activity. In this context the South Australian challenge is to support space industry growth and increase research and development collaborations. In particular, the State aims to exploit the high level of sophistication of the Space industry in order to promote South Australian science, technology, engineering and mathematics (STEM) capabilities and to increase collaborations between private companies and research organisations. The paper concludes by highlighting some policies successfully implemented by countries such as UK and Canada which could be considered best practices in context of developing South Australia's Space strategy.

CHAPTER 1: SPACE INDUSTRY AND ECONOMY

DATA AND COMPOSITION

'Space Industry' is a broad term. It includes a huge variety of different sectors and industries. It is not easy to track down an accurate definition of its boundaries. Estimations of the global value of the industry present significant discrepancies. It can be agreed, however, that the Space industry generates important revenues: SIA[1] estimates USD 322.7 billion of global revenues for the industry in 2014, while the Space Foundation[2] estimates USD 330 billion.

Figure 1. Comparison of the mean annual growth for Space revenues and World GDP



Source: see Annex

The space economy has presented a constant and sustained growth over the last 40 years. As can be observed in Figure 1 in the last 40 years space sector revenue's has grown significantly faster than the global GDP. Moreover, the development of many modern widespread technologies have been driven by the investments sustained in space. Not only satellite television, phone services and GPS; but also scratch-resistant lenses, fire-resistant materials, electronics and lasers[3] have benefited from space related technology and the subsequent products and services provided by the space industry. It can be concluded that space is a driving force for technological development and for the global economic growth.

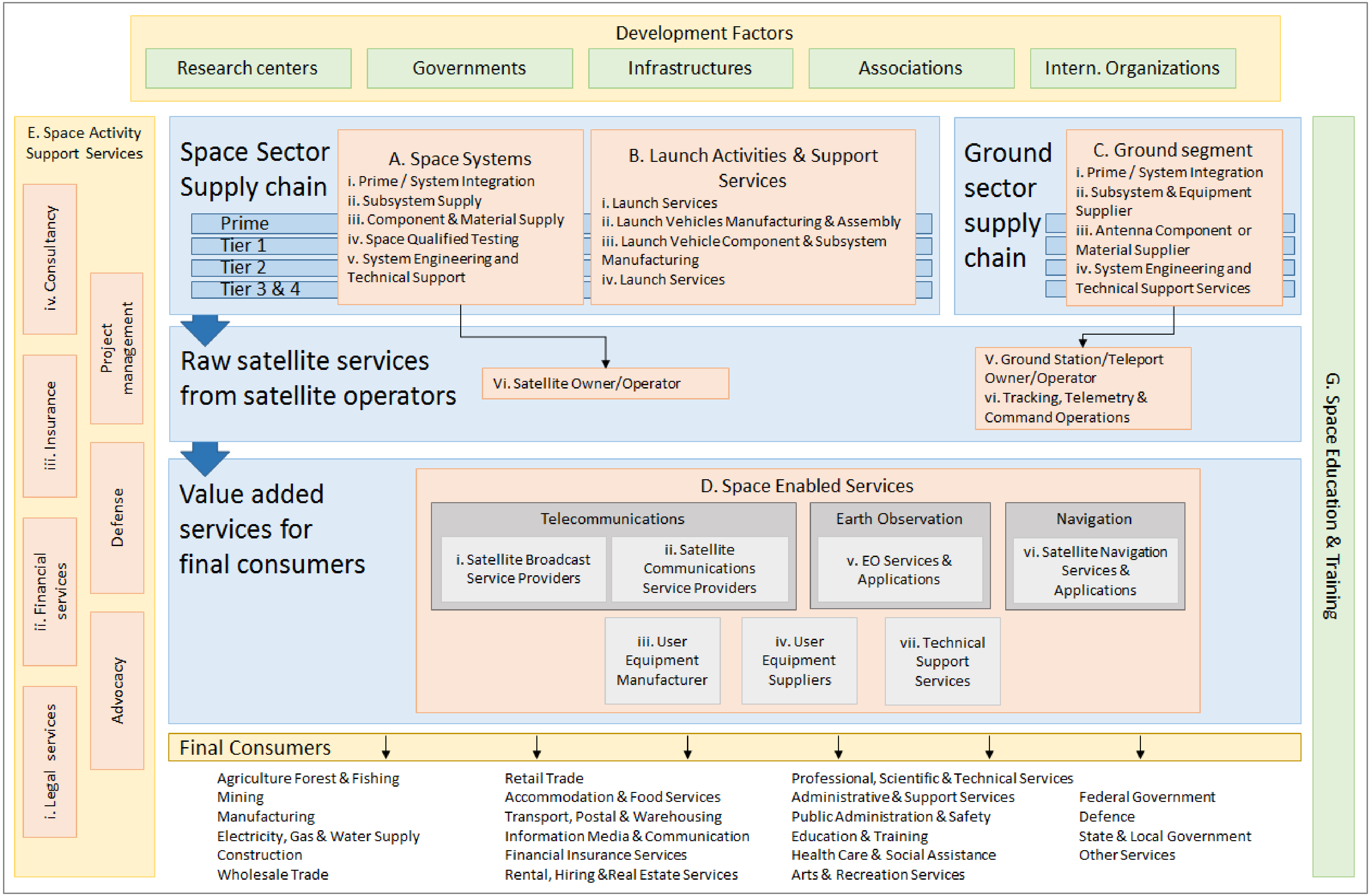
The space economy comprehends a multiplicity of sectors, industries and even individuals, and because of its broad application to an extensive range of diverse stakeholders, some of which cannot alone be defined by their relationship with the space community, it is not easy to clearly track down its boundaries. Each actor will have bring a different perspective that will inform their relations within the space community and their actions.

In broad terms, the literature[4] distinguishes between three different sectors: scientific, military, and commercial. The scientific sector aims to develop new academic and technological knowledge, providing other sectors the capabilities needed for their activities. Universities and research institutes are important scientific and technological actors. The military sector, on the other hand, provides the conditions required to secure national assets. Last but not least, the commercial sector aims to create richness and business growth out of the Space industry. The commercial sector is of fundamental importance for the sustainability of the Space sector as a whole, as, in contrast to the scientific and military sectors, is the only one specifically designed to be profitable.

The final objective of this paper is to provide an overview for the development of a sustainable, innovation driven, space economy in South Australia, the commercial and the scientific sectors will be the crucial units of analysis of the paper, but not in isolation, as each sector is closely linked with the others, and has no chance to survive alone.

[1] The Tauri Group, 2015. *State of the Satellite Industry report 2015*. SIA Publishing.
[2] The Space Foundation, 2015. *The Space Report 2015. The Authoritative Guide to Global Space Activity.* The Space Report Publishing.
[3] Institution of Mechanical Engineers, 2015. *Seeking resolution: Growing the UK Small Satellite Industry*.
[4] Thompson A. D., Smith G. P., 2009.*ce Policy Development via Macro Economic Analysis*.

Figure 2: Composition of the Space industry



Source: Own elaboration

SPACE INDUSTRY'S VALUE CHAIN

When asked about space activities, most people tend to think about big government and public funded projects such as the International Space Station (ISS), the Voyager program, which is now exploring the boundaries of our solar system, or the Mars Rover, which is studying Mars' surface. This is understandable, as such programs are inspiring for our imagination and push for new, and more exiting, discoveries and goals. However, this is just the tip of the iceberg of a broader set of projects and activities. Space industry is ubiquitously present in our daily life, and provides vital support for communication, navigation monitoring, weather forecasting, and many other services. A broadly spread industry like this influence deeply our lives and is an important source of welfare.

A first and high level classification of the space economy is provided by identifying the 'upstream' and the 'downstream' segments. The upstream segment refers to the activities that focus on design, assembly and launch of spacecraft destined to be sent out of Earth atmosphere. The downstream segment, on the other hand, aims to employ data produced by satellites for Earth-related objectives, such as providing communications or for weather forecasting.

DEVELOPMENT FACTORS

At the very top of the value chain in the space economy there is a group of actors, which have the fundamental role to foster research and investments by engaging the private sector in activities that present uncertain outcomes, or that would not generate commercial profit. This group is usually composed of public, non-profit actors, like governments, research centres, space agencies and international organisations. These actors can arguably be considered as key players and key development factors, engaging prime suppliers to develop space crafts, satellites and rocket launchers for commercial and scientific scopes. They are the engine behind important missions like the *Apollo Program* or the *Cassini-Huygens* mission.

SPACE MANUFACTURING SUPPLY CHAIN

The upstream sector is formed by the actors that design and assemble spacecraft destined to be sent into space. This is the high peak of the space manufacture industry, i.e. the space manufacturing supply chain, to use OECD[5] terminology. The supply chain is a category which comprises, in the higher tiers, only 20 manufacturers. The structure of the space sector's value chain resembles those in the aerospace or automotive industries. Here lower tiers supply the sub-systems for higher tiers. The highest peak of the supply chain is composed by prime companies, which deliver the final product. Systems and sub-systems at each level must comply with stringent quality, manufacturing and business standards.

'Prime' companies provide design and production of complete spacecraft systems. They are usually commissioned by Space Agencies for military, scientific or commercial purposes. The complexity of their tasks require high technological and engineering capabilities, together with extensive financial capacity and goals that can be achieved only with sustained heavy investments in R&D: the segment is dominated by huge multinational companies like Airbus, Thales Alenia Space and Boeing.

'Tier 1 and 2' companies are responsible for the design and the production of major spacecraft sub-system and equipment. These companies are usually not in contact with the aforementioned 'development factor' actors (like space agencies). Again, such companies have important financial and technological capabilities, and the boundary with "prime" producers is often blurred. Due to the previously mentioned complex production and assembly of spacecraft systems, prime tiers find it convenient to integrate vertically within their production chain. The creation and acquisition of lower tier companies is widespread, and this trend is growing.

'Tier 3 and 4' companies specialise in the production of specific electric, electronic and mechanical components and materials. Firms in these tiers tend to be small specialised firms or large electronics group with limited activities in the space sector.

[5] OECD, 2014. *The Space Economy at a Glance*. OECD Publishing.

Core industries of the space sector supply chain are the ‘Space system’ and the ‘Launch activity’ industries.

The ‘Space system’ industry involves all the actors taking part in satellites design and assembly. Design, assembly and launch of satellites has always been an extremely expensive task, so the industry historically relies on government investment and expenditure. In recent years, however, we are observing a shift of paradigm. Commercial and technological changes in the sector allow increasing private investments, and nowadays more and more private companies are capitalising on these opportunities. An interesting and growing trend is to build smaller satellites, with fewer functions and duration, but at a lower price. Private companies and smaller enterprises are entering into the sector as they find economically suitable to launch a fleet of small satellites. Particularly interesting is the CubeSat case. CubeSats are extremely small satellites (sometimes referred to as pico-satellites) with standard dimensions of 10x10x11.35 cm, used for commercial, academic and government purposes. In 2014 130 CubeSats were launched across the world, up from 29 sent in 2012 and 91 in 2013[6].

‘Launch activity’ industry consists of all the companies that design and assemble spacecraft able to leave Earth’s atmosphere and reach outer space. Similar to what happens in the ‘Space system’ industry, governments play a fundamental role in the launch industry. Two reasons drive government’s investment in this segment. Private companies are deterred from the complexity of the industry, as it requires huge investment, and high investment implies high risk, and high risk discourages private investment. Rocket capabilities, moreover, imply military threats, and military threats require public control.

Trends active in the space system segment are present also in the launch activity’s segment. The so-called ‘Space 2.0’ revolution is changing the commercial space environment. Jeff Bezos’ Blue Origin and Elon Musk’s SpaceX are just some specific examples of private investments in the sector. Remarkable investments, indeed, both companies have just successfully achieved vertical landing for their rockets, allowing important reduction of operational costs in the future.

Alongside the space manufacturing supply chain there is a parallel ‘Ground segment supply chain’, which is not strictly part of the upstream chain but offers essential services and products for satellites’ functioning and exploitation. This segment is composed of prime and tier suppliers involved in the design and assembly of ground systems, earth-based structures required to launch and to control satellites, as well as for the terrestrial reception of satellites’ signals.

Raw satellite services and Value added services

Moving lower in the value chain, we find the downstream segment. Economic literature provides this segment with various and different classifications[7] [8]. In general terms it is possible to classify downstream activities as those that require satellite technology and satellite data in order to be exploited. We can identify the ‘raw satellite services’ and the ‘value added services for final consumers’ segments as downstream activities.

The ‘raw satellite services’ are provided by companies that own and operate satellites and ground stations, and provide the carriage of raw satellite signal. Such companies have a broad variety of customers, and offer their services to public agencies, public institutions and commercial companies.

At the lowest step of the value chain there are the ‘value added services’. This category includes all the companies that use satellite data in order to provide their services. The definition of this segment is broad and inclusive, and its boundaries blurred. If providing raw data is valuable, the market for interpreting the data is even larger and it is the space economy’s most lucrative part in term of revenues. Actors involved in this segment provide both commercial and non-commercial services. They are private companies, public agencies or even individuals and they are usually not part of the space community. These actors are key intermediaries between the supply chain and the final consumers. The higher the technological capabilities, the better the services can be delivered to the final consumers. This strong

[6] The Tauri Group, 2015: *State of the Satellite Industry report*. SIA Publishing.
[7] OECD, 2012. *OECD Handbook on Measuring the Space Economy*. OECD Publishing.
[8] ESA, 2007: *Value Chains and Market Segments of Downstream Value-Adding Sectors of Space Applications*. ESA Publishing.

link pushes innovation in the whole space economy, being one of the most important paths to provide economic-driven innovation in the space sector.

It is possible to consider the activities that take place at this stage as 'Space Enabled Services'. Satellite signals are used mainly to provide Earth Observation (EO) services (with related resource and natural disaster management), Telecommunications and Broadcasts (SatCom), and Navigation Satellite System (NSS) services. Aside from service providers, user equipment manufacturers and suppliers integrate the value chain, and technical support provide assistance and help.

Many useful applications rely on such services, and a huge variety of supporting industries and services exist and flourish around them. A recent ANPAC study[9] revealed that in Australia at least 22 ANZSIC industrial segments rely in some way on the space industries. Agriculture, mining, media, construction are just some of the sectors involved.

Space related R&D and Support services

Space industry is considered to have a high R&D intensity. A survey conducted on selected advanced economies has calculated[4] that the level of investment in R&D in the space economy is comparatively six to eight time higher than in all other manufacturing R&D sectors. The most relevant investments are made by government actors and space agencies. They entrust R&D centres, laboratories, and universities with the main responsibility to develop basic research to apply at the higher steps of the supply chain.

The space economy, therefore, requires important and continuous investments. Aside from the core industry's value chain, there is a heterogeneous variety of services which are necessary for industrial wellbeing. Companies with different expertise provide financial and legal services, insurance policies, specialised consultancy, advocacy, project management and defence assistance.

Historic and future trends

From 1973 to 1998 the global space revenue grew at an annual growth rate of 6.3%, from USD 15 billion to USD 68.8 billion. This growth rate is approximately double the GDP growth, which for the same period had a compound annual growth rate of only 2.96%. Over the 16 year period from 1998 to 2014 the world GDP grew at an annual growth rate of 2.71%, while, in the same period, the space sector economy grew at 10.14%, four times that rate.

An interesting economic trend within the space industry economy is revealed by examining the recent extraordinary growth of the global commercial space revenue's, compared with the decreasing proportion of the government revenue rate. In 1973 the government contribution to global space revenue was around 80% and commercial industry accounted for the remaining 20%, while in 2014 the commercial space revenue was 80% of the global space revenue and the remaining 20% was from government contributions. This back flip of the space revenue breakdown reveals a remarkably strong commercial annual growth rate of 13.42%.

We can affirm that nowadays we are living within the shift from the 'Experimentation Phase' to the 'Exploitation Phase', characterised by higher technical and scientific capabilities, which leads to lower risks and higher business maturity of the sector.

At the end of the 2000s the term 'Space 2.0' was coined in order to study the trend for which companies started to capitalise on the commercial purposes for space infrastructure within the lower steps of the value chain[10]. Nowadays, however, many new companies are entering in the space business not only in the lower tiers of the value chain, but also in terms of prime contractors. Space 2.0 is still present and has shifted to a whole new level. Modern and privately initiated space companies are now pushing forward to become prime contractors themselves.

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[9] APAC, 2015: *A Selective Review of Australian Space Capabilities: Growth Opportunities in Global Value Chains and Space Enabled Services*. APAC Publishing.

[10] Fort B.O., 2009, *Space 2.0: bringing space tech down to Earth*. http://www.thespacereview.com/article/1362/1

More trends are foreseen for the industry. There is growing demand for more complex EO services and for Augmented NSS both at regional and global level. This will allow more accurate navigation system and all-weather positioning and navigation. Commercial aviation has started to rely on satellite services for Airline Operations, On-board connectivity, and Air Traffic Management.

One of the newest and most important trend is the reduction in size and cost of satellite design and assembly. This is important particularly in the field of EO services. In 2014 nearly 300 satellites have been launched: out of a total of 158 nano/micro satellites[11], 130 were CubeSats. 94 of these 158 satellites were launched for commercial companies in order to provide EO services. It is expected[12] that in the next decade, a cluster of small satellites will complement and partly replace larger EO satellites. Clusters of satellites are more convenient in term of risk and costs, and thanks to their modularity it is possible to change the design and the composition of the fleet even after the satellites have been sent into space. In other words they provide similar quality of service but with more flexibility at lower cost.

One of the most important problems for space economy is the high cost and the low flexibility of launch systems. Launch failure of the Falcon 9 in June 2015 led to a 4 month delay in launching satellites, while the failure of the Antares-130 in October 2014 led to a 14 months delay[13]. Each launch, moreover, require rocket spacecraft, which are expensive and not reusable. In the last months, however, SpaceX has safely landed the first stage of the Falcon 9 rocket, once on the land and once on an autonomous spaceport drone ship (ASDS), after a cargo resupply mission to the International Space Station. Deployment of such technology will allow the reutilisation of the rockets, allowing cheaper and more flexible launches.

[11] SpaceWorks, 2015: *Small Satellite Market Observations. Key metrics for continued market success*. SpaceWorks Publication.
[12] Frost & Sullivan, 2014: *Space Mega Trends. Key Trends and Implications to 2030 and Beyond*. Frost & Sullivan Publication.
[13] SpaceWorks, 2015: *Small Satellite Market Observations. Key metrics for continued market success.* SpaceWorks Publication.

CHAPTER 2: SPACE INDUSTRY GLOBAL PLAYERS

CANADA

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

Canada has been strongly involved in space from the early years of space activity. In 1962, only 5 years after the launch of the *Sputnik*, Canada was the fourth country, to orbit a satellite, the *Alouette-I* (after USSR, USA and UK). In contrast with the USA and USSR, which were engaging in a space race in order to prove economic, technologic and politic supremacy; Canada saw the new technology as a powerful tool for connecting its vast territory (the second largest country in the world) with a scarce and dispersed population.

Canada's first space effort focused on the design and assembly of scientific satellites. After *Alouette-I,* Canada launched *Alouette-II*, *ISIS-I* and *ISIS-II* satellites, all for scientific purposes. The knowledge gained during this first, scientific-led stage allowed Canada to develop the capabilities needed to build satellites tailored to meet its needs. Satellites were used to connect the population scattered around the country. In 1972 Canada launched *Anik A1*, built to connect the remote northern part of the country for the first time and in 1976 launched *Hermes*, the most powerful communication satellite at the time. Satellites were used to monitor Canada's huge landmass and vast sea area. *RADARSAT-1* and *RADARASAT-2* satellites were developed to perform detailed EO services both night and day through all weather conditions[14].

Canada has collaborated with USA since 1960 and with Europe since the 1970s and currently has the status of 'Associate member' within the European Space Agency (ESA). Moreover, Canada has an active role in major international space programs, is one of the few partners in the International Space Station (ISS), and is a heavy investor in new commercial and scientific satellite development.

SPACE POLICY

One of the most important national actors is the Canadian Space Agency (CSA) was established in 1989 with the mandate "*To promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians*"[15]. In the last 26 years CSA worked in order to achieve these goals. In 2012 (50th anniversary of the launch of *Alouette-I*) the government saw the necessity to reform and renovate Canadian space environment and published papers aimed to study Canadian situation. The process culminated in 2014 with the announcement of a new space policy framework[16], in which CSA states 5 principles for the next Canadian space policy and three way to achieve them. In particular, CSA aims to support national interests, increase Canadian industrial and scientific capabilities, specialise and excel in key capabilities, and inspire the next generation of Canadians through a focus on commercialisation, R&D objectives and exploration of space.

Ambitious programs like that of the CSA need strong organisational capabilities as well as important and stable investments. Emanating from the Ministry of Industry, CSA relies on ministerial funds for its ordinary activities, and on the Department of National Defence's funds for military-related activities. Even though in the 10 year period after 2001 Canadian space-related public budget suffered a 48% reduction, in more recent years the public sector had the capacity to invest with higher consistency in Canadian projects (as shown in Figure 3). For the financial year 2014-2015[17] [18] the total budget was estimated at CAD 462.45 million. The main programs currently funded and implemented by the agency are aimed to enhance downstream activities in the form of investments on space data, information and

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[14] Aerospace Review, 2012. *Reaching Higher: Canada's Interests and Future in Space*. Aerospace Review Publishing, Mandated by the Government of Canada. www.aerospacereview.ca.

[15] Canadian Space Agency, Mission and Mandate.
Canadian Space Agency website*: http://www.asc-csa.gc.ca/eng/about/mission.asp*. Accessed 19/04/2016.

[16] CSA, 2014. *Canada's Space Policy Framework: Launching the next generation*. CSA Publishing.

[17] Government of Canada. *The Canadian Space Agency. 2014-15 Estimates. Report on plan and estimates.* Government of Canada Catalogue Number: ST96-7/2014E-PDF.

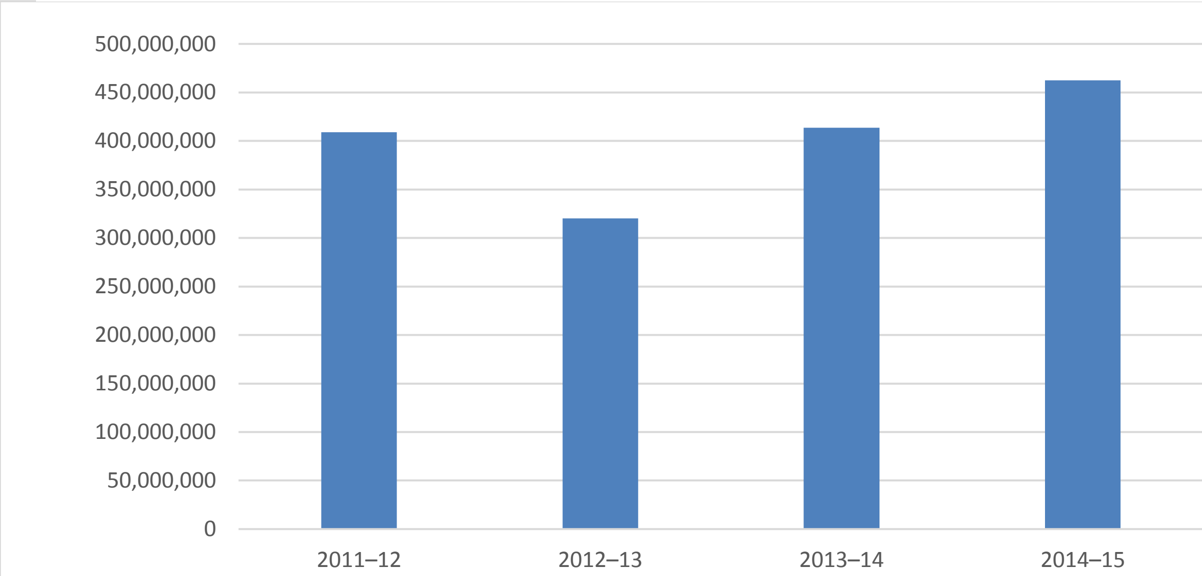
[18] Treasury Board of Canada Secretariat, 2014. Table 88.
Treasury Board of Canada Secretariat website: https://www.tbs-sct.gc.ca/ems-sgd/me-bpd/20142015/me-bpd02-eng.asp. Accessed 6/05/2016.

communication, with one of the main projects being to launch a new *RADARSAT* constellation before 2018. Other important investments are addressing 'space exploration', 'future Canadian space capacity' and 'internal services' (see Figure 4).

The CSA has always aimed to involve Canadians in space activities, and its continuous research has produced results. Canadian space capabilities and achievements are well publicised within the country, and the space industry is recognised for its fundamental contribution to Canadian economic and social growth.

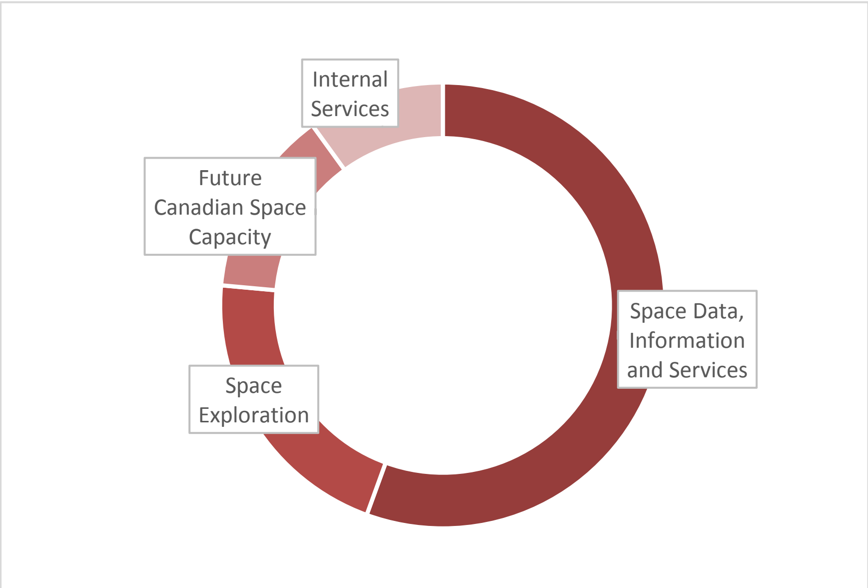
The CSA developed a vast network with many national and international space institutions around the world. Of particular relevance is its collaboration with the European Space Agency. As already mentioned, the CSA has had the unique status as an ESA's *associate member* since 1979. This relationship, supported by small financing to ESA (€ 15.5 million in 2015) allowed the Canadian space ecosystem to interact more closely with Europe's vibrant space environment and with Canadian space industry to compete and cooperate with European firms, fostering the two-way transfer of technologies between Europe and Canada.

Figure 3: Total Public expenditures in Canada's space industry (in CAD)



Source: OECD, 2014. The space Economy at a Glance.

Figure 4: CSA 2014-15 Budget Breakdown



Source: Treasury Board of Canada Secretariat, 2014. Table 88.

Industry composition

Canada has a reasonably well developed space industry, which employs 8,231 workers and generates a total of CAD 3.49 billion revenue. As seen in Figure 5, data[19] shows that, except for 2012, Canada's space revenue has always grown. More than 200 private firms are involved in the sector. Similar to other capital-intensive industries, the Canadian space economy is characterised by an oligopolistic structure, where the 10 biggest companies account for 88% of the revenue and for 64% of employment. Between the most relevant Canadian companies in the sector there are MacDonald, Dettwiler and Associates, a multinational communications and information prime company, and COM DEV, a Tier 1 Company specialising in international space sciences and telecommunications.

Government and the public sector has historically been a strong ally for the industry, with clear guidance and important investments aimed to support both large companies and SMEs. However, experts have noted that Canadian companies depend strongly on government contracts[20], and with the increasing commercialisation and internationalisation of the space economy, this excessive reliance could lead to competitive disadvantage. In fact, when public involvement decreased during the last decade (as seen before, the CSA budget between 2001-02 and 2013-14 suffered a 48% reduction) and the number of SMEs within the Canadian space economy decreased too[21].

Canada's particular geographic characteristics have been one of the first, and most relevant, enhancers for the development and the specialisation of its space economy. The necessity to monitor and to connect the country has enhanced the development of industrial capabilities, particularly in the fields of SatCom and EO. These sectors alone account for more than 90% of total Canadian space revenue. The Satellite communications sector accounts for nearly 80% of total revenue, and today Canada has 5 communication satellites (all owned by Telesat), and 2 more satellites will be launched in coming years (both by CSA). It is interesting to note that 76% of communication's revenue is derived from applications and services (i.e. a remarkable 60% of total revenue of the industry).

As Figure 5 shows, the Canadian space economy has a well-developed downstream segment. The importance of applications and services on overall revenue can be explained by the fact that space-derived services are enhancers for Canadian economy. When compared with international peers, Canada is assessed to be one of the most effective users of space services[22].

Exports account for 47% of total revenue, and rely mainly on US (42.5%) and European (31.4%) markets. In the overall aerospace sector, exports are significantly higher than imports. Canada is well positioned in the global value chain and possesses good capabilities in term of value creation.

The Canadian space economy sustains the creation and attraction of well-qualified, science-oriented workforce. Of the total, 35.1% of the employees have a science, technology, engineering or mathematics (STEM) background, and 52.9% are considered as 'Highly Qualified Personnel' (HQP is defined as individuals with university degrees of bachelors' level or above).

Canadian space manufacturing R&D intensity involves an impressive 28% of total revenue, outperforming sectors, such as pharmaceutical and automotive. Over the years Canada has been able to develop a wide variety of ground and satellite infrastructures. Consistent with its positioning in the global space economy's value chain, Canada is lacking only in terms of launch capabilities. However, the country has an impressive infrastructural capacity regarding R&D, space system design, development, integration and test, with a particular focus on Satellite Communications and EO[23].

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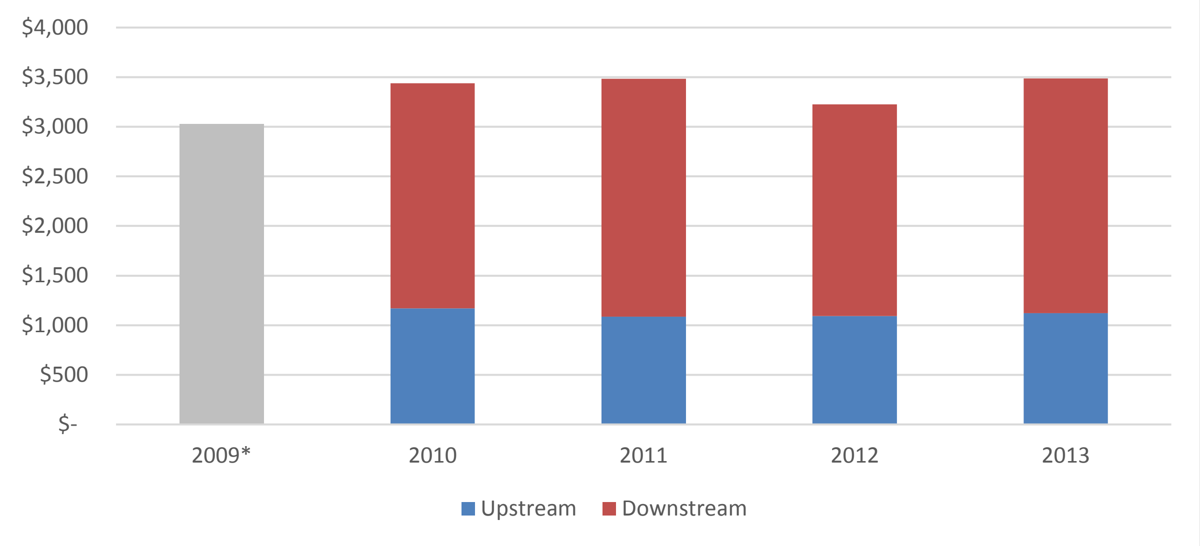
[19] Government of Canada, 2014. *State of the Canadian Space Sector 2013*. Government of Canada Catalogue No.: ST96-8E-PDF.
[20] Aerospace Review, Mandated by the Government of Canada, 2012. *Reaching Higher: Canada's Interests and Future in Space*. www.aerospacereview.ca.
[21] Lansdowne, 2012. *A Report on the Development of a National Space Infrastructure to support the Global Competitiveness of the Canadian Space Industry*. Lansdowne technologies Inc. Publishing.
[22] Futron, 2012. *Assessing Australia's Use of Space Products and Services: a Comparative Benchmarking Analysis*. Futron Publishing.
[23] Lansdowne, 2012. *A Report on the Development of a National Space Infrastructure to support the Global Competitiveness of the Canadian Space Industry*. Lansdowne technologies Inc. Publishing.

Figure 5: Canadian Space economy revenue, from 2009 to 2013 (CAD million)



Source: State of the Canadian Space Sector, 2010, 2011, 2012 and 20103 reports.
*(*breakdown data for 2009 not available)*

Figure 6: Composition of Canada space economy in2013

	Canada space economy		% of national share
Space Research	$	38.36	1.10%
Ground Segment	$	324.29	9.30%
Space Segment	$	763.65	21.90%
Downstream	$	2,364.19	67.80%
Total Space Revenues	**$**	**3,487**	**100%**

Source: State of the Canadian Space Sector 2013.

The real geographic hub for Canadian space industry is Ontario. It is the most populous province in Canada, where 38.5% population resides and 36.6% of the total GDP is produced. The province developed strong specialisation in space related sectors, and now Ontario employs 58.1% of the overall space workforce and produce 68.1% of the total space outcomes.

CHINA

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

China's involvement in space has always been important on the world stage and China's activities have led to internationally relevant results. However, until recently, the political and cultural Chinese context led the country to follow a radically different path from the one pursued by western countries. As opposed to countries in the western block, which have always presented a good rate of international cooperation, during the early stage of space development China was forced to develop space related technologies almost independently, as China has been isolated from the rest of the world for some time.

Chinese involvement in space activities dates back to the end of Korean War, when Mao Zedong realised that the current world superpowers were not considering China as a powerful player in the global political arena. Mao stated that China's development of a nuclear deterrent was one of the most important steps to achieve this acknowledgment.

Missiles and space, therefore, started to be considered as strategic assets for China's future, and in October 1956 China began its official involvement in space activities with the creation of the Fifth Academy of the Ministry of National Defence, the first Chinese organisation with the mandate to oversee national space activities. At the time, given the low qualification levels of Chinese workforce in the field, the Academy's main role was to set up basic expertise for the development of missile capabilities, technology needed both for nuclear deterrent and space exploration. During the same year the Academy organised scientific exchanges between Chinese and Soviet scientists, and Chinese scientists were sent to Moscow in order to set up collaborations with USSR, which at the time arguably possessed the most advanced rocket technology in the world. The Academy's strategy was to develop its own launch capabilities by imitating the Soviet *R-2* rocket and developing an Earth Observation satellite at the same time[24]. Collaboration effectively started and scientists worked on the plan until 1960, when diplomatic relationships between China and USSR deteriorated due to Mao's public endorsement against Nikita Khrushchev.

The so-called 'Sino-Soviet split' bore its effects on the Chinese space program, as communist engineers left China when local scientists had not yet developed the skills required to develop a rocket within short timeframes. Also the development of the EO satellite appeared impossible within contracted deadlines. The complexity of the tasks were significant, and now the country was isolated both from the West and from the USSR, its previous 'ideological' ally. For the following 40 years China's space sector developed in isolation and few collaborations occurred. Only in recent years has China started to set up the basis for new collaborations.

Undoubtedly this situation represented wasted opportunities and years of delay for Chinese space industry and exploration. However, despite its isolation, the country was able to achieve remarkable goals. Given the low Chinese capabilities at the beginning of the space era, the country showed an impressive capacity for endogenous growth.

Compensating for the harsh environmental conditions, politicians remained committed in space. After years of well-funded programs, and after the transformation of the Academy into an autonomous department, the Seventh Ministry of Machine Building Industry, in 1970 China finally launched its first satellite, the *Dong Fang Hong I*, with its own design and assembled *Chang Zheng-1* rocket.

After Mao's death in 1976, Deng Xiaoping came into power. During this period space received less attention, nonetheless the government carried out important reforms. The Seventh Ministry was transformed into the ministry of Space Industry in 1982, which was merged in 1988 with the Ministry of Aeronautics in order to create the Ministry of Aerospace Industry.

The collapse of the USSR brought a time of uncertainty and change. The Chinese environment was affected by global trends, and between the late 1980s and early 1990s Chinese society, and consequently its economy, experienced radical renewal. Jiang Zemin emerged as the new leader, completing reforms toward a new economic setting, characterised as a 'socialist market economy'. Space industry was involved in these changes too. In 1990, China entered the commercial launch

[24] Harvey B., 2004. *China's Space Program. From Conception to Manned Spaceflight*. Springer Publishing.

market[25], and in 1993 the Ministry of Aerospace Industry was split into the China National Space Administration (CNSA) and the China Aerospace Corporation (CAC).

CNSA is still active and assumes the main responsibilities of "*signing governmental agreements in the space area on behalf of organisations, inter-governmental scientific and technical exchanges; and is also in charge of the enforcement of national space policies and managing the national space science, technology and industry*"[26].

In order to pursue the capitalistic reform of the industry, in 1999 CAC was split into the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation (CASIC).

The idea behind CAC's transformation was to lose government control over space and aerospace industries and to promote a higher level of competition inside the sector by dividing the gargantuan CAC into two smaller conglomerates, no longer state managed but still owned by the Chinese government.

After these reforms China reached several important goals. In 2003 the national space program successfully achieved its first manned launch, being the third country in the world able to send men in to space with indigenous developed technologies. In 2013, moreover, Chinese performed the soft landing of *Chang'e 3* rover explorer on the lunar surface, the first since Soviet's *Luna 24* landing in 1976.

SPACE POLICY

Complexities emerge from the heterogeneous mosaic of bureaucratic offices involved in the space economy (Figure 7). The Chinese economy, despite the reforms carried out during the last 25 years, is strongly controlled and guided by the government, and these bureaucratic actors have a fundamental political and economic role.

Although there are no official records of it, analysis of the Chinese environment[27] find plausible (and perhaps necessary) the existence of a 'Space Leading Group', structured as per other bodies, called 'Leading Small Groups', common within China's governance model. This body has no mandatory power, rather it is a platform for dialogue between government, the Party and the military, resulting in a fundamental movement toward consensus-building around space issues. Although the group does not effectively provide policies, its recommendations give important guidelines for later policy decisions. Military involvement in space decisions is important not only for the traditional reason that rocketry involves national security, but also for a further one, specifically related to the Chinese case. While the rest of the world's space enterprise generally separates civilian and military spacecraft, China's satellites serve both for civilian and military purposes[28].

Space Leading Group recommendations are received by the General Armament Department (GAD) and by the State Administration on Science, Technology and Industry for National Defence (SASTIND), body of the Ministry of Industry and Information Technology (MIIT).

GAD is the military department responsible for Chinese weapons and equipment research, and because of the dual use of Chinese spacecraft, it has important influence over most of launch vehicles and satellite R&D.

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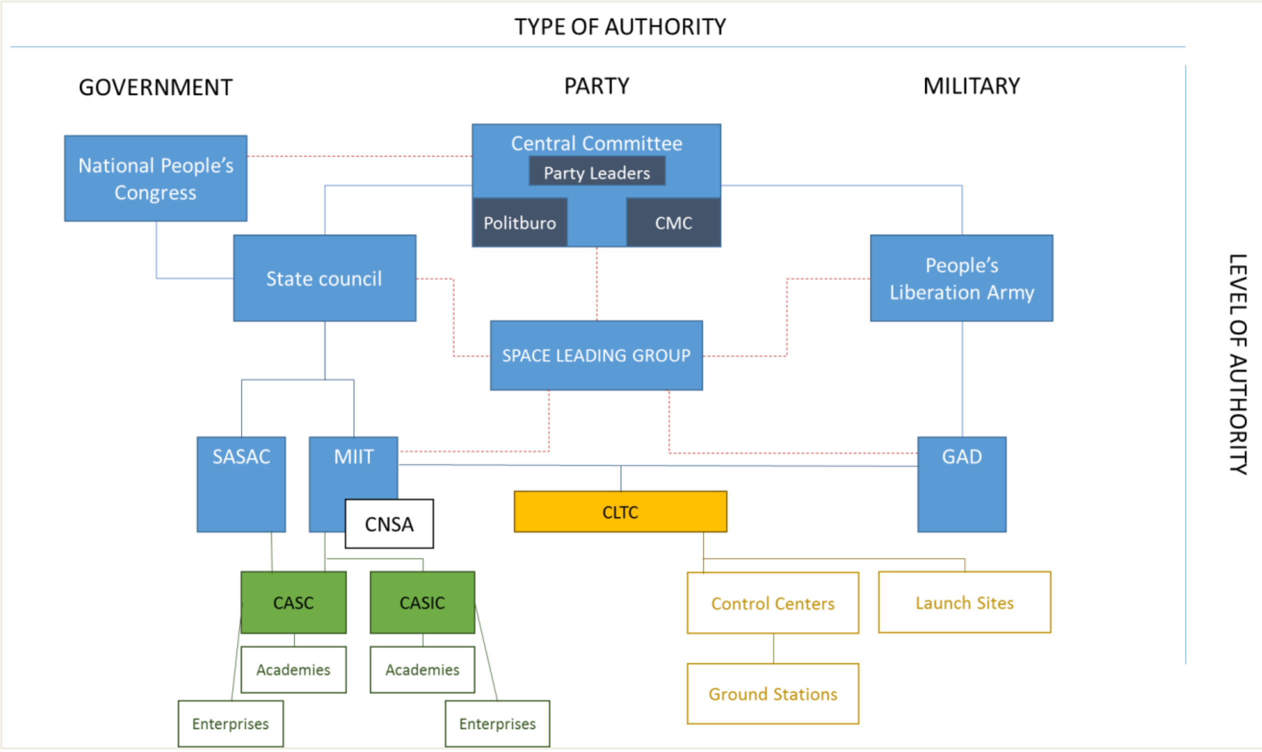
[25] Royal Aeronautical Society, 2013. *The Chinese Aerospace Industry: A Background Paper*. Royal Aeronautical Society Publishing.
[26] China National Space Administration, Organization and Function. China National Space Administration Website: http://www.cnsa.gov.cn/n615709/n620681/n771918/index.html. Accessed 4/05/2016.
[27] Aliberti M., 2015. *When China Goes to the Moon...* Springer Publishing.
Johnson-Freese J., 1998. *The Chinese Space Program. A Mystery within a Maze*. Krieger Publishing Company.
[28] Pollpeter K. et al., 2014. *China Dream, Space Dream. China's progress in Space Technologies and implications for the United States. A Report prepared for the U.S.-China Economic and Security Review Commission*. Institute on Global Conflict and Cooperation Publishing.

Figure 7: Organisation of Chinese space activities



Source: Re-elaboration from "Aliberti, M., When China Goes to the Moon..."

SASTIND, on the other hand, is a civil department under the MIIT, which has policy making powers and is responsible to manage defence related works and workforce, and seems to be in charge of the Chinese lunar program. The already cited CNSA act mainly as the liaison office between SASTIND and the international community and between SASTIND the Chinese aerospace industries[29], namely CASC and CASIC.

CASC and CASIC are the two most important conglomerates in the aerospace industry in China.

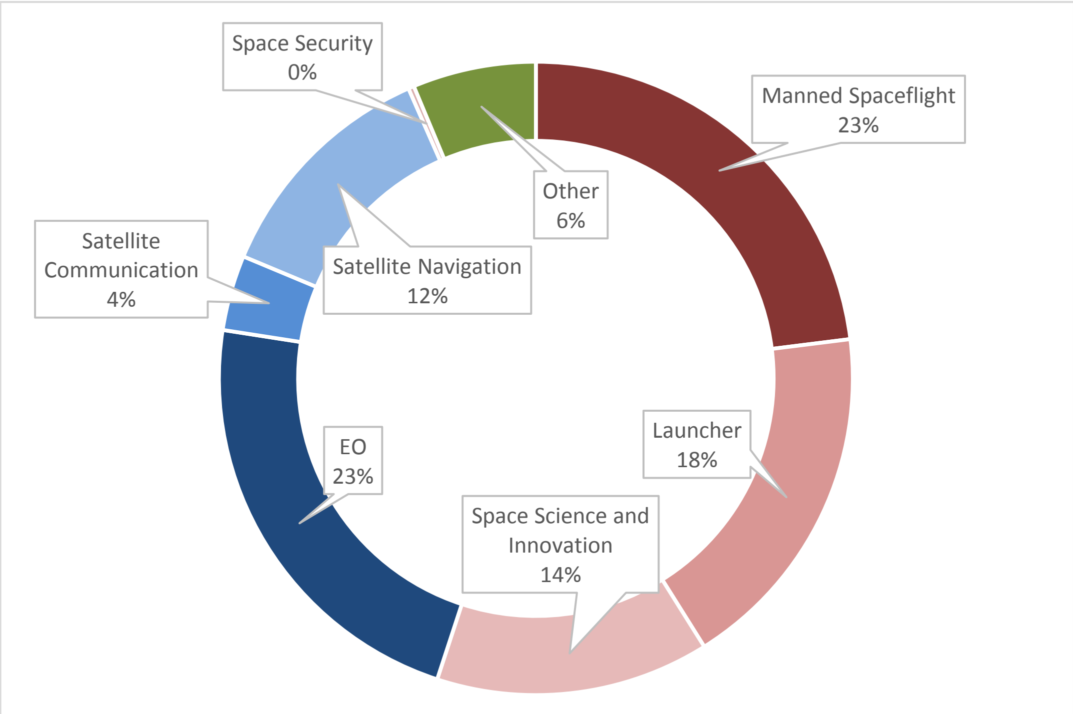
In particular, CASC is one of the most important actors in space industry. It is a state-owned company which conglomerates more than 130 companies, employs nearly 170,000 workers and has total assets for RMB 294.02 billion (nearly USD 45 billion)[30]. It is structured on 8 major companies, called 'Academies', scattered around the country. They are involved in research, design, development and assembly of many spacecraft like rocket launchers and satellites; but also in the downstream application of space derived products and services like IT, space applications, space commerce, financial investments or software services. Nonetheless, CASC is the monopolist provider of satellite broadcast communications. Nearly all the headquarters of CASC's academies are based in Beijing, Shanghai and Hong Kong areas.

CASIC, on the other hand, is mainly involved in the aerospace sector and has a direct connection also with the Army via GAD. Still, the company is an important player, conglomerating 570 institutes and industries across the country, with nearly 135,000 employees[31]. As its sister company, CASIC organised into 7 Academies which are engaged in research, development and production of defence related space systems, like air defence rockets or missile weapons. Moreover, the company is

[29] Aliberti M., 2015. *When China Goes to the Moon...* Springer Publishing.
[30] China Aerospace Science and technology Corporation, Company profile.
China Aerospace Science and technology Corporation website:
http://english.spacechina.com/n16421/n17138/n17229/c127066/content.html. Accessed 5/05/2016.
[31] China Aerospace Science and Industry Corporation, Company profile.
China Aerospace Science and Industry Corporation website:
http://english.casic.cn/n189298/n189314/index.html. Accessed 5/05/2016.

Figure 8: China's Budget Breakdown by Application (in USD million)

Application	
Manned Spaceflight	$ 790
Launcher	$ 620
Space Science and Innovation	$ 479
EO	$ 769
Satellite Communication	$ 132
Satellite Navigation	$ 416
Space Security	$ 10
Other	$ 216
Total	**$ 3,432**



Source: "Euroconsult, 2013. Government Space Markets. World Prospects to 2022. Euroconsult Publishing." via "Aliberti M., 2015. When China Goes to the Moon... Springer Publishing."

developing a space-ground integrated system for the main Chinese projects, like manned spaceflight and lunar exploration.

The China Satellite Launch and Tracking Control General (CLTC) is a body which acts under the conjunct supervision of SASTIND and GAD, concrete proof of the civil-military symbiosis in the Chinese space environment. The organisation is responsible for overseeing and manage China's 4 major launch sites, 3 main control centres, and all the integrated ground stations.

There is no official data on the total Chinese space budget. Many organisations, however, have tried to estimate the government's involvement in the space economy. One of the latest estimations was made by the Space Foundation[32], which calculated a total budget of nearly RMB 26.56 billion (USD 4.28 billion) total space spending in 2014. The most recent detailed breakdown for China's Budget is available for the year 2012[33]. As figure 8 shows, the insight estimates that the biggest investments are made in the upstream segment. In particular, the government invests strongly in manned spaceflight projects and in launch system development. More than 13% of the national budget is invested for Space

[32] The Space Foundation, 2015. *The Space Report 2015. The Authoritative Guide to Global Space Activity*. The Space Report Publishing.
[33] "Euroconsult, 2013. *Government Space Markets. World Prospects to 2022. Euroconsult Publishing*." via "Aliberti M., 2015. *When China Goes to the Moon...* Springer Publishing."

Science and Innovation, which gives usually low immediate returns but is essential to reduce the Chinese technological gap. Great effort is given to Earth Observation (23% of the budget), while Satellite Navigation and Satellite Communications (which usually generates more spill over effect in the economy) receive together only 16% of total funds.

Most of the publications and the literature regarding Chinese space economy focuses upon technological capabilities, data, and concerns regarding the upstream segment of the space economy, and in particular on the supply chain, while low attention is given to the downstream segment, to the space enabled services and application and in general, to all of the sectors that benefit from space technology. As shown in Figure 8, however, satellite communications and satellite navigation sectors are not main priorities for the Chinese government. Satellite communication in particular, is under the CASC monopoly, and future developments are threatened by the low competitiveness of the environment faced by Chinese companies.

Consistent with is original socialists background, Chinese economic policy is regulated and guided by so-called ‘5 years plans’. In 2001 China’s state council started to publish, in the form of a White Paper, 5 year plans specifically for the space economy. These white papers have been an important tool to increase the transparency of the space program[34]. The next plan will be released later this year, and the last plan available is “China Space Activities in 2011”, which set space policy strategy for the 2011-2015 period. Relying on 2011’s White Paper, four guidelines have driven China’s latest space involvement. In particular, while adhering to the concept of the peaceful use of outer space and encouraging the creation of a national vibrant innovation ecosystem through space technology applications, China envisages keeping technological and operational independence of its space industry but, at the same time, balances this self-reliance with increasing international cooperation.

In order to improve its space transportation and launch capabilities China has invested to upgrade and enlarge the *Chang Zheng* missile family with newer, more efficient and more reliable rockets. Since 1970, 178 launches over 186 have been successful, with a remarkable 95.7% launch success rate.

At the same time China designed spacecraft capable of reaching the Moon, and planned for the next decade to reach Earth’s satellite with a manned expedition. Moreover, China is developing the *Tiangong* project, a large modular space station comparable to the former Russian *Mir* space station.

If it is remarkable that all these goals, until today, have been achieved almost independently, it is also true that due to isolation, Chinese space technologic capabilities are now lagging behind world’s best practices. *Tiangong*, as stated, is comparable with the *Mir* space station, which ceased its activities in 2001. China has scheduled a landing on Mars surface in the next decade, while the US has already reached Mars’s surface three times.

It is useful to reiterate that one of the guidelines indicated in the last white paper aimed to increase efforts in international cooperation. This has certainly begun to happen. In the last few years China launched a new era of cooperation with different countries around the world. Important collaborations, in particular are being carried on with Roscosmos, with the intention to allow Chinese astronauts inside the ISS; and with ESA, with the intention to implement the *Discovering the Sky at the Longest Wavelengths* (DSL) project. China is strengthening its networks in South-Eastern Asia and in the Asia-Pacific region. This path however, is not easy, and there are many obstacles for China’s full integration into the global space circuit. One of the most inhibitive is represented by the US congress statement, issued in 2011, to ban NASA from having any bilateral or multilateral collaboration with Chinese organisations and individuals.

[34] Pollpeter K., 2012. *China’s Space White Paper: Increasing Transparency…to a Degree*.
The Jamestown Foundation website:
http://www.jamestown.org/programs/chinabrief/single/?tx_ttnews%5Btt_news%5D=38968&cHash=4a58f0b2d730affbf09a52dd75c80909#.VyrQfIR961s. Accessed 5/05/2016.

FRANCE

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

Since the end of WWII, France has been an important player in the evolution of the space environment, particularly in Europe. Alongside the other victorious countries, France's initial space technology development came due to the possibility to study the technological capabilities of the defeated German army. Accordingly, France studied the *V-2* rocket, which was at the time the most advanced missile technology available, and nearly 40 German engineers and scientists were forced to continue their studies under French supervision. As was common at the end of the 1940s and beginning of the 1950s, French space endeavours were aimed at this time to develop independent rocketry capabilities. Subsequently, in 1949, the *Laboratoire de Recherches Balistiques et Aérodynamiques* (Laboratory for Ballistic Research and Aerodynamic, LRBA) was created, and in 1952 *Veronique*, the first French rocket, was successfully launched[35].

At the end of the 1950, however, France was lagging behind the US and USSR superpowers. In 1958 General de Gaulle was re-elected president, and its *grandeur* policy stimulated even further French space ambitions. In 1959, in order to develop more advanced rockets in collaboration with LRBA, the *Société pour l'étude et la réalisation d'engins balistiques* (Society for the study and the realisation of ballistic missiles, SERB) was founded, while in 1961 the *Centre national d'études spatiales* (National Centre for Space Studies, CNES) the French space agency was created, with the mandate to organise French space activities. Remarkably, France was the first European nation to establish a space agency.

Under CNES sponsorship began the development of the *Diamant* rocket family, while in 1965 the French designed and built the *Asterix* satellite, successfully launched aboard a *Diamant* missile. France was the third nation, after USSR and USA, to autonomously send a satellite into space.

These years coincided with the first attempts of European cooperation: despite the significant successes, France and some other space-involved European countries realised that they couldn't alone obtain the same accomplishments achieved by USSR and US; and thus ELDO and ESRO were created. Coordinating 6 European countries, ELDO was committed for the development of the *Europa* launcher. However, the organisation was not able to develop a capable and competitive launcher, and in 1972, after the announcement of American Space Shuttle program, European countries ceased *Europa*'s funding and ELDO ended its activities. However, ELDO's and ESRO's legacies survived: in 1973[36] ESA was born and the French proposal of a new, and more developed launcher was approved[37]. This launcher is *Ariane*, Europe's most important access to space with more than 227 launches performed in the last 37 years.

France has always been one of the ESA's most important financiers, and with *Ariane* the country increased its pivotal role. Over the decades France became the European leader in the launch industry, and since the 1970s all European launches have been conducted at CNES *Guiana Space Centre* in French Guiana (operated together with ESA).

SPACE POLICY

France has always put great effort into the development of its space capabilities, and CNS itself has always been heavily funded from the French government. In 2015 France dedicated to space activities € 2.12 billion, being the first investor in Europe. With nearly € 30 dedicated per inhabitant, France is the 2nd highest per-capita space investor value in the world[38]. As Figure 9 shows, in recent years France

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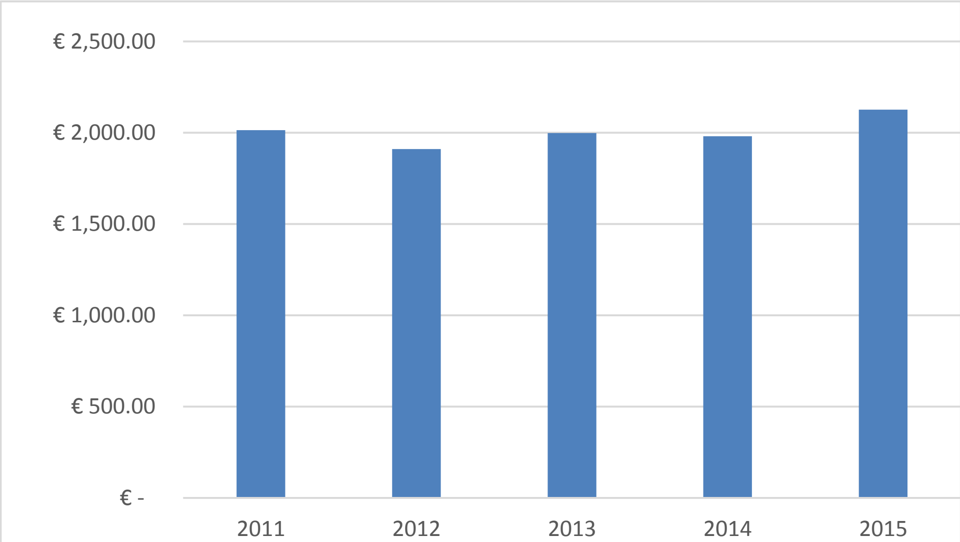
[35] Miselem C., 2014. *History and Analysis of French Contributions to Space Exploration.*
[36] ESA, 2014. *ELDO/ESRO/ESA: Key dates 1960-2014*. ESA website: http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/ELDO_ESRO_ESA_br_Key_dates_1960-2014. Accessed 18/05/2016.
[37] ESA, 2014. *Thirty-five years of Ariane: how Ariane was born*. ESA website: http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/Thirty-five_years_of_Ariane_how_Ariane_was_born. Accessed 18/05/2016.
[38] CNES 2014, *Le 2ème budget au monde*. CNES website: https://cnes.fr/fr/web/CNES-fr/11507-le-2eme-budget-au-monde.php. Accessed 18/05/2016.

has sustained important space-related public investments (nearly € 2 billion per year), although some budget reductions were caused by the European financial crisis.

France commits more resources than any other European country in space activities, and historically the country has always had a *de facto* leadership position regarding the ESA's activities[39].Despite this important involvement, France is only the second contributor to ESA, even if at close call with Germany (ESA's largest contributor). This happens because, as Figure 10 shows, French space program allocates only 38% of its budget to ESA's activities, a share considerably lower than other ESA's major contributor. To provide a comparison, Germany, ESA's first contributor, Italy, third, and UK, fourth, allocate to ESA respectively 61%, 78% and 75% of their budgets.

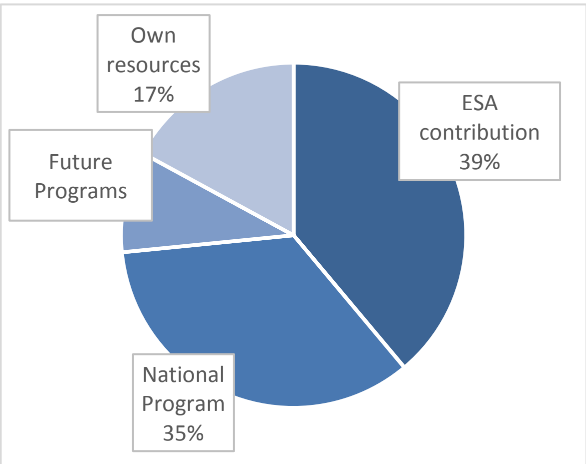
Unlike most of other ESA's members, France divides as equally as possible its budget spending between ESA's programs and the programs run outside ESA, either by France alone or in extra-European multilateral collaborations (e.g. the ChemCam laser involved in NASA's Mars Science Laboratory mission)[40].

Figure 9: France's Space Budget



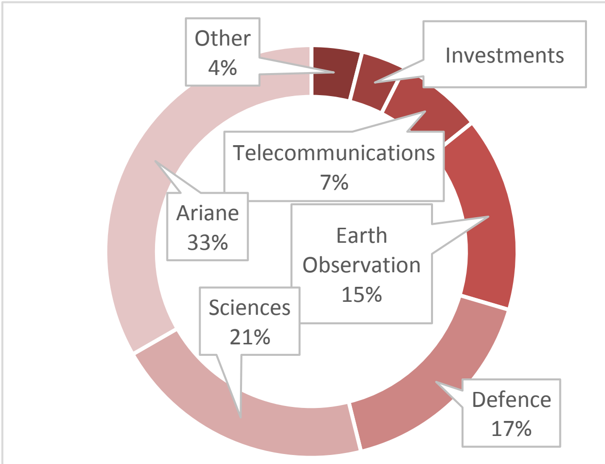
Source: CNES, 2012. Rapport d'activité 2012; OECD, 2014: The space Economy at a Glance; and CNES 2014, Le 2ème budget au monde.

Figure 10: CNES Budget Breakdown by Destination



Source: CNES, Le 2ème budget au monde.

Figure 11: CNES Budget Breakdown by Program Area



Source: The Space Report 2015. The Authoritative Guide to Global Space Activity.

[39] Handberg R., 1995.*The Future of the Space Industry: Private Enterprise and Public Policy*. Greenwood Publishing Group.
[40] de Selding P., 2012. *CNES Budget Increasing 6 Percent in 2012 Thanks to Bond Issue*. SpaceNews Website: http://spacenews.com/cnes-budget-increasing-6-percent-2012-thanks-bond-issue/#sthash.Ca0Kw7O3.dpuf. Accessed 19/05/2016.

INDUSTRY COMPOSITION

France's long intensive involvement in space led French industry to have the largest space economy in Europe, and one of the largest in the world. French space policies work to position the upstream segment in order to maximise the export share. This approach led the industry to focus mainly on the upstream segment: few studies are made and minimal data are provided for the downstream applications of the industry. However, this focus on the manufacturing led to astonishing results.

Only the third largest economy in Europe, France's efforts in space activities led the national space manufacturing industry to employ, in 2014, 15,000 workers[41] (the second largest European space manufacturing economy, Germany, employs 8,300 workers), and to generate € 6.91 billion in revenue, resulting the largest space economy in Europe. As shown in Figure 12, the most relevant sector in France's space manufacturing industry is the production of space systems, followed by the production of propulsion systems and finally, equipment manufacturing.

Similarly to what happens in other countries, French space economy is highly concentrated. In particular, France has some of the largest space prime manufacturers. The most important French prime contractors are Airbus Space and Defence, and Thales Alenia Space. These companies receive commissions directly from governments, space agencies or commercial companies to build complete spacecraft systems. It is interesting to note that Airbus is a Franco-German company, while Thales is Franco-Italian. Reasons behind this fact include the high capital intensity in the space industry, which led to a conglomeration process which characterised the European and the French context.

Other relevant French companies are Snecma, a subsidiary for Safran's space-related space subsystem manufacturing, and Sodern, specialising in the manufacturing of major electronic equipment.

France's space industry is often seen as a subcategory of the broader French aerospace industry. In this view, French space industry is a small niche of the overall industry, representing only the 8.1% of the total aerospace employment but the 13.6% of the global revenue. This discrepancy shows that French space industry is more productive than the already productive aerospace industry. French space workforce is highly qualified, and nearly 60% of the employees have an engineering or managerial background.

Among the reasons behind French space competitiveness there is the well-organised cluster-based approach in space and aerospace industrial development. French cluster initiatives tend to coordinate the distribution of R&D tasks by region, trying to avoid double or redundant funding[42]. Major clusters for space production and R&D are in Toulouse, Paris and Provence[43].

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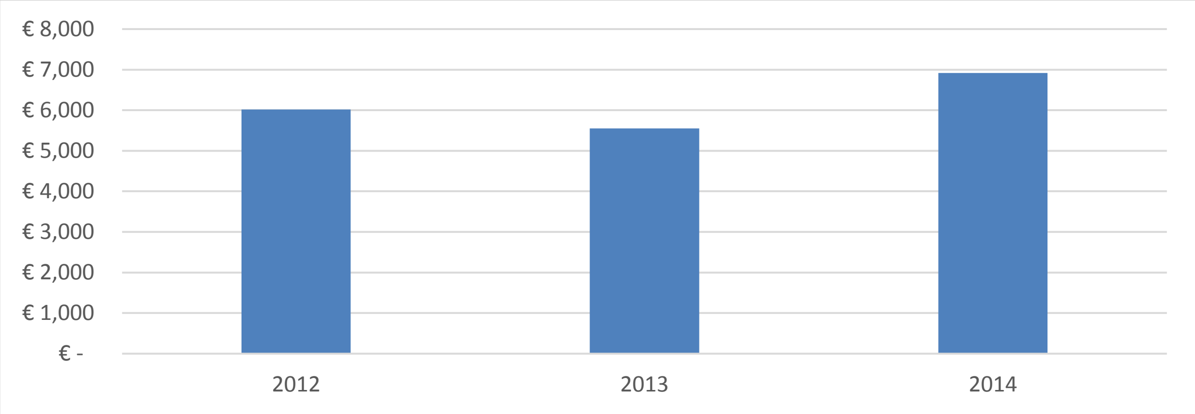
[41] GIFAS, 2014. *Annual Report 2014-2015*. GIFAS Publishing.
[42] ECORYS, 2009. *Competitiveness of the EU Aerospace Industry with focus on: Aeronautics Industry.*
[43] OECD, 2014. *The space Economy at a Glance*. OECD Publishing.

Figure 12: France Space industry upstream segment revenues (in € million)



Source: GIFAS. 2014. Annual Report 2014-2015.

Figure 13: 2014 sectorial composition of France's space upstream segment (in € million)

Space system manufacturers	€	6,256
Propulsion system manufacturers	€	375
Equipment manufacturers	€	286
Total	**€**	**6,917**

Source: GIFAS, 2014. Annual Report 2014-2015.

GERMANY

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

The very first German involvement in space activities can be dated back in Post-World War I period, and were strictly connected with the economic and military restrictions of the Treaty of Versailles and the subsequent wounded national pride. In fact, one of the main focuses of the treaty was to disarm German military capabilities. Germany therefore, was banned from possessing and developing any kind of heavy artillery, but no mention was made of rocket technology. In order to rearm the army, German engineer Karl Emil Becker was charged with developing rocketry capabilities able to replace artillery. After the advent of the National Socialist party, the development of rocket capabilities for military experienced a remarkable boost, and in 1936 the *Peenemünde* Army Rocket Range was opened where the first modern rocket technologies were developed.

After the loss of World War II, Germany again suffered the demilitarisation of its army. Peenemünde was dismantled and in the 1945-1955 period rocket technology was completely banned. In this period, most German rocket engineers were forced to work for the victorious Allied powers, allowing the creation of the very first rocket (and therefore space) capabilities in those countries. The most famous and emblematic example is the case of Wernher von Braun, the German engineer developer of the *V2* rocket, widely regarded as one of the fathers of the American space program, which developed *Saturn* V, the rocket used in the Apollo program first and later also in the *Skylab* mission.

German involvement in space however did not end. After 1955 the restriction ceased and in 1957, after the launch of *Sputnik*, European countries understood the necessity to join resources and capabilities. West Germany, with its industrial and scientific aptitudes, became an active player in the European space race. In order to develop a solid national space program, since then Germany has tried to balance its space efforts between the involvement in European multilateral partnerships (ELDO, ESRO, and later ESA), and the involvement with bilateral partnerships, mainly with the United States.

In particular, since the 1950s Germany has perceived the necessity to cooperate with the United States in order to recover the technological gap that grew after 1945. The first German achievement in the post-war period was the result of this collaboration. *AZUR*, West Germany's first satellite, was launched in 1969 in collaboration with NASA, and the more sophisticated *Helios* twin satellites, launched in 1974 and in 1976, were developed in a joint venture with NASA. Germany, moreover, was NASA's main partner in the *Spacelab* missions during the 1980s, which gave a fundamental contribution for the later development of further space stations, including the ISS.

In the European context, Germany was asked to take part in the ELDO program by providing the third stage of *Europa*, the European launcher. After some negotiations, which included a closer collaboration with NASA, Germany entered into the project[44]. After the withdrawal of the United Kingdom from the organisation, Germany increased its share in the project, and became one of the main actors in the creation of the new European Space Agency in the 1970s. This agency was created both for the necessity to join its forces in the wider European context and due to the political willingness to promote European integration.

SPACE POLICY

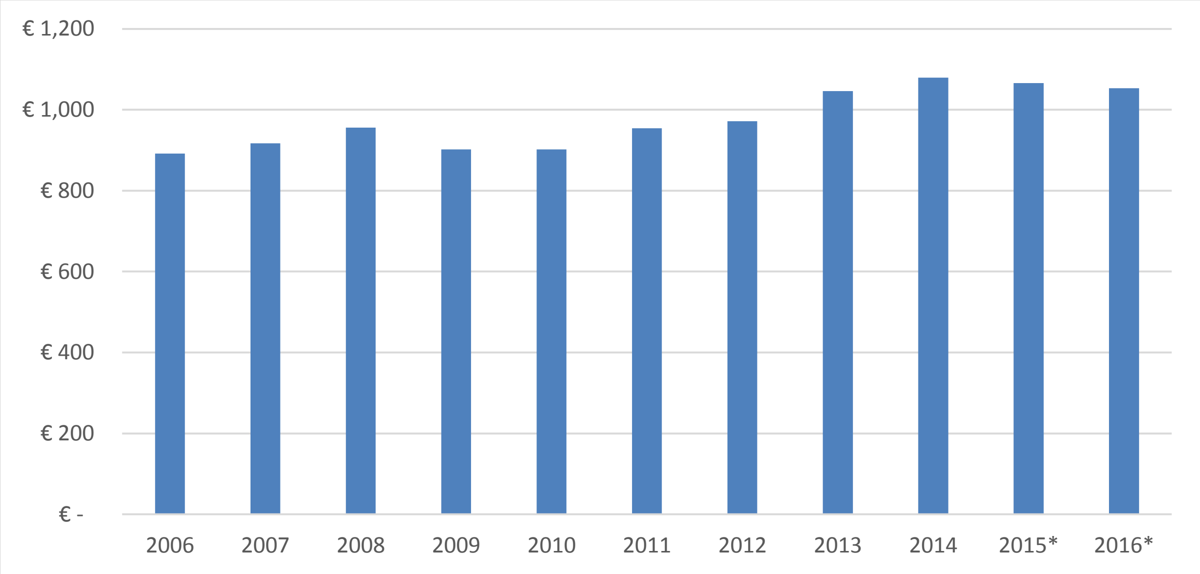
The necessity to administer space activities led to the creation of the first space-dedicated organisation in 1969, with the creation of the German Research and Testing Institute for Aviation and Spaceflight. After German reunification, in 1989, the institute was transformed into the German Research Institute for Aviation and Spaceflight and collected all the space-related assets present in the former East Germany. Finally, in 1997 the Institute merged with the German Agency for Spaceflight Affairs, forming the *Deutsches Zentrum für Luft- und Raumfahrt* (German Aerospace Centre, DLR), which is Germany's governmental body dedicated to the coordination of German space efforts[45].

[44] Trischler H., 2002. *The "Triple Helix" of Space German Space Activities in a European Perspective*. ESA Publishing.
[45] DLR, 2014. *The German Aerospace Center*. DLR Publishing.

However, DLR does not have the sole responsibility for space activities. The agency encompasses a wider role of research enhancer in the fields of aeronautic, transport, defence and energy. Space-related activities, however, remains the core of DLR's efforts.

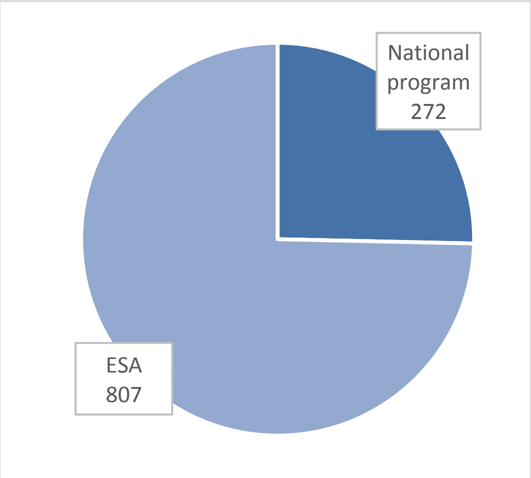
As shown in Figure 14, Germany has always dedicated important resources to space activities, allocating € 1.08 billion in 2014. As shown in Figure 15, € 807 million are allocated to ESA's contributions, making Germany ESA's largest contributor, slightly ahead of France. These funds are committed for a remarkable variety of different purposes, but the most important ESA programs funded with German money are: the ISS project; the development of a new version of the *Ariane 5* launcher (in oppositions to the French vision to develop a brand new *Ariane 6*)[46]; ESA's SWARM mission, dedicated to the study of Earth's magnetic field; and the development of *PLATO*, a space-based exoplanet observatory[47].

Figure 14: DLR Space Administration Funding Budget (in € million)



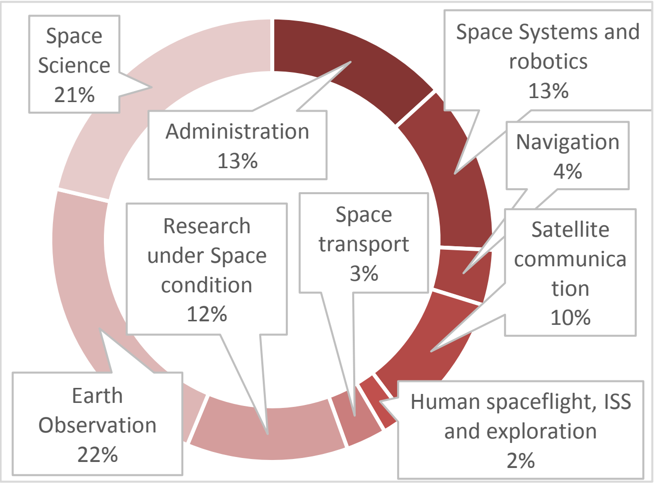
Source: DLR Research Report and Economic Development, 2006/2007 - 2014/2015 editions.

Figure 15: 2014 DLR Budget Breakdown by Destination (in € million)



Source: DLR Research Report and Economic Development,. 2014/2015 edition

Figure 16: 2014 DLR National Program's Budget Breakdown



Source: DLR Research Report and Economic Development., 2014/2015 edition

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[46] Clark S., 2014. *Germany calls for redesign of next-generation Ariane.* Spaceflight Now website: http://www.spaceflightnow.com/news/n1403/27ariane6/#.V0UPxfl961t.
Accessed 25/05/2016.

[47] The Space Foundation, 2015. *The Space Report 2015. The Authoritative Guide to Global Space Activity*. The Space Report Publishing.

The remaining contributions, € 272 million, are destined for the development of the national program. The agency is organised into eight specialist programs. As Figure 16 shows, the most funded program is the one dedicated to Earth observation (for example, with the development of the *TerraSAR-X* and *TanDEM-X* twins satellites); followed by space science; space systems and robotics; research under space conditions; and satellite communications. Navigation, space transportation and human spaceflight account together only the 9% of the overall national budget, as researches and activities in these fields are usually delegated at European level (e.g. the *Galileo* satellites for European navigation, or the ISS program and the development of *Ariane*, mainly funded through ESA).

As previously mentioned, Germany has developed a wide network of partnerships outside Europe. Without considering the already-cited collaborations with NASA, DLR signed a Memoranda of Understanding and bilateral agreements with Algeria, Brazil, China, Israel, Japan, Canada, Kazakhstan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, and Ukraine.

INDUSTRY COMPOSITION

Similarly to other mainland European largest space economies, Germany's focus in space activities concentrates mainly on the upstream segment of the industry, in particular on the manufacture and production of space crafts and space system and subsystems, while few reports provide an inclusive study of the broader downstream industry, including the space-space enabled services and applications. Nonetheless, the last space strategy, developed by the ministry of Economics and Technology (BMWi), specifically addressed the downstream applications, stating that "*German industry must display creativity and entrepreneurial spirit if it is to establish a presence in world markets, both with space products themselves and with downstream services*"[48].

As a matter of fact, German space industrial production, i.e. the upstream activities like space system, launch systems and ground systems production, is the second largest in Europe, accounting 8,300 employers and generating € 2.5 billion revenues in 2015[49]. As it is possible to observe in Figure 17, however, in recent years revenue started to lower its growth rate, resulting in a flat growth between 2014 and 2015.

Supporting the space manufacturing environment, Germany has the second largest aerospace economy in the Euro-zone, generating € 34,664 million of revenue and employing 106,800 workers in 2015. Overall exports in the aerospace industry overcome imports by 1.6 times, proving that Germany's manufacturing focuses on the production of high-value and sophisticated goods.

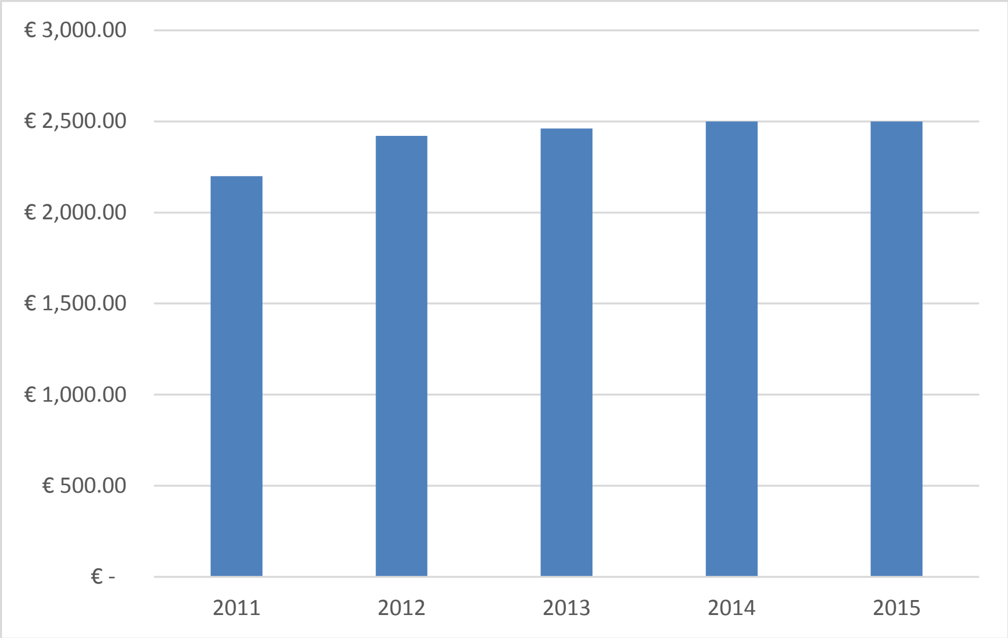
German aerospace and space industries are mainly concentrated in the southernmost part of the country, in particular in Bavaria and Baden-Württemberg. Bavaria developed its cluster between the late 1950s and early 1960s, when, due to important state-driven investments, the *Industrieanlagen-Betriebsgesellschaft* industrial complex was created[50]. The development of the space sector in Baden-Württemberg, on the other hand, can be attributed to the number of research organisations in the state, and in particular to the University of Stuttgart[51]. Another important industrial cluster is based in Bremen, Headquarter of OHB System, one of the most important space prime contractors.

Other important companies based in Germany are Airbus Space and Defence (which is a Franco-German company) and Tesat-Spacecom, an Airbus owned company that produces major subsystems and equipment for telecommunication via satellite.

Additionally, Germany is the home of many highly sophisticated infrastructures. The Institute of Space Systems in Bremen and the Institute of Aerodynamics and Flow Technology in Göttingen are important R&D space-related facilities; while the European Astronaut Centre in Cologne is a centre for the training

[48] BMWi, 2010. *Making Germany's space sector fit for the future. The space strategy of the German Federal Government.* BMWi Publishing.
[49] BDLI, 2016. *Key Figures of the German Aerospace Industry 2015*. BDLI Publishing.
[50] Trischler H., 2002. *The "Triple Helix" of Space German Space Activities in a European Perspective*. ESA Publishing.
[51] OECD, 2014. *The space Economy at a Glance*. OECD Publishing.

Figure 17: German Space industry upstream segment revenues (in € million)



Source: BDLI Key Figures of the German Aerospace Industry, 2012 and 2015 editions.

of European astronauts. Moreover, Darmstadt house ESA's European Space Operations Centre, one of ESA's most important ground stations[52].

[52] Lansdowne, 2012. *A Report on the Development of a National Space Infrastructure to support the Global Competitiveness of the Canadian Space Industry*. Lansdowne technologies Inc. Publishing.

INDIA

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

India's first steps into space began in 1961, when Indian Prime Minister Jawaharlal Nehru decided to set up a space program and established, together with scientist Vikram Sarabhai, the Indian National Committee for Space Research (INCOSPAR). A decade after its foundation, as the organisation grew, in 1969 it was transformed into the Indian Space Research Organisation (ISRO), the Indian space agency. In 1972, in order to coordinate military, civil, and commercial space activities, the Department of Space (DoS) was formed and the ISRO was moved under its aegis[53].

At the beginning of its activities, ISRO had nearly no competencies and infrastructures for the development of its space program[54]. However, the work of the agency was fruitful, and after some years India was able to design and assembly its first satellite, *Aryabhata*, was sent into space in 1975 aboard of the Soviet launcher *Kosmos-3M*. After the success of *Aryabhata*, India collaborated with NASA for the development of the Satellite Instructional Television Experiment (SITE) project, one of the first attempts at satellite TV and radio broadcasting. After the success of SITE, Indian capabilities in satellite communication grew. In 1983 India commissioned the creation of the Indian National Satellite System (INSAT) project, a constellation of satellites[55] (still updated and in use, the last INSAT satellite was launched in 2014) which provides broadcasting, communication and meteorologic data. Due to the INSAT project, the country developed competitive capabilities in space manufacturing and many countries started to buy Indian-made satellites, making India an important actor in the space environment.

At the same time ISRO started to work to ensure India's independent access to space. In 1980 the agency launched a satellite with the autonomously designed and built *Satellite Launch Vehicle-3* (SLV-3)[56]. India's competencies in the field strengthened, and two new rockets were developed: the *Polar Satellite Launch Vehicle* (PSLV) in 1993 and the *Geosynchronous Satellite Launch Vehicle* (GSLV) in 2001.

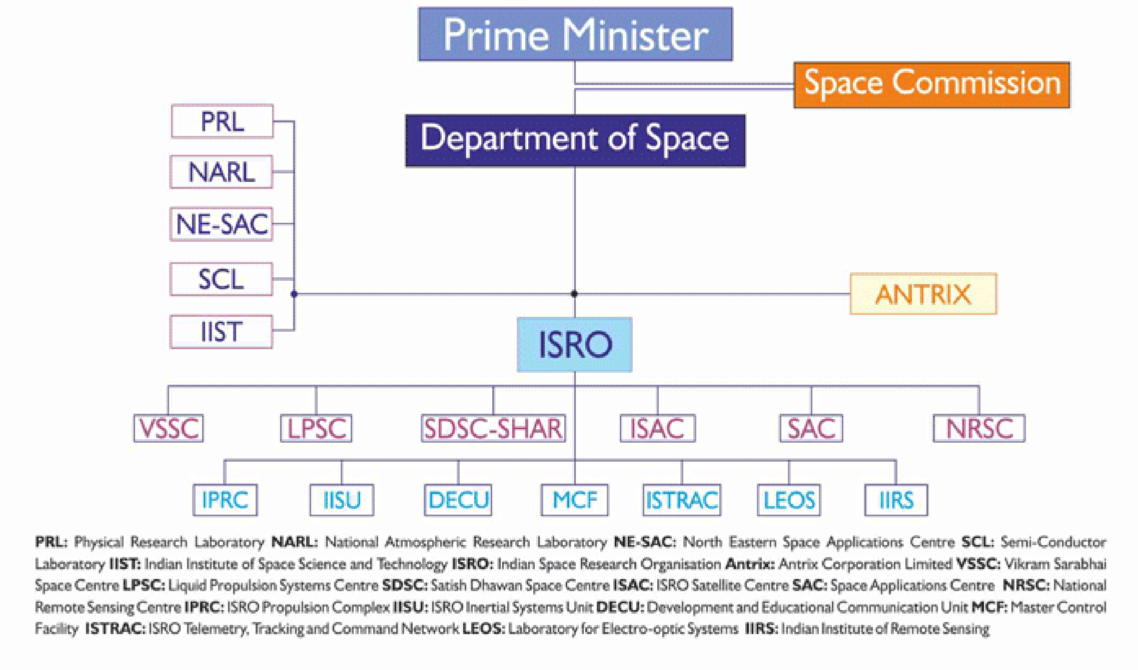
Lately, India has started to increase its efforts in space science. In September 2014 the Indian-made *Mangalyaan* space probe started to orbit around planet Mars. The mission is a unique case in space exploration, as it costed only USD 73 million. Although there were diminished scientific capabilities of the probe, it demonstrated India's capacity to access outer space at an incredibly low cost[57]. ISRO, together with Roscosmos, planned to send a rover to the lunar surface in 2018.

SPACE POLICY

The Indian government dedicates great consideration to the Space Industry. Space policies are settled from the government through the 'Space Commission'. The decisions are absorbed by the previously mentioned DoS, which coordinates and implements the activities via ISRO, *Antrix*, and several space centres and laboratories spread across the country[58].

[53] Chakrabarti C., Bhargava P.M., 2003. *The Saga of Indian Science since Independence: In a Nutshell*. Universities Press (India) Publishing.
[54] Narasimhan T., 2015. *The 40-year journey of India's space programmes*.
Business Standard website: http://www.business-standard.com/article/current-affairs/indian-space-s-40-years-journey-from-launching-358-kg-satellite-to-3-000-kgs-satellite-115042000728_1.html. Accessed 06/06/2016.
[55] Roychowdhury A., 2016. *From Aryabhata to RLV-TD: A history of India's space journeys*.
The Indian Express website: http://indianexpress.com/article/research/isro-rlv-td-history-of-indias-space-research-space-activities-space-journeys-isro-launches-reusable-launch-vehicle-spacecraft-2815247/. Accessed 06/06/2016.
[56] Encyclopædia Britannica. *Indian Space Research Organisation (ISRO).* Encyclopædia Britannica website: http://www.britannica.com/topic/Indian-Space-Research-Organisation. Accessed 06/06/2016.
[57] Amos J., 2014. *Why India's Mars mission is so cheap - and thrilling*.
BBC News website: http://www.bbc.com/news/science-environment-29341850. Accessed 06/06/2016.
[58] ISRO. *Department of Space and ISRO HQ*.
ISRO website: http://www.isro.gov.in/about-isro/department-of-space-and-isro-hq. Accessed 06/06/2016.

Figure 18: Organisation of India's space activities



Source: Department of Space Structure. Department of Space website: http://www.dos.gov.in/node/79. Accessed 06/06/2016.

Established in 1992, *Antrix* is a commercial state-owned corporation with the mandate to commercialise and sell in the international market ISRO's technologies and services[59].

ISRO is India's space agency. Strictly controlled by the government (the chief of the agency is also the chairman of the Space Commission and the secretary of the DoS), ISRO has the mandate to coordinate the Indian space program. ISRO's projects include "*satellite communication, earth observation, launch vehicle, space science, disaster management support, sponsored research scheme, contracts management, international cooperation, safety, reliability, publications and public relations, budget & economic analysis, civil engineering and human resources development*"[60].

The importance of the Space Agency in the Indian space environment is enhanced by the fact that, differently from all other space agencies in the world, ISRO develops, designs and assembles spacecraft within its organisation, without commissioning external private companies. Even if the Space Commission stated the necessity to increase the capabilities of the private industry, ISRO remains a *de facto* monopolist in the Indian space economy. This is one of the main reasons that made ISRO the world's largest space agency in terms of employees, with 18,560 workers in 2014[61].

In order to maintain its important commitment in space, since 2009 the Indian government has invested growing resources in ISRO's activities. ISRO's overall budget for the fiscal year 2016-2017 amounted to INR 75.09 billion[62] (nearly USD 1.12 billion).

Nearly 70% of these funds are allocated for the development of space technologies. Among space technologies, the largest effort is made in space launchers and, in particular, in the development of the new GSLV-MkIII, a more powerful rocket capable to send up to 8 tons to Low Earth Orbit, allowing India to send autonomously its heavy commercial communication satellites. The GSLV-MkIII is planned to be the rocket that will send Indian astronauts into space before 2021.

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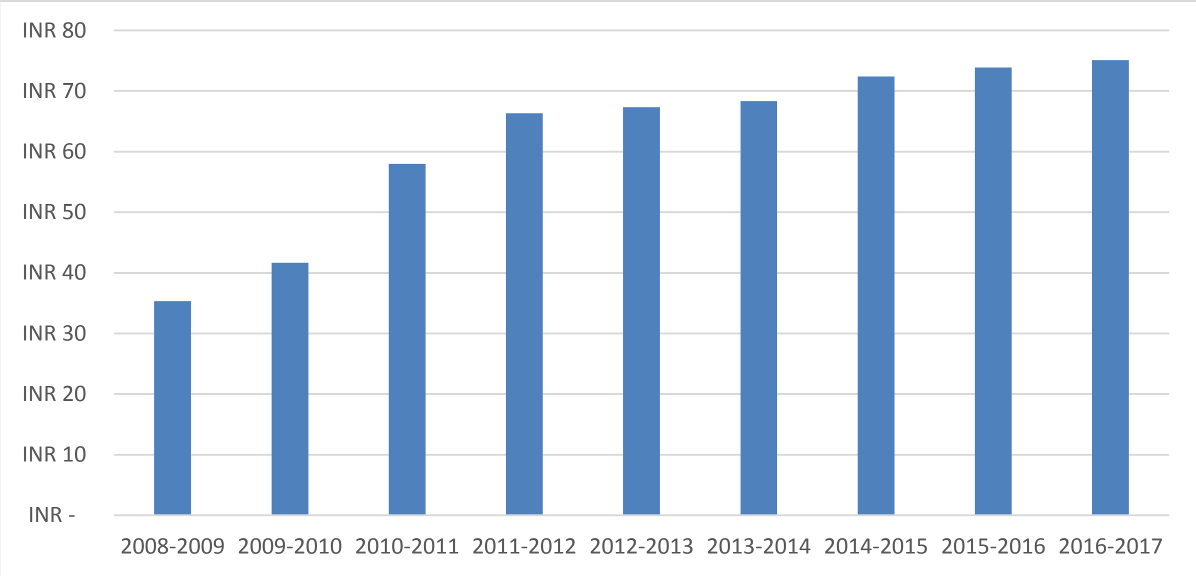
[59] ISRO. *Antrix Corporation Limited*.
ISRO website: http://www.isro.gov.in/about-isro/antrix-corporation-limited. Accessed 06/06/2016.
[60] ISRO. *Department of Space and ISRO HQ*.
ISRO website: http://www.isro.gov.in/about-isro/department-of-space-and-isro-hq. Accessed 06/06/2016.
[61] The Space Foundation, 2015. *The Space Report 2015. The Authoritative Guide to Global Space Activity*. The Space Report Publishing.
[62] ISRO 2016. *Budget at a Glance*.
ISRO website: http://www.isro.gov.in/budget-glance. Accessed 06/06/2016

Another 14% of the budget is allocated for downstream application of the space data (i.e. Earth observation, satellite communication, disaster management and climate management), while a further 10% is dedicated to maintain operative the aforementioned INSAT constellation.

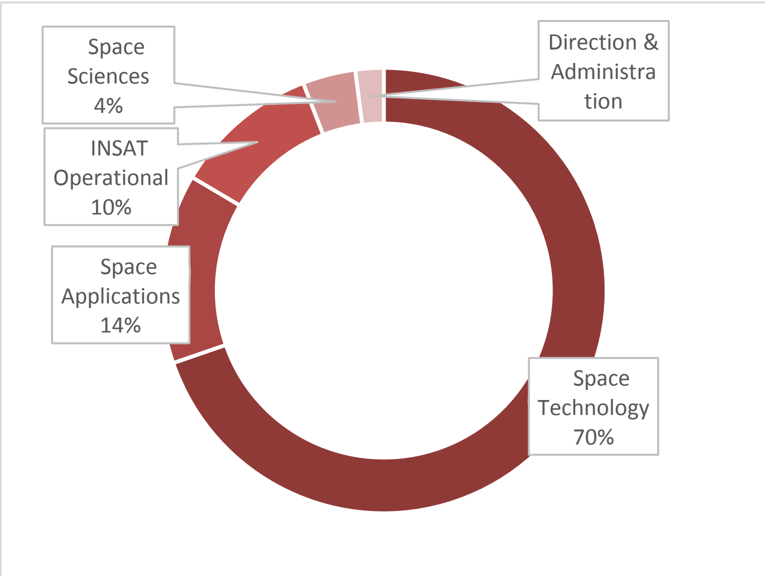
The Indian space agency seeks international cooperation, both at bilateral and multilateral level, as an important driver for the development of the space environment. At current days has signed cooperation agreements with 33 countries and 3 international organisations. In the Asia-Pacific region, ISRO strongest partnerships are with Brunei, Bhutan, Myanmar and Thailand[63] [64].

Figure 19: ISRO Budget (in INR billion)



Source: ISRO 2016. Budget at a glance; and OECD, 2012. OECD Handbook on Measuring the Space Economy.

Figure 20: ISRO Budget Breakdown, 2016-2017



Source: ISRO 2016. Budget at a glance

[63] Make in India, 2016. *Space. International Cooperation*.
Make in India website: http://www.makeinindia.com/sector/space. Accessed 07/06/2016.
[64] Private message from the Confederation of Indian Industry.

Industry composition

Even after the recent attempts to increase private industry capabilities, ISRO remains Indian largest producer of space products. A study on the allocation of ISRO's workers, therefore, can give a glance of Indian industrial capabilities. As Figure 21 shows, 76% of the workforce is employed at some level in the upstream segment of space industry. Namely 12% is employed in Launch systems R&D (the main facilities are allocated in the Liquid Propulsion Systems Centre in Bangalore), 45% in launchers and spacecraft manufacturing (in the Vikram Sarabhai Space Centre in Thiruvananthapuram and in the ISRO Satellite Centre in Bangalore) and 19% in ground control infrastructures (in the Satish Dhawan Space Centre in Shriharikota and in the Master Control Facility in Bhopal and Hassan). Only 21% of the workers are employed in the downstream application of space technology: 7% for ground data reception and management (in the National Remote Sensing Centre in Hyderabad) and 14% for the provision of satellite services (in the Space Applications Centre in Ahmedabad).

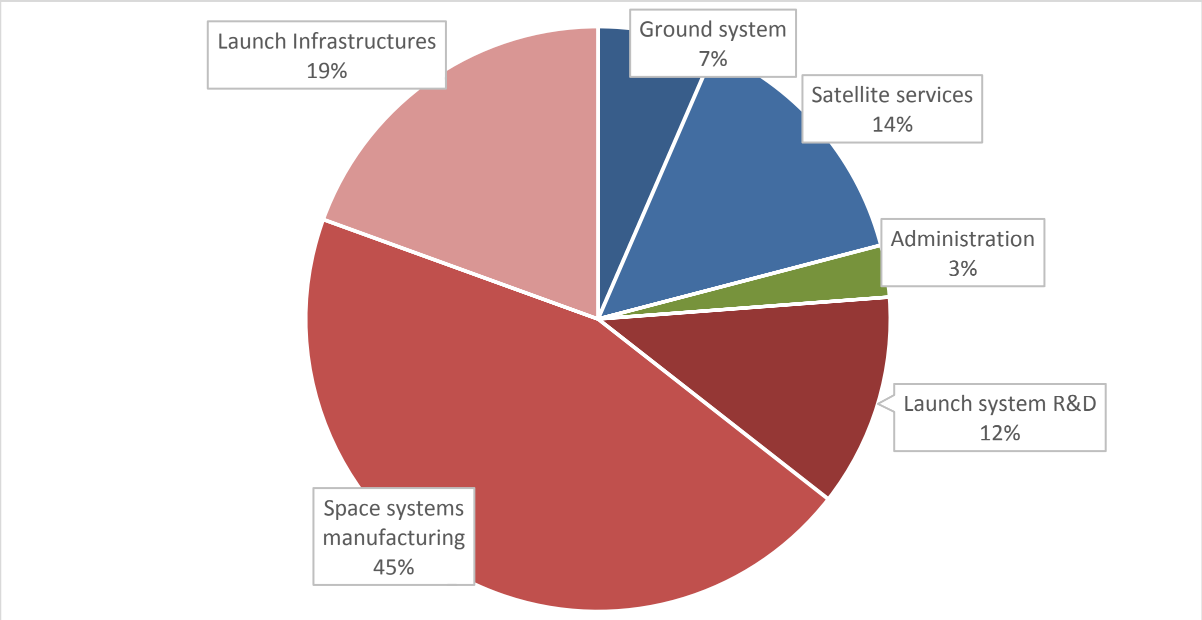
ISRO's relatively small engagement in downstream applications, however, doesn't necessarily mean that India has low capabilities in the provision of space-enabled services. As mentioned, the boundaries of this industrial segment are blurred, and it is difficult to provide a clear estimation of them. It is clear, however, the role of India in Satellite Communication, Navigation and Earth Observation. INSAT is one of world's most developed communication satellite constellations, and India accounts 67.57 million of subscriptions for Direct-to-Home satellite television[65]. Moreover, on 28 April 2016, India successfully launched the last satellite of the Indian Regional Navigation Satellite System (IRNSS) and has had the GPS-Aided Geo Augmented Navigation (GAGAN) system active since 2014. Both systems cover the whole South Asia region, making India, together with China, one of the most important actors for Satellite Navigation services in the region.

Antrix Corporation, Indian largest export company, reported in 2014-2015 fiscal year total revenues for INR 18.60 billion (USD 372 million).

The production of space products is mainly concentrated in the regions around Thiruvananthapuram, Bangalore and Shriharikota. In particular, Bangalore hosts both *Astrix Corporation* and some ISRO's most important facilities, like the *ISRO Satellite Centre*, the *Liquid Propulsion Systems Centre* or the *ISRO Telemetry Tracking and Command Network*.

[65] Television Post, 2014. *India's DTH sector has 43.4% inactive subscribers*.
Television Post website: http://www.televisionpost.com/dth/indias-dth-sector-has-43-4-inactive-subscribers/. Accessed 07/06/2016

Figure 21: ISRO employment allocation



Source: Own elaboration from 'OECD, 2014. The space Economy at a Glance.'

ITALY

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

Italy started its involvement in the space field after the launch of the *Sputnik* satellite, when Western Bloc countries perceived the necessity to close the gap created with USSR. The country officially started its space activities in 1959 with the creation of the *Commissione per le Ricerche Spaziali* (Space Research Commission, CRS), and soon began with the test of a sounding rocket. In 1964, Italy become the first European country to build a satellite, the *San Marco 1*, launched with NASA's cooperation. The San Marco's launch coincided with the end of the first phase of the Italian space industry. In 1964, in fact, Italian companies started a concentration process, where public and private capital converged in order to create large conglomerates. Echoes of this phase are still vibrant in the Italian space (and aerospace) industry, and the largest and most influential of the Italian prime companies, like Finmeccanica or Thales Alenia, have their roots in these years.

At the end of the 1960s, Italy saw the development of the Satellite Communication industry as an opportunity to capitalise. In 1968 launched *SIRIO,* a project aimed to the development of an experimental telecommunication satellite. Initially scheduled for 1971, the satellite was finally launched in 1977. Although the delays and the difficulties, *SIRIO* contributed to the growth of capabilities among Italian industry, useful for the further expansion of the space sector.

After this project Italian companies developed expertise in systems, subsystems and ground operation design and the assembly. To provide some example, Galileo and Aeritalia, two of the companies involved in the project, became important ESA suppliers[66].

The 1960s was a period of increasing collaboration among European countries. In this early stage, the lack of clear political guidance and the immaturity of the national space industry penalised Italy, which wasn't able to capitalise upon the opportunities given by international commitments. The investments made in the European Launcher Development Organisation (ELDO) and in the European Space Research Organisation (ESRO) wasn't fruitful for Italian companies (in 1969 the industrial return of the Italian contribution to ESRO was a mere 53%).

It was only in the second half of the 1970s that the country started to be able to capitalise on international collaborations. In 1973 ELDO and ESRO were merged into the European Space Agency (ESA), and Italian companies had the capability to enter the international market even more than before (like in the case of collaboration with NASA in the *Spacelab* program).

In 1979 a more coherent plan of action was identified as necessary and Italy released its first national space plan. In these years emerged the necessity of a single management structure, and in 1988 the *Agenzia Spaziale Italiana* (Italian Space Agency*,* ASI) was created. This governance's reorganisation finally provided a comprehensive institutional framework and allowed the formulation of coherent policies for the Italian scientific and industrial space activities, giving consistent guidance in the sector and allowing Italy to pursue its collaboration with ESA and NASA in a more effective way.

SPACE POLICY

ASI has a pivotal role for the Italian space activities and for the integration of Italian space activities and industry in the wider European and international context. The agency is funded by the Ministry for Instruction, University and Research (MIUR), but for specific programs is funded also by other organisations and Ministries.

ASI's budget, like the budget of all ESA's members, has the double objective to fund the national and the European programs. In the last few years (see Figure 22) the agency suffered a shrinking budget, and in 2016 the agency was awarded nearly € 520 million.

As shown in Figure 23, nearly 77% of the national budget (€ 400 million) is allocated to ESA for the development of European and international space projects, meaning that Italy is the third largest contributor in the agency. This European agency is a major player in the Italian environment, and provides the possibility for closet collaboration with other countries, providing the possibility to approach

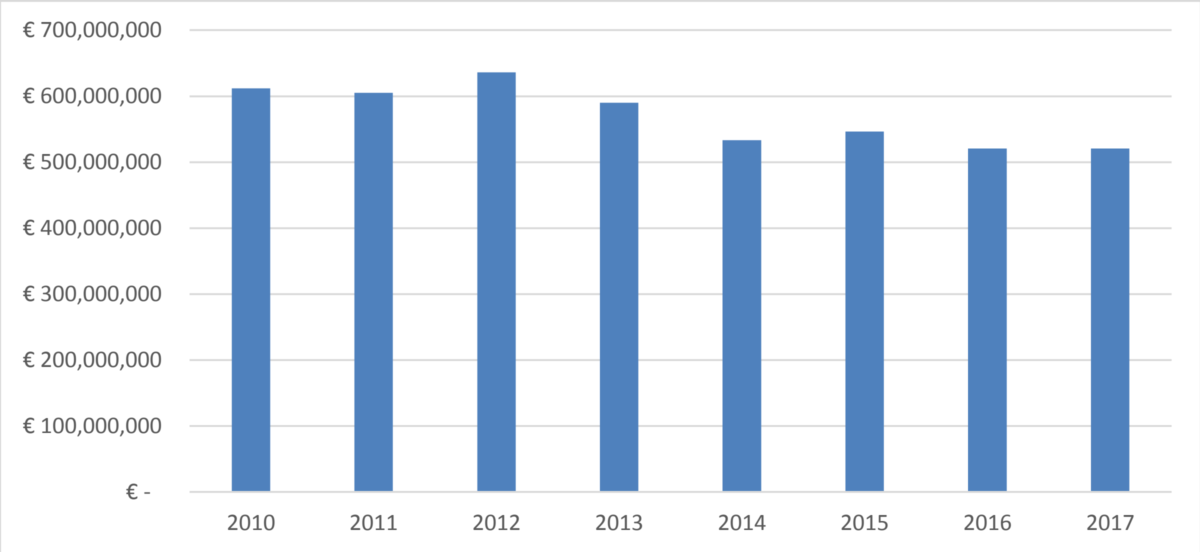
[66] De Maria M., Orlando L., Pigliacelli F., 2003. Italy in Space. 1946-1988. ESA Publishing.

projects and missions that would otherwise be too expensive if faced by single countries. In particular, Italian funds to ESA are aimed principally for the development of *Ariane*, the family of European space launch vehicles; to human spaceflight, largely via ISS missions; and for further Space exploration, with the intent to capitalise upon Italian expertise in building high technology space crafts.

Allocated to the national program there are € 60 million, i.e. 12% of the national budget. As Figure 24 shows, the largest share of the budget is allocated for the enabling of downstream activities. In particular, the Earth observation sector alone account for nearly 65%: ASI is engaging Italian industry in order to build the second generation of *COSMO-SkyMed* satellites, a fleet of satellites that will provide high quality images of the Mediterranean basin. The rest of the budget is allocated for upstream activities such space launchers, for manned spaceflight, for space-observation and exploration, and for the management of ground systems.

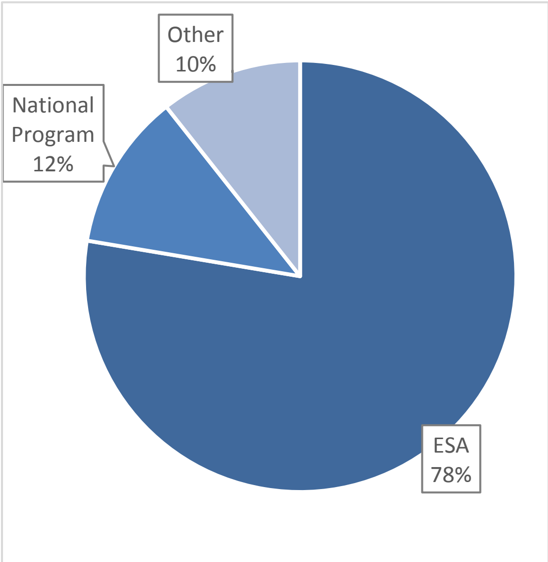
The agency, moreover, works in order link Italy in the international context. Without counting the vital collaboration with ESA and Europe in general, ASI collaborate in several scientific missions. The most relevant collaboration are established with NASA (primarily for spacecraft design and assembly), with

Figure 22: ASI's allocated and estimated budget (in €)



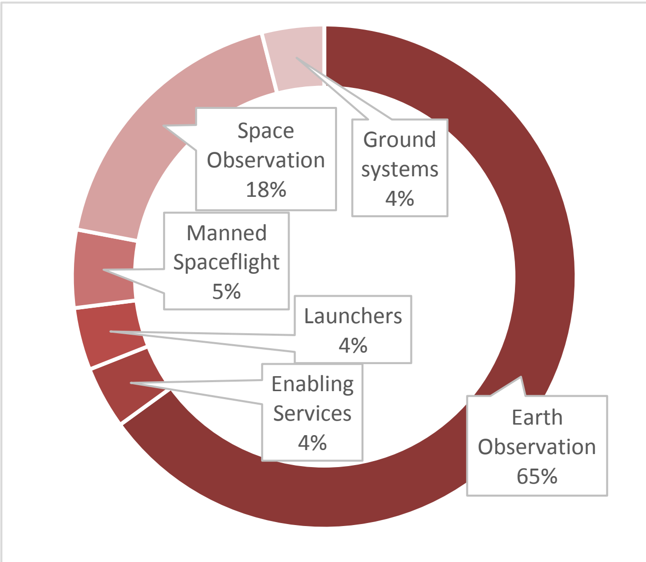
Source: Piano Triennale di Attività 2010-12, Piano Triennale di Attività 2013-15 and Piano Triennale di Attività 2015-17 (sic.)

Figure 23: Expenditure breakdown of ASI's Budget (2016)



Source: Piano Triennale di Attività 2015-17

Figure 24: National Program's Budget breakdown



Source: re-elaboration from Piano Triennale di Attività 2015-17

Roscosmos, with the Japanese Space Agency (JAXA), with CNSA, with the CSA and with the Israel Space Agency (ISA).

Italian industry usually looks forward to having important exports. Consistent with this background, the agency works to drive the upstream segment in order to support export shares, rather than the downstream applications.

INDUSTRY COMPOSITION

Unfortunately, at the national level there is low attention on the downstream application and the data found refers only to the upper segment of the value chain, in particular to the space manufacturing sector, intended as 'space sector and 'ground sector' supply chains, and 'satellite services from satellite operators' (see Figure 2 in the previous chapter).

Italy is an important player in the space industry. With more than 4,500 workers, the country has the 3rd largest space manufacturing industry workforce in Europe, after France and Germany, and ahead of Great Britain (when excluding the broadcast sector)[67] [68]. As shown in Figure 25, the space employment seems to endure a cyclic expansion and reduction.

The industry is particularly concentrated, and the 4 largest companies generate 83% of the turnover and employ 82% of national workforce. The largest Italian space companies are *Thales Alenia*, *Telespazio* and *Selex Galileo*. These companies are totally or partially owned by *Finmeccanica*, one of world's largest players in the aerospace and defence industries. The Italian space industry competitiveness is in some ways helped and connected with the competitiveness and the development of the national Aerospace and Defence industry, which ranks 7th in the world, employs 50,000 workers and generates a turnover of USD 20 billion[69].

Commercial space revenue driven by private demand has increased exponentially in the last decades. This trend is consistent with the Italian case, but, nonetheless, national space industry relies strongly on the public demand. Public demand accounted for nearly 68% of Italian space revenue, significantly more than the European average of 54%[70].

Consistent with the Italian focus on export, 51% of the national space output is destined to the foreign market. It is interesting to note that 93% of the total exports are destined to the European market, denoting the strong network built at continental level. Moreover, national exports are 2.4 times higher than national imports[71], positioning the country as an important manufacturer of space products and services.

Among the other Italian manufacturing sectors, the Italian space economy is extremely R&D intensive. The Italian space segment employs only 0.11% of the total workforce, but produces 0.18% of the total turnover and accounts for 2% of the national R&D expenditure, which suggest that the space industry generates important spill over for Italian industry overall[72]. More than 100 universities and research centres are scattered across the country, thanks to their connections with the industrial sector and with the Italian and European space agencies, are pivotal players in supporting the innovation process.

The production is very widespread on the national territory, and there are 6 regional space industry clusters recognised by the OECD in Piedmont, Lombardy, Tuscany, Latium, Campania and Puglia.

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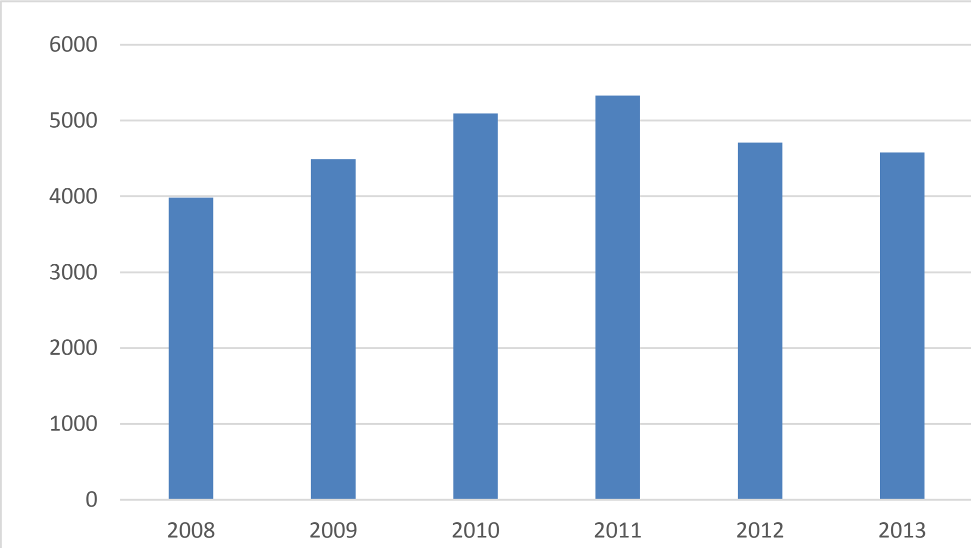
[67] OECD, 2014. *The space Economy at a Glance*. OECD Publishing.
[68] Cristini A., Graziola G., 2013. *Misure e rilevanza degli spillovers delle industrie ad alta tecnologia, con particolare attenzione all'industria spaziale: il caso italiano*. Univer**sità** degli Studi Bergamo.
[69] Export.gov, 2015*. Aerospace Resource Guide: Italy*.
Export.gov website:
http://www.export.gov/industry/aerospace/aerospaceresourceguide/italy088806.asp#P12_296.
Accessed 16/05/2016.
[70] Cristini A., Graziola G., 2013. *Misure e rilevanza degli spillovers delle industrie ad alta tecnologia, con particolare attenzione all'industria spaziale: il caso italiano*. Università degli Studi Bergamo.
[71] OECD, 2014. *The space Economy at a Glance*. OECD Publishing.
[72] Cristini A., Graziola G., 2013. *Misure e rilevanza degli spillovers delle industrie ad alta tecnologia, con particolare attenzione all'industria spaziale: il caso italiano*. Università degli Studi Bergamo.

Figure 25: Space manufacturing industry employment in Italy



Source: OECD, 2014. The space Economy at a Glance.

RUSSIA

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

Since the beginning of the space era, Russia has always played a major role in the development of space activities. The very first achievements carried out in the space sector were made by the Soviet Space Program in the so-called 'space race' that involved the USSR, the USA, and, by extension, all their affiliated countries. Thanks to the rivalry between these two worlds, global space technology achieved amazing results in relatively short timeframes.

It is said that the Soviet's rocket technology in the 1930s was highly developed, comparable in capabilities to that of German's, but suffered the Great Purge enforced by Stalin in the late 1930s, when many rocket scientists were killed or sent to the Gulags. Therefore, as happened for many other WWII winner nations, USSR's involvement in space activities boosted only in the immediate aftermath of the Second World War, when Soviets benefited from the direct study of Germany's highly advanced rocket program, in particular thanks to the access to the projects of the *V-2* rocket found in Peenemunde.

In contrast to the US, which would later organise all space activities under the unitary direction of the NASA, USSR decided to organise its space activities between several distinct competing groups. In the early years this setting led to astonishing results. The Soviets were the first to launch an artificial satellite, the *Sputnik* in 1957, the first to send a human in space, Yuri Gagarin in 1961, aboard the *Vostok 1* spacecraft, and the first to conduct an extravehicular activity, aboard the *Voskhod 2*. Moreover, the first image of the far side of the moon arrived thanks to the Soviet *Luna 3* in 1959, and the first spacecraft to perform a soft landing on the lunar surface was the *Luna 9* probe in 1966. However, 1966 saw also the death of Sergei Korolev, Soviet space program's most prominent figure. The loss of Korlev, together with budged cuts suffered during the mid-1960s[73], led to a drastic delay in the development of the Space Program and of its lunar ambitions. Since then, Americans won nearly all the most important achievement in the 'space race', in particular after the first human moon landing in 1969 in the *Apollo 11* mission. After *Apollo 11*, it was clear that USSR lost the race.

The technological development achieved in the 1960s, however, has been highly useful for the later development of the Soviet space program: those were the years when Soviet strengthened their rocketry capabilities, the years of the *Soyuz* program. *Soyuz* spacecraft, the successor of *Voskhod*, had and still have enormous importance not only in Soviet-Russian space activities, but also in international space engagement. *Soyuz* spacecraft played a fundamental role in the development of the *Salyut* space stations during the 1970s and the 1980s, and in the more famous *Mir* space station between 1986 and 2001. The latest configurations of *Soyuz* are still operative and widely used for ISS. Many widely used Russian rockets, like the *Proton* and the *Soyuz* rocket families, were firstly developed in the 1960s.

[73] Zak A., 2016. *Human missions to the Moon.* Russian Space Web website: http://www.russianspaceweb.com/spacecraft_manned_lunar.html. Accessed 06/06/2016.

SPACE POLICY

After the dissolution of the Soviet Union in 1991 the legacy of the Soviet Space Program was inherited by the national entities that emerged from this split. Nearly all the assets, however, were collected by the new Russian Federation. After the years of disjunct coordination policies sustained by the Soviet government, the new politic decided to pursue a different organisation of the system, and created in 1992 the Russian Aviation and Space Agency, later renamed Roscosmos.

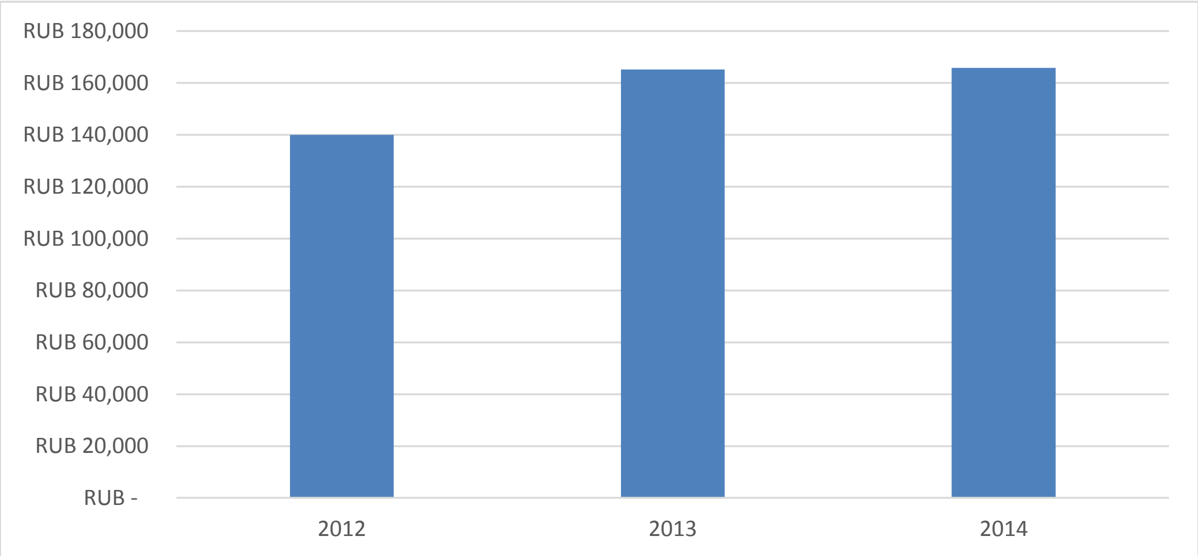
In recent years the space industry saw a process of conglomeration that led to the creation of the state owned United Rocket and Space Corporation (URSC) in 2013. In 2015 Roscosmos and URSC were merged to form Roscosmos State Corporation for Space Activities (still called Roscosmos)[74]. After this process, nearly all of Russia's largest companies fall under direct government control.

Federal government allocated RUB 165.81 billion (USD 2.39 billion) for space activities in 2014. These funds were mainly used for the development of a brand new launcher, the *Angara* rocket (the first launch occurred in 2014), and for the building of a new spaceport, the *Vostochny* Cosmodrome. Total costs for the cosmodrome are forecasted to be nearly RUB 50 billion (USD 750 million) before 2020.

Another important Roscosmos commitment regards the ISS; the agency manage the *Russian Orbital Segment* of the ISS, which supervises the guidance and the control of the station. Before 2013, moreover, nearly all the launchers that reached the ISS were Russian.

In March 2016 the federal government approved the Federal Space Program, providing RUB 1,400 billion (USD 21 billion) for space activities in the 2016-2025 period, an average of only RUB 140 billion (USD 2.10 billion) per year[75]. This budget cut, linked with current Russian suboptimal economic situation, threatens country's historic competitive advantage in space activities.

Figure 26: Russian Government Space Budget (in RUB billion)



Source: The Space Foundation, 2015. The Space Report 2015. The Authoritative Guide to Global Space Activity.

[74] Bodner M., 2015. *Putin Approves Roscosmos Merger with Conglomerate*.
Space News website: http://spacenews.com/putin-approves-roscosmos-merger-with-conglomerate/#sthash.IUjj6FY5.dpuf. Accessed 06/06/2016.
[75] Zak A., 2016. *Russia approves its 10-year space strategy*.
Planetary Society website: http://www.planetary.org/blogs/guest-blogs/2016/0323-russia-space-budget.html. Accessed 07/06/2016.

Industry composition

Russia is currently one of the largest producers of spacecraft design and assembly. As Figure 27 and 28 shows, since 2012 Russian production grew both in absolute terms, with a total turnover of USD 5.73 billion, and in relative terms, producing slightly less than 20% of global space manufacturing in 2014.

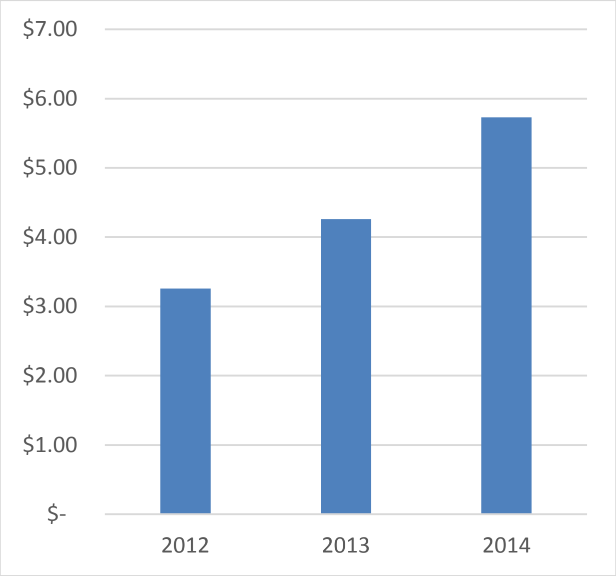
However, the situation of the Russian space industry is not completely positive. In 2014 industrial exports shrunk by 13%. Moreover, the aforementioned Roscosmos budget cut will most likely reduce the domestic market's turnover. These facts represent serious threats for the economy. In addition, the enormous national infrastructure system seems to be excessively large for Russia's needs, and its capacity utilisation was a mere 50.1% in 2015[76].

A possibility to overcome these problems has been seen in opening the industry to private investments: in the last years new private companies, like *SPUTNIX* and *Dauria Aerospace*, have been born.

Russian state-owned companies include colossus like *Energiya, Khrunichev State Research and Production Space Center,* or *OKB Fakel.*

[76] de Selding P. B., 2015. *Roscosmos Details Russia's Struggling Space Sector*. Space News website: http://spacenews.com/roscosmos-details-russias-struggling-space-sector/#sthash.8CeC2af2.dpuf. Accessed 07/06/2016.

Figure 27: Russian spacecraft manufacturing value (in USD billion)



Source: The Space Foundation, 2015. The Space Report 2015. The Authoritative Guide to Global Space Activity.

Figure 28: Russian spacecraft manufacturing value as percentage of global production (in USD billion)

	Production	% of world share
2012	$ 3.26	8.87%
2013	$ 4.26	12.54%
2014	$ 5.73	19.53%

Source: The Space Foundation, 2015. The Space Report 2015. The Authoritative Guide to Global Space Activity.

UNITED KINGDOM

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

At the end of World War II, Great Britain emerged as a victorious nation, one of the most influential powers on the global set. Thanks to the possibility to study the *V*-2 German missiles, Britain became one of the early players in the space race. It was the first nation outside USSR and USA to design and assemble a satellite, *Ariel 1*, in 1962. The satellite, constructed in the United States, carried six scientific experiments designed from British space scientists[77]. The UK, moreover, was one of the first countries able to autonomously achieve an orbital launch with its own rockets design, when the Black *Arrow* rocket successfully deployed the *Prospero* satellite in 1972.

The path to reach these early successes, however, was not linear or clear. In 1955, at the early stage of the space race, UK steered toward the development of *Blue Streak* ballistic missile and boarded the *Black Knight* test vehicle as part of missile's re-entry program. At the end of the 1950s, however, after failures in launching *Blue Streak,* the government discarded the idea to use national rocketry as a military strategic deterrent, and definitively abandoned the *Blue Streak* project in 1960. Britain decided to rely on US's launch systems, as American offered cost-effective contracts for the launch of science satellites: the British rocket was replaced with the cheaper and more reliable American *Skybolt* system[78].

The decision was a significant setback for further developments in national launch capabilities. In order to recover part of the *Blue Streak* capabilities and to avoid a complete waste of the project, the UK worked together with France and created the European Launch Development Organisation (ELDO), a pan-European organisation with the goal to gather and coordinate efforts for the creation of a European launcher. At the same time the *Black Knight* project changed, was renamed *Black Arrow* and reprogrammed for the development of a two-stage rocket for the delivery of satellites at orbital level. However, the first successful *Black Arrow* launch was also the last one, as the administration had already decided to cut any further financing, considering it too expensive for British space ambitions. At the same time ELDO expenses rose and UK's government decided to withdraw from the organisation in 1969. Without British support, the organisation couldn't survive long: in 1973 it was officially shut and reorganised, together with the European Space Research Organisation (ESRO), in the ESA.

As we can see, since it early stages, the British approach to space policies was infused with pragmatism[79]. Thanks to policies focused on industrial development, Great Britain's government avoided injecting capital into programs with ambiguous short-term economic returns, preferring instead to focus its efforts on supporting space related industries. Due to this pragmatic approach, at the end of the 1970s the UK space industry had competitive capabilities in almost all space related technologies and productions. This pragmatism was considered excessive by the critics. To date, Great Britain's government has sent only one astronaut into space. The most important issue arisen from this attitude is the low 'fashion' of the UK space environment, which undermines UK's competitiveness due to a lower capacity to attract interest both at a national and at an international level. Internally, space is not perceived as important and economically valuable, with decreasing attentions on space-related topics; while externally, at a global level, there is a low recognition of British space capabilities.

The ambiguous commitment of the government in space led to two parliamentary enquires in 1967 and in 1971 which recommended the setting of a dedicated space agency[80]. However, it was only in 1985 that, in order to coordinate UK public civil space program, the British National Space Centre (BNSP) was created. The agency was set as a voluntary partnership between research centres and different British government agencies and departments that had previously shown difficulties in the development of a coherent strategy able to encompass scientific, industrial and defence components[81].

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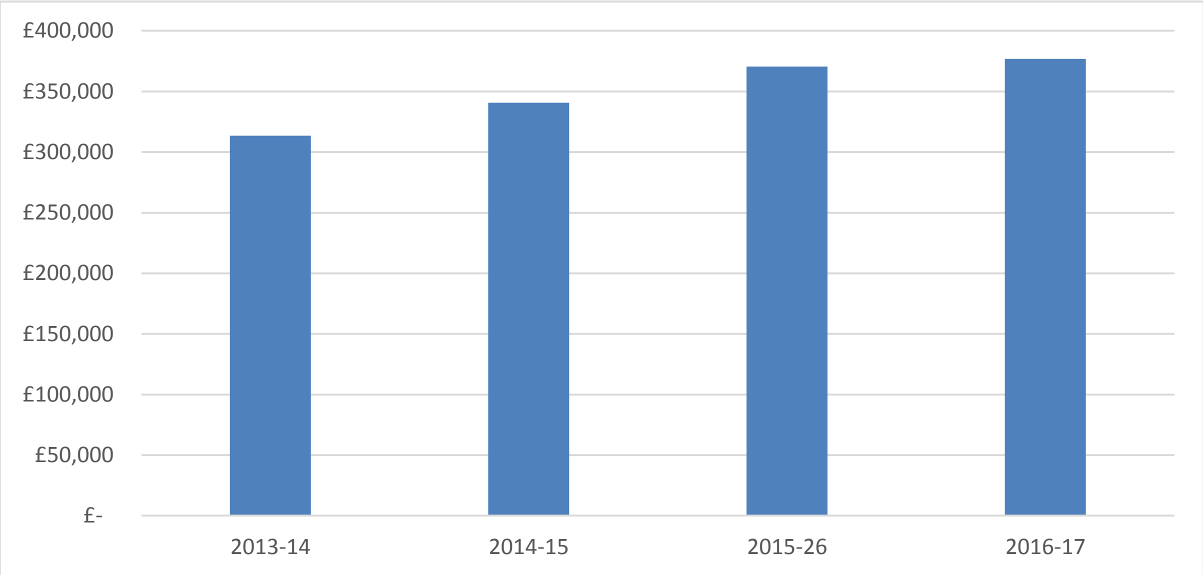
[77] University College London, 2012. *50th Anniversary of the UK's first step into space*. UCL website: https://www.ucl.ac.uk/news/news-articles/1204/26042012-50th-anniversary-uk-first-step-space. Visited 9/05/2016.
[78] Millard D., 2005. *An Overview of United Kingdom Space Activity, 1957-1987.*
[79] Royal Aeronautic Society, 2014. *UK Space Policy: a 'hidden success story'*. www.aerosociety.com.
[80] Millard D., 2005. *An Overview of United Kingdom Space Activity, 1957-1987.*
[81] Royal Aeronautic Society, 2014. *UK Space Policy: a 'hidden success story'*. www.aerosociety.com.

In 2010, therefore, the BNSC was transformed into the UK Space Agency (UKSA), which redefined priorities and set a Space Action Growth plan for the 2014-2030 time period. The new-born agency has "*the goal of raising* [United Kingdom's] *share of the expected £ 400 billion global space-enabled market to 10% by 2030*"[82].

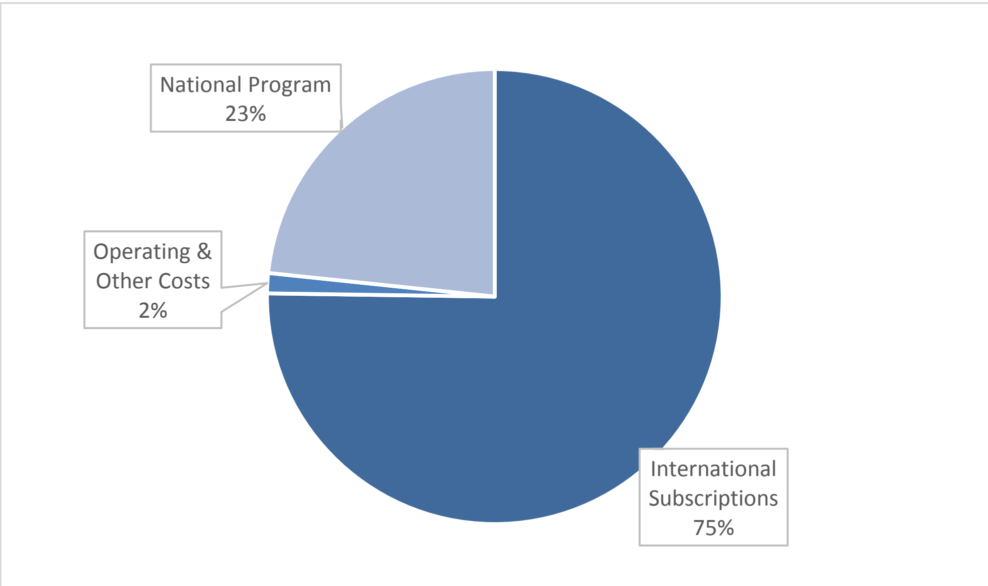
To accomplish such an ambitious plan, UKSA has a budget of £ 377 million for the financial year 2016-17[83]. Unfortunately, there are no data available regarding the budget allocation on the main projects funded. The only breakdown available for the current budget provides, as Figure 30 shows, data on expenditures for the national program (£ 88 million) and for international subscriptions, mainly to the European Space Agency (ESA), with £ 283.6 million. Great Britain is ESA's 4th largest contributor.

Figure 29: UK Space Agency budget (in £ thousands)



Source: UK Space Agency Corporate Plan, 2013-14, 2014-15, 2015-16, 2016-2017

Figure 30: UKSA, 2016-17 Allocation by Expenditure Category



Source: UK Space Agency Corporate Plan 2016-2017.

[82] Space Innovation and Growth Strategy, 2013. *Space Growth Action Plan 2014-2030*. Space IGS Publishing.
[83] UK Space Agency, 2016. *UK Space Agency Corporate Plan 2016-2017*. UK Space Agency Publishing.

Consistent with British past policies, UKSA's strategy reflects a market oriented approach to space investments, particularly regarding policies to fund upstream R&D for the best positioning of the industry in order to maximise benefits for the downstream segment[84]. This approach is completely different from the one adopted by other European countries, as their policies focus on positioning the upstream segment in order to expand export shares.

INDUSTRY COMPOSITION

The aforementioned economic, technological and political background led the UK space economy to generate an aggregate turnover of £ 10.8 billion[85] in the 2012-13 fiscal year and £ 11.6 billion in 2013-14. The industry itself (direct effect) generated £ 4.8 billion, while the rest was derived from activities indirectly linked with space (indirect and induct effects)[86]. In particular, £ 1.20 billion generated from upstream activities and £ 10.40 from downstream activities. As seen in Figure 31, since 1999 the UK space industry has never decreased, growing in the 1999-2014 period at an impressive compound annual growth rate of 7.49%. Estimates say that UK captures between the 6.3%[87] and 7.7%[88] of the global space economy.

In particular, as per Figure 31 and 32 show, British space economy is specialised in the downstream segment, specifically in the provision of space-related services.

The main UK's total turnover is produced in a few areas of the country. The region of London alone accounts for 79.6% of space applications turnover (consistent with the service-provider vocation of the city). More interesting is the situation within the regions South East and East of England, which specialise in space manufacturing. While they account only for the 20.5% of overall space-related British turnover, together they produce 83.2% of total British space manufacturing. Indeed, the only space cluster acknowledged by the OECD in the UK is located in Harwell, South East England.

Great Britain space manufacturing industry is well developed and employs nearly 800 workers, being the 4th largest in Europe. Encompassing also the downstream activities, UK space industry employs 35,600 workers. In total, 72,000 jobs depend in some way on the space economy. At least 171 enterprises compose space economy in the UK, and 121 of them are micro, small or medium enterprises. However, the British space industry, as most capital intensive industries, is characterised with an oligopolistic structure, as the 26 largest enterprises employ nearly 83% of the workers. While SMEs tend to be specialised in the space economy, larger companies usually have more diversified business interests and a lower share of space-related activities in their portfolio.

Focusing on the supply chain, in 2015 'space manufacturing' generated a turnover of £ 907 million, 8% of the national turnover. The most relevant firms in British space manufacturing are Airbus Defence and Space UK, Surrey Satellite Technology Ltd, QinetiQ Group, and Qioptiq Space Technology Ltd.

British 'services from the satellite ownership and operations' sector generated a turnover of £ 1.45 billion, 12% of the national turnover. British 'firm's ownership' is the predominant generator of turnover, as the leasing capacity of satellite owners companies generate alone £ 1.04 billion of turnover.

However, the most important turnover in British space economy is generated by 'space applications', with a total turnover of £ 9.25 billion. This industrial segment is the closest one to final consumers, provides Direct to Home (DTH) services, equipment supply and VSAT networks. Great Britain hosts global companies such as Sky plc, Cambridge Silicon Radio and Cobham.

British broadcasting industry is one of the biggest users of space services. In particular, Sky plc is one of the most important players in the field, hiring satellite capabilities in order to supply DTH services to nearly 21 million customers across Europe, 50% of them in Great Britain. This is an important way of

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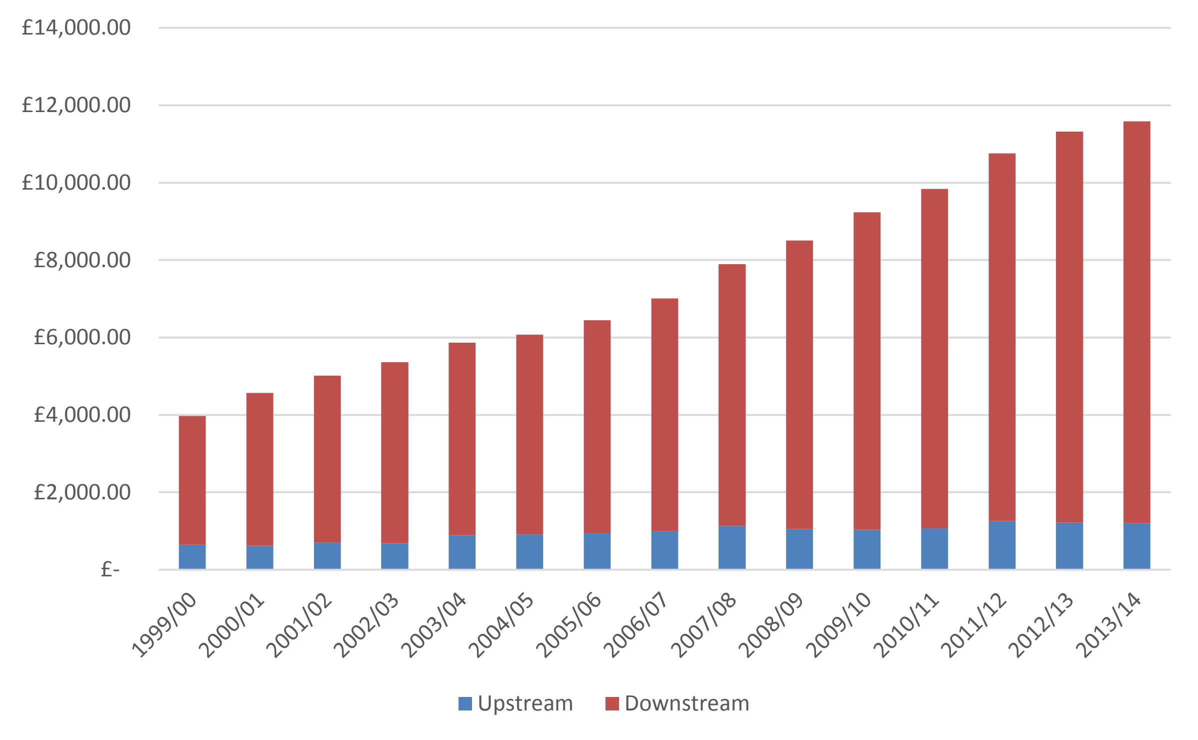
[84] Royal Aeronautic Society, 2014. UK Space Policy: a 'hidden success story'. www.aerosociety.com.
[85] London Economics, 2015. *The Case for Space 2015. The impact of space on the UK economy*. London Economic Publishing.
[86] London Economics, 2014. *Executive Summary: The Size and Health of the UK Space Industry*. UK Space Agency Publishing.
[87] Space Foundation, 2014*. The Space Report 2014. The authoritative guide to global space activity*. Space Foundation Publishing.
[88] OECD, 2014. *The space Economy at a Glance*. OECD Publishing.

Figure 31: UK Space economy turnover, from 1999-00 to 2013-14 (in £ million)



Source: Executive Summary: The Size and Health of the UK Space Industry

Figure 32: UK space economy, sectorial composition and global comparison

	UK space economy (£ million)		*% of word share (OECD estimates)*
Space Manufacturing/Supply Chain	£	907	1.8%
Services from Satellite Operators	£	1,453	11.2%
Space enabled applications	£	9,253	10.3%
Ancillary Services	£	236	
Total	**£**	**11,849**	**7.7%**

Source: The Case for Space 2015. The impact of space on the UK economy.

innovation for the space industry. Returns for the British economy in the upper tiers of the value chain however are not clear.

When compared with other British industries, the UK space economy is strongly export oriented. Space activities export share is 31%, double the average export share of other British exports, which have an average share of 15% of the export market.

National space economy attracts and produces high qualified personnel: 57% of the workforce is considered as HQP. This capacity is more marked in the space manufacturing sector, where the HQP is 68% and 31% of employees have a higher degree.

British space manufacturing (building the launch systems, ground systems and satellites) R&D intensity includes an impressive 26.1% of total GVA, outperforming the automotive sector but rating behind the pharmaceutical sector. Within the UK space economy (including space related services) the rate of R&D intensity drop to 9.8%, showing that the most R&D intensive area of the industry is in the space manufacturing sector. UK is home of important R&D infrastructures, like the European Centre for Space Applications and Telecommunications in Harwell, one of ESA's most important R&D facilities.

UNITED STATES OF AMERICA

HISTORIC NATIONAL INVOLVEMENT IN SPACE ACTIVITIES

The United States of America has influenced the development of the space environment as a whole more than any other country in the world. Since the beginning of the space era, after the end of WWII, the US plays a pivotal role in pushing space technologies forward and influencing the global space framework and economy.

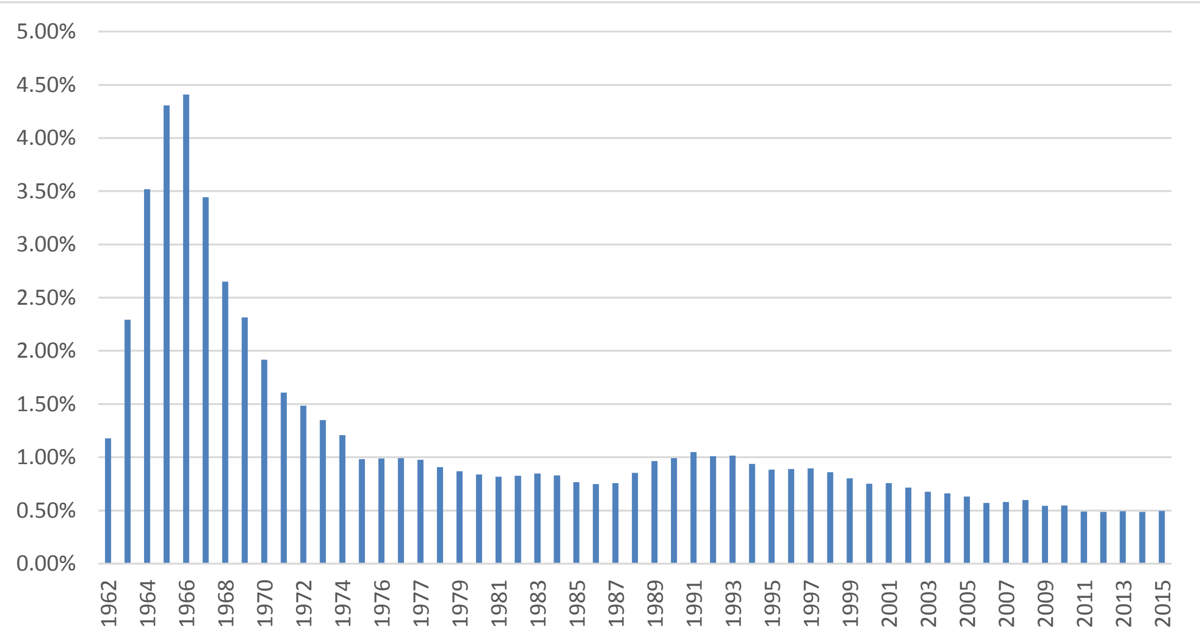
The space era began just after the end of WWII, when the victorious Allies recruited German rocket engineers and had the possibility to study Germany's *V*-2 rockets. The US, in particular, benefited from the contribution of Wernher von Braun, former director of the German missile program, and of his team. This collaboration was fundamental for American space activities, and nowadays von Braun is considered as one of the fathers of the American space program

Post WWII coincided also with the outbreak of the Cold War, and one of the fields in which USA and USSR engaged competition is Space. Space technology is a driving factor for the innovative capacity of an industry and rocket capabilities imply military capabilities. Moreover, space has the power to inspire the necessity to push forward humankind's borders and implies great propaganda opportunities. These are just some of the reasons that led USA and USSR to participate in the 'Space Race'.

The race started *de facto* the 29th of July, 1955 when the US declared its intention to send a satellite into space between 1957 and 1958. Shortly after, USSR announced plans to launch artificial satellites as well. USSR won the first goal of the race, sending *Sputnik 1* in orbit in 1957. The US was only able to accomplish this goal in 1958, when the 21st of January *Explorer 1*, the first American artificial satellite, was sent to space. Later that year, in order to ensure a better coordination of space-related issues, the National Advisory Committee for Aeronautics (NACA) was reorganised and transformed into the still operative National Aeronautics and Space Administration (NASA), the government's agency responsible for the civilian space program's development and for aeronautic and aerospace research.

But again USSR defeated the US, when, on the 12th of April, 1961, Soviets sent the first man in space, making Yuri Gagarin the first human to fly above Earth's atmosphere. The first American manned space launch occurred nearly one month after, on the 5th of May, when Alan Shepard reached outer space aboard NASA's *Freedom 7*. Rather than feeling defeated, the United States increased its involvement

Figure 33: Historic overview of NASA's budget, as percentage of Federal budged, 1962-2015.Figure 23: NASA's budget as percentage of federal fundig



Own Elaboration from Office of Management and Budget, Table 4.2—Percentage Distribution of Outlays by Agency: 1962–2021. Office of Management and Budget Website: https://www.whitehouse.gov/omb/budget/Historicals. Accessed 01/06/2016.

in space. On the 25th of May, 1961, President Kennedy held a speech addressing the nation regarding the goal to send a man to the moon before the end of the decade. The *Project Apollo* began. The 1960's became one of the most challenging years for American and global space development. As Figure 33 shows, in those years the importance of space activities led the federal government to allocate NASA huge funds. Without neglecting the birth of commercial application of space satellites (in 1962 was launched *Telstar I*, the first privately built satellite), the main focus and the largest amount of funds were allocated to the development of the *Saturn* space launcher and for the *Gemini Project*, which prepared the final *Apollo Project*. This project culminated on July 20 1969, when the first man stepped onto the lunar surface. *Apollo* continued until 1972, sending a total of 6 missions to the Moon. USA was the first country, and by far the only country, able to reach this goal.

The huge amount of public resources spent led America to achieve impressive technological capabilities, gaining a huge competitive advantage that led the nation to be the most advanced country in the space environment. In the long run this enormous public subsidy could not last, and after the accomplishment of the lunar goal, the space budget decreased dramatically. The post-*Apollo* period was characterised by a reconsideration of the national space program. The moon research was abandoned, there was a reduction of public spending and, at the same time, there was a higher focus on international collaborations, both with its traditional European partner and, thanks to the *détente* period that followed the 1972, with USSR space program.

In 1973 *Skylab,* the USA's first space station program, began and in 1975 the USA and USSR joined their efforts and performed the *Apollo-Soyuz Test Project*, the first international human space flight. At the same time, NASA promoted many programs aimed toward discoveries of the solar system. Just to cite a few American missions, NASA developed *Pioneer 10* and *Pioneer 11,* the first probes to exit the asteroid belt; *Pioneer Venus Orbiter* for the study of Venus; and the *Viking* alongside the more recent *Opportunity* missions for the study of Mars.

The most remarkable project in the 1980s in regards the development of the *Space Shuttle*, was the widely famous low Earth orbital spacecraft system. The Space Shuttles probes were partially reusable and a relatively cheap way to reach Low Earth Orbit, and allowed the further development of the *Spacelab* space laboratory later in the 1980s[89] [90].

Space policy

The US is, by far, the largest investors in space activities: in 2014, the federal government allocated USD 42.96 billion in space activities. The national budget is distributed between various federal agencies and departments, with the Department of Defense (DoD) being the largest fund receiver (USD 22.5 billion, approximately 52% of the overall budget). DoD funds are dedicated for the development of National Security programs. DoD's most important programs are developed within the US Air Force and include the Evolved Expendable Launch Vehicles (EELV) program, the Global Positioning System (GPS) program, the Space Based Infrared System (SBIRS) program, and the Advanced EHF (AEHF) program.

EELV started in 1994 with the intention to provide USA's defence independent and reliable access to space and received USD 1.38 billion in 2015. Commenced in 1973, GPS program was created to provide a more advanced and reliable positioning system, and it is nowadays widely used for civilian application. It received USD 1.02 billion in 2015, used primarily for the development of the new GPS III satellites, for the maintenance and the upgrade of the ground control system and for R&D activities.

The rest of the budget, USD 20.47 billion, is distributed for the development of civilian space activities.

NASA, as the most relevant agency to coordinate American civilian space efforts, is heavily financed by the government and received in 2015 USD 18.01 billion, 89% of the national civilian budget. NASA's budget is expected to grow in 2016 and 2017 (see Figure 34). NASA's most relevant involvements focuses on the very top of space industry's value chain, making the agency one of the most important

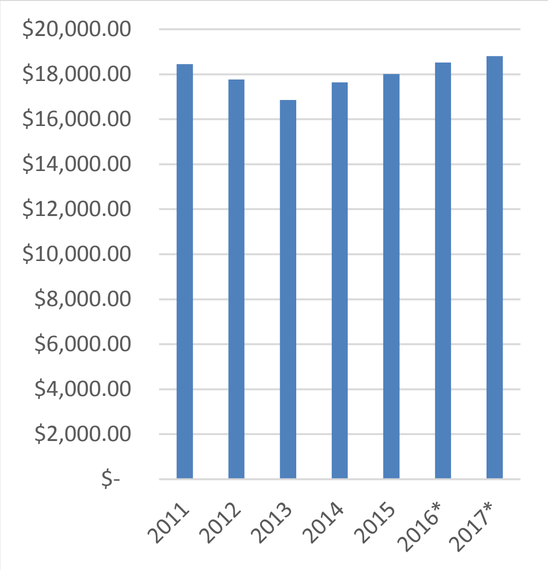
[89] NASA History Division, 2012. *A Chronology of Defining Events in NASA History, 1958-1998.* NASA History Division website: http://history.nasa.gov/40thann/define.htm. Accessed 02/06/2016.
[90] NASA. *NASA History Overview*. NASA website: https://www.nasa.gov/content/nasa-history-overview. Accessed 02/06/2016.

'Development Factors' mentioned in Chapter 1. The agency allocates to 'Science', 'Exploration' and 'Space Operations' more than USD 13.4 billion, nearly 76% of its budget.

The 'Science' budget was USD 524 billion, mainly dedicated to Earth science activities (such as the Global Precipitation Measurement and the Orbiting Carbon Observatory-2 satellites) and to planetary science activities (focusing on the study the history of the universe with the development of the James Webb Telescope, or on Mars exploration with the MAVEN mission).

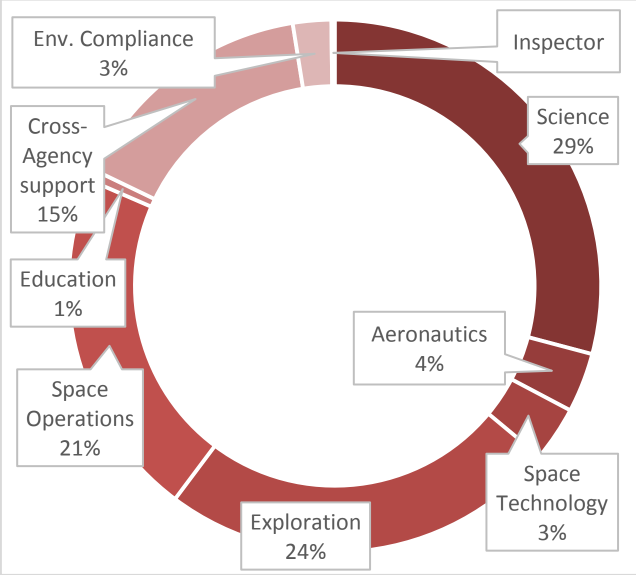
NASA dedicates USD 4.36 billion for 'Exploration'. The most relevant programs here are the development of the Space Launch System (SLS) before 2018, a super heavy-lift launch vehicle designed to be the most powerful launcher ever built and for the development of the *Orion* spacecraft, a Multi-Purpose Crew Vehicle created with the objective to have manned missions outside low Earth orbit for the first time after the end of the *Apollo* missions in the 1970s.

Figure 34: NASA overall Budget, 2011-2017 (in USD million)



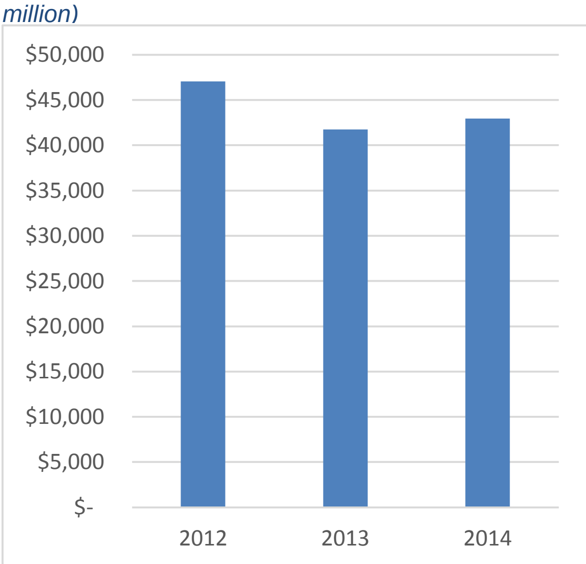
Source: The Space Report 2015. The Authoritative Guide to Global Space Activity.

Figure 35: NASA Budget Breakdown



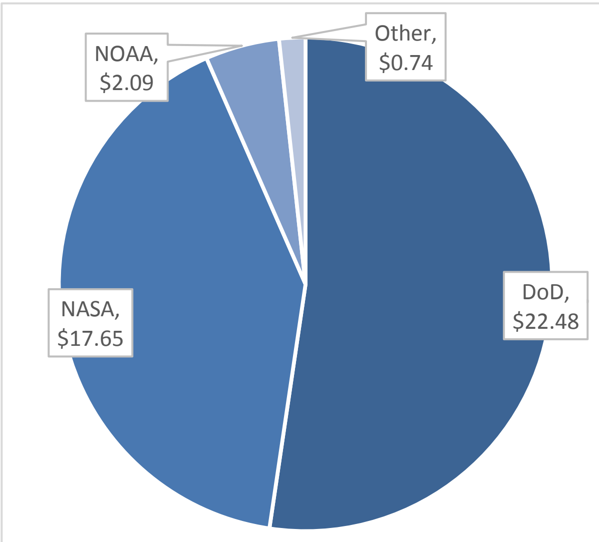
Source: The Space Report 2015. The Authoritative Guide to Global Space Activity.

Figure 36: Government Total Space Budget (in USD million)



Source: The Space Report 2015. The Authoritative Guide to Global Space Activity.

Figure 37: US Government Budget Breakdown, 2014



Source: The Space Report 2015. The Authoritative Guide to Global Space Activity.

The third most funded budget programs are the ones included in the 'Space Operations' Budget Authority. The most important program here regards American involvement in the ISS. The ISS program officially started in 1998 when 15 countries met in Washington to sign the Intergovernmental Agreement on Space Station Cooperation. The US has always been a major player in the development of this program, whether in terms of funding, of international networking and the technological capabilities provided.

INDUSTRY COMPOSITION

The USA has an incredible set of industrial capabilities. It is the most important actor in space, whether in terms of R&D intensity, industrial production or policy guidance. In 2014 US companies generated revenue of USD 82.20 billion, 43% of the global space revenue, and employed nearly 238,000 workers[91]. This massive production is the result of more than 60 years of heavy investments in the sector. Today the country is the largest producer in nearly every space industry's segment.

Looking at Figure 39 the segment in which the US has a smaller is the launch industry, historically dominated by the Russian industry. With USD 2.4 billion, the US capture 40.7% of the global commercial launch industry, a slightly smaller share if compared with other segments of the space industry. It is projected, however, that US space industry will shortly overcome this backwardness, thanks not only to strong public investments, but also thanks to the strong competition in the field, enhanced by the latest regulations[92]. Almost non-existent in 2011, the commercial launch industry earned in 2014 nearly USD 1.1 billion. Competition affected also the military launch industry[93]: in 2015 SpaceX entered in the segment traditionally dominated by Lockheed Martin, Boeing, and United Launch Alliance (ULA, a Lockheed Martin-Boeing joint venture).

With regard to satellite manufacturing, excluding Cubesats, the US built 29% of the satellites launched and earned 62% of the global revenues[94], meaning that US satellite are relatively more expensive and more sophisticated than satellites built elsewhere. Including Cubesat production, the US built 62% of the global production and earned 63% of the revenue. Although the competitiveness of American satellite manufacturing, the revenues decreased by 9% from 2013 and 2014.

With regard to the downstream application of space technologies, national revenues accounted at USD 74.8 billion, 41.3% of the global revenues. The most important revenues come from the provision of satellite communication. In particular, revenue in the DBS-DTH satellite TV segment alone accounted at USD 40.6 billion in 2014, while its total turnover is expected to grow by USD 3.3 billion in the 2011-2017 period[95].

The US space sector is part of a wider aerospace and defence industry. In geographical terms, the production is widespread across the country. More than 15 states show significant involvement in space activities, but the largest clusters are based in California, Texas, Florida, New Mexico, Colorado and Alabama.

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[91] The Space Foundation, 2015. *The Space Report 2015. The Authoritative Guide to Global Space Activity*. The Space Report Publishing.

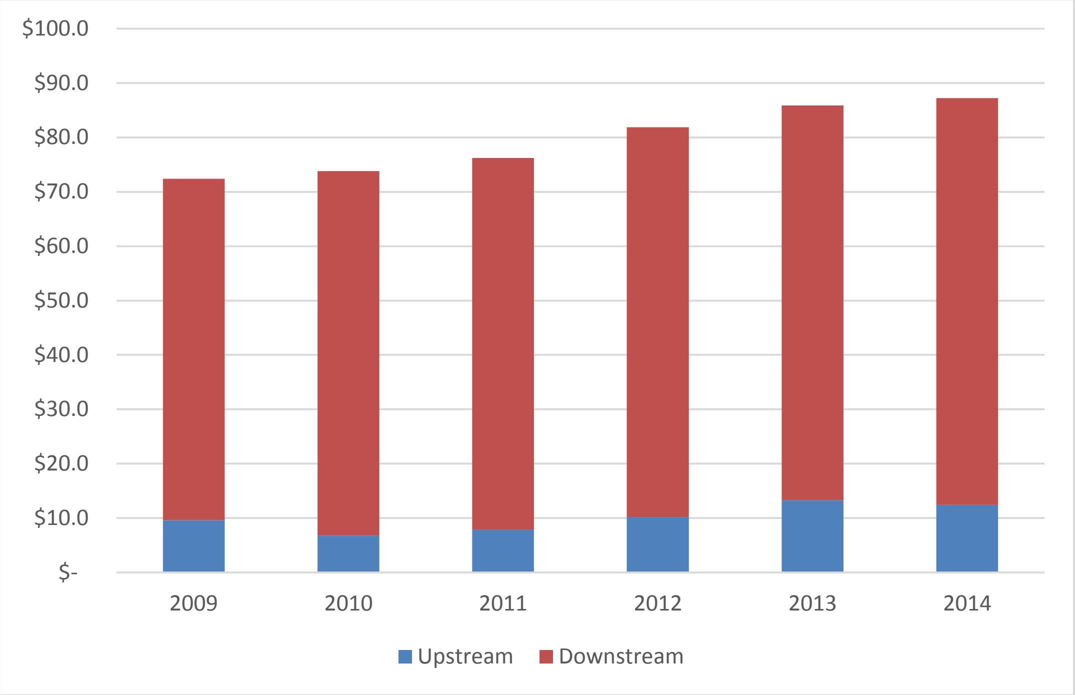
[92] Howell O'Neill P., 2015. *The U.S. has the world's largest private space industry—now what?*
The Daily Dot website: http://www.dailydot.com/politics/us-commercial-space-industry-expands-faa-regulation/. Accessed 05/06/2016.

[93] Iacopini A., 2015. *ULA ha i motori contati e rinuncia ad un lancio per l'USAF: SpaceX ringrazia*.
Fly Orbit News website: http://www.flyorbitnews.it/2015/11/19/ula-ha-i-motori-contati-e-rinuncia-ad-un-lancio-per-lusaf-spacex-ringrazia/. Accessed 05/06/2016

[94] The Tauri Group, 2015. *State of the Satellite Industry report 2015*. SIA Publishing.

[95] Digital TV research, 2015. Global pay TV revenues crawl to $200 billion.
Digital TV research website:
https://www.digitaltvresearch.com/ugc/DTVrevenues12%20product%20copy%20PDF_sample_51.pdf. Accessed 05/06/2016.

Figure 38: US Space industry revenue, excluding non-satellite industry (in USD billion)



Source: Own elaboration from State of the Satellite Industry report 2015

Figure 39: Composition of the US space economy in 2014 (in USD billion)

	USA Space Economy		% of Global Share
Commercial Launch	$	2.4	40.7%
commercial Satellite Manufacturing	$	10.0	62.9%
Total Upstream	*$*	*12.4*	*56.9%*
Ground Equipment	$	23.9	41.0%
Satellite Services	$	50.9	41.4%
Total Downstream	*$*	*74.8*	*41.3%*
Total Revenues (Exlcluded Non-satellite industry)	**$**	**87.2**	**43.0%**

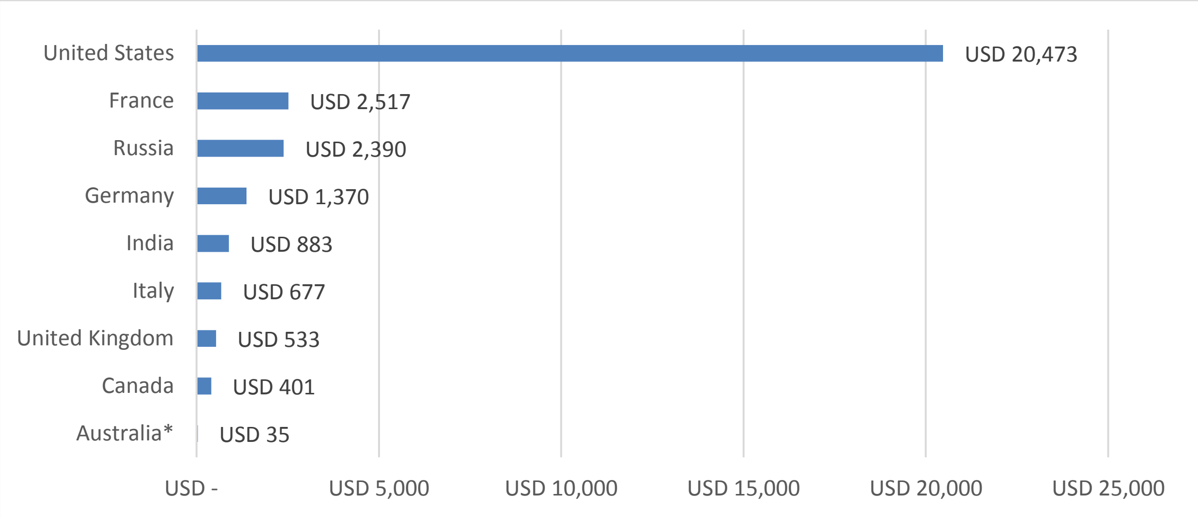
Source: Own elaboration from State of the Satellite Industry report 2015

CHAPTER 3: AUSTRALIA AND SOUTH AUSTRALIA

The roots of Australian involvement in space activities dates back at the end of the 1940s when, in 1947, Australia and United Kingdom signed an agreement for the creation of the *Long Range Weapons Establishment*, later renamed the *Woomera Test Range*, in South Australia. Initially Great Britain, and later the European Launcher Development Organisation (ELDO), selected Woomera as an integrated facility for their launch program. Another important and long-lasting Australian collaboration in space has been pursued with NASA; in 1965 NASA and the *Commonwealth Scientific and Industrial Research Organisation* (CSIRO) founded the *Canberra Deep Space Communication Complex* (CDSCC). This highly-technological ground station formed part of the *Deep Space Network*. Also, in 1967 Australia launched WRESAT 1, its first satellite, aboard an US Redstone rocket.

More recently policy makers have shown less attention on the Australian space environment. OECD estimates Australian public expenditures in civil space to be AUD 40 million (USD 35 million), a low commitment if compared with other countries (Figure 40). It should be noted however, that different countries have different economic conditions, policies and definitions. Comparison of their space budgets in absolute terms could therefore be deceptive. When comparing space expenditures as a

Figure 40: Civil space public expenditure in 2014 (in USD million)



**Data for Australia refer to 2013. Source: OECD, 2014. The Space Economy at a Glance.*
****China not present as no official data could be provided (see paragraph "China")*

Figure 41: Civil space public expenditure as % of GDP

	2014 GDP (in billion of current LCU)		2014 Civil Space Expenditure (in million of current LCU)		% of GDP spent for space
Russia	RUB	71,406	RUB	165,814	0.232%
United States	USD	17,419	USD	20,473	0.118%
France	€	2,132	€	1,982	0.093%
India	INR	125,412	INR	68,330	0.054%
Germany	€	2,915	€	1,079	0.037%
Italy	€	1,613	€	533	0.033%
Canada	CAD	1,974	CAD	462	0.023%
United Kingdom	£	1,816	£	341	0.019%
Australia*	AUD	1,524	AUD	40	0.003%

**Data for Australia refer to 2013. Source: OECD, 2014. The Space Economy at a Glance.*
***China not present as no official data could be provided (see paragraph "China")*

percentage of GDP, the results show useful benchmarks for comparison. Australia spends only the 0.003% of its GDP in space (Figure 41).

Through having an understanding of Australia's broader national ecosystem, its capabilities and of its position in the international context, potential opportunities within the highly strategic space industry can be made clear. While for decades Australia lacked a coherent policy on its space activities, in the last few years the Australian government has envisaged the necessity to set up a clear and consistent space vision. This process began in 2008, when the Australian Senate Economics Committee released *"Lost in Space? Setting a New Direction for Australia's Space Science and Industry Sector*". In the report the committee studied the Australian civil space environment, underlining the contrast between Australia's low attention on space activities and its contradictory dependency on space-enabled services and applications. The following year the Space Policy Unit (SPU) was created and later renamed the Australian Government Space Coordination Committee within the Federal Department of Industry, Innovation and Science.

This Unit continues to develop a consistent and unitary policy for Australia's space environment. In 2013 it published 'Australia's *Satellite Utilisation Policy'*, which is a key document that can be considered the first national strategy on space-related matters. The paper set up seven different principles in order to strengthen the Australian space environment. It recognises the focus that Australia should put in the downstream segment of the market, stressing the importance of Space Applications and of their significant impacts on the national economy; as well as recognising the necessity to support innovation, science and skill creation both through improved domestic coordination and strengthened international collaboration with key allies and partners. Here, the Australian government has identified the three elements of the 'Triple Helix', industry, government and university model where collaborative processes can lead to the endogenous development of the Australian space environment industry, and cooperating with the major global players in the Space industry.

SOUTH AUSTRALIA

The South Australian Government sees opportunities to open a discussion on the role of South Australia in the national and international space environment. A critical step toward pursuing these opportunities is the formation of the 'Space Industry and R&D Collaborations Office' within Defence SA in April 2016. The aim of this Space office is to promote the growth of the South Australian economy and innovation ecosystem through the endogenous growth of the South Australian space environment and the international cooperation with space leading countries.

The key direction, mission and actions of the new office will be defined in the "South Australia Space Innovation and Growth Strategy: Action Plan 2016 to 2020". The strategy's vision is to include all local stakeholders in order to create a "space enabled economy", where the South Australian space sector advances to become an important area of growth, job creation with an increased market share in areas not traditionally linked to Space.

In particular, the new office will increase awareness on the strategic importance of space applications to Australia and South Australia, including their relevance to a range of industries (i.e. national security, advanced manufacturing, telecommunications, agribusiness, environment, position navigation and timing, ICT etc.) and will support the growth of a 'National Hub of Space Industry, Research and Development' where high tech industries, universities and research organisations are actively involved in developing a vibrant innovation ecosystem.

In order to achieve the ambitious goal to upgrade South Australian space environment, the strategy envisions the creation of a "Space Hub", including an online portal aimed to share information, data and publish relevant news and documents. This will promote the South Australian space economy and increase awareness of the space sector as an innovative area to invest and collaborate. Specific focus will be placed on the development of science, technology, engineering and mathematics (STEM) skills and activities.

Another objective of the strategy is to consolidate and stimulate South Australian capabilities and expertise. A simple and widely accessible overview of these skills will be given in the "South Australian Space Industry Capability Directory", published in June 2016 (available online on Defence SA website).

It is intended that the Capability Directory will be published annually for the first two editions and later biennially. The 2016 publication provides data on the expertise, capabilities, skills and unique selling points of nearly 40 between private companies, industrial associations, consultancies and government departments involved in South Australian space environment. Its double objective is to increase linkages and connections within the state space environment and to promote the industrial and scientific south Australian space ecosystem in the rest of the world.

Another important pillar of the strategy is to increase the international cooperation with leading countries and the growth of a network of strategic partnerships in the space sector. Therefore, the office promotes international initiatives, like state missions led by Ministers to countries that have remarkable Space activity, aiming to facilitate international partnerships, agreements and joint activities and, more generally, the involvement of South Australian companies and organisations in the rest of the world,

Perhaps the most important short-term goal of the strategy is the inclusion of the 68th International Astronautical Congress (IAC) in South Australia's environment development process. In September 2017 Adelaide will host the IAC, a global event where more than 3,000 delegates will come to Adelaide from across the world. This important event can be capitalised upon and included in the process of Space ecosystem development embarked by the state. In the lead up to IAC2017, the Space Office organised the first Space Forum on 27 May 2016. More than 100 delegates from local academic, industrial and government organisations participated in the forum. Information was shared relating to the IAC2017 and attendees were encouraged to play an active role in South Australia's research and entrepreneurial Space ecosystem both within and beyond the framework of IAC2017.

CONCLUSION

The space industry is synonymous with incredible opportunities for economic development.

Studies in the UK have shown that each space related job indirectly support the creation of 2.1 new jobs, while each dollar of turnover generated from the space industry enhances the creation of another 1.2 dollars of turnover in the economy[96]. Referring more directly to the Australian context, a recent study[97] has shown that in 2015 the Australian economy benefitted from the application of Earth Observation data by nearly AUD 861 million.

The aforementioned national experiences provide a number of useful hints for the further development of the Australian space sector. The first, and most interesting model, is the British one. Similarly to Australia, Great Britain has recently reorganised its space activities and created in 2010 the UK Space Agency. UKSA is different from every other space agency in Europe, and is strongly oriented to the application of the downstream segment of the space industry in British economy, in order to exploit all the possible economic and social benefits from it. Similarly, during the past five years the United States have been focusing on the downstream application of space technologies, thus proving how this strategy can foster the long-term development of the space industry.

Perhaps the most suitable reference model for Australia is the Canadian one. Canada's geographic features are similar to Australia: a vast country with scattered population. Canada has long been successful in conveying to citizens the importance of space research through mass promotion of its achievements aimed at generating public support around the space industry. However, what is even more interesting is Canada's attitude towards international collaboration, in particular within the European context. Canada collaborates with the European Space Agency and it is ESA's associate member since 1979. This relationship is supported by small financing to ESA (€ 15.5 million in 2015), but this investment, strengthening the collaboration with the European vibrant space environment, generates positive returns on the Canadian economy. So far Canada is the only non-European country to do so, but a similar investment could leverage considerable positive effects on the Australian space industrial and academic environment. Canada's cooperation with the European Space Agency represents a specific form of Foreign Partnership. These Partnerships constitute a critical opportunity in a capital-intensive sector such as the space industry: they allow for economies of scale, cross-fertilisation and mutual exchange of unique resources. Nonetheless, the essential element for a

[96] London Economics, 2014. *Executive Summary: The Size and Health of the UK Space Industry*. UK Space Agency Publishing.
[97] ACIL Allen Consulting, 2015. *The Value of Earth Observations from Space to Australia*. ACIL Allen Consulting Publishing.

profitable partnership is the presence of valuable *capabilities* to be shared between the main stakeholders. With such conditions in place, the partnership becomes a self-enforcing mechanism to enhance sustained industrial growth in the long run, as it allows for an accurate *skills planning* which fosters the development of a clear strategy. Further empirical evidence to the importance of foreign partnerships can be found in the Russian experience: in the aftermath of the USSR collapse, they constituted the only lifeline for the main space companies. For instance, Khrunichev created a joint venture with Lockheed Corporation in 1993.

By looking at the best performing actors, it is straightforward to verify the role of personnel skills and technical knowledge. France's space workforce is highly qualified: 60% of employees have an engineering or managerial background. Similarly, United Kingdom's space manufacturing sector strongly relies on highly qualified personnel (68%), and 31% of employees achieved a higher level degree. As a general statement, the ability to educate local students and to attract and retain talent brings about valuable benefits to the districts that are able to pursue this task. In the specific case of an innovation-driven sector such as the space industry, this ability becomes a priceless asset. From this viewpoint, today Australia shows a remarkable comparative advantage: four Australian universities rank among the top 50 engineering (Mechanical, Aeronautical & Manufacturing) universities, together with a number of American and European universities which are now training the world's best engineers. As for university students from Asia-Pacific countries (including China, South Korea and India), Australia represents an elite destination for their studies abroad: out of 249,990 higher education international students enrolled during the year 2014, the Chinese constituted the largest share (25.9%), and Koreans amount to the 4.7%[98]. The vibrant Australian innovation ecosystem could represent an opportunity for these students but also for Australia.

Australia and South Australia's focus on space activities is sharpening in recognition of the speed of Space industry related economic growth. This lens reveals a clear view of the associated opportunities that may be harnessed by those that engage with this burgeoning, exciting and dynamic space sector. Government is actively working in order to engage industries and universities, recognised as the principal actors that can create, with their interaction, the most favourable environments for the economy, social innovation and growth. It is clear that with strategic government support that catalyses a strong and sustainable space sector, looking to the sky can play a key role in the future of South Australia's strong economic growth and development.

[98] Source: The Australian Trade Commission, End of Year Summary of International Student Enrolment Data1 – Australia – 2014, file:///C:/UserData/Downloads/ISD_MonthlySummary_December2014%20.pdf

ANNEX: SPACE INDUSTRY'S REVENUES, 1973-2014

	1973	1998	2014
Space revenue (billion USD)	$15	$69	$323
Government Space revenue (billion USD)	$12	$34	$65
Commercial Space revenue (billion USD)	$3	$34	$258
World GDP (billion of 2005 USD)	$18,284	$37,923	$58,148

Compound annual grow rate	1973-1998	1998-2013	1998-2014
Space Revenue	6.28%	10.65%	10.14%
Government Space revenue	4.30%	5.65%	4.01%
Commercial Space revenue	10.25%	13.68%	13.42%
World GDP	2.96%	2.72%	2.71%

GDP compound growth rate 'g' is calculated with the following formula:

g=(e^(1/n)*ln(V0/Vn))-1

Where
n = number of periods
V0 = initial value of the variable
Vn = final value of the variable

Data from:
APAC 2015: A Selective Review of Australian Space Capabilities
knoema.com, GDP Statistics from the World Bank. Visited 13/04/2016
http://knoema.com/mhrzolg/gdp-statistics-from-the-world-bank