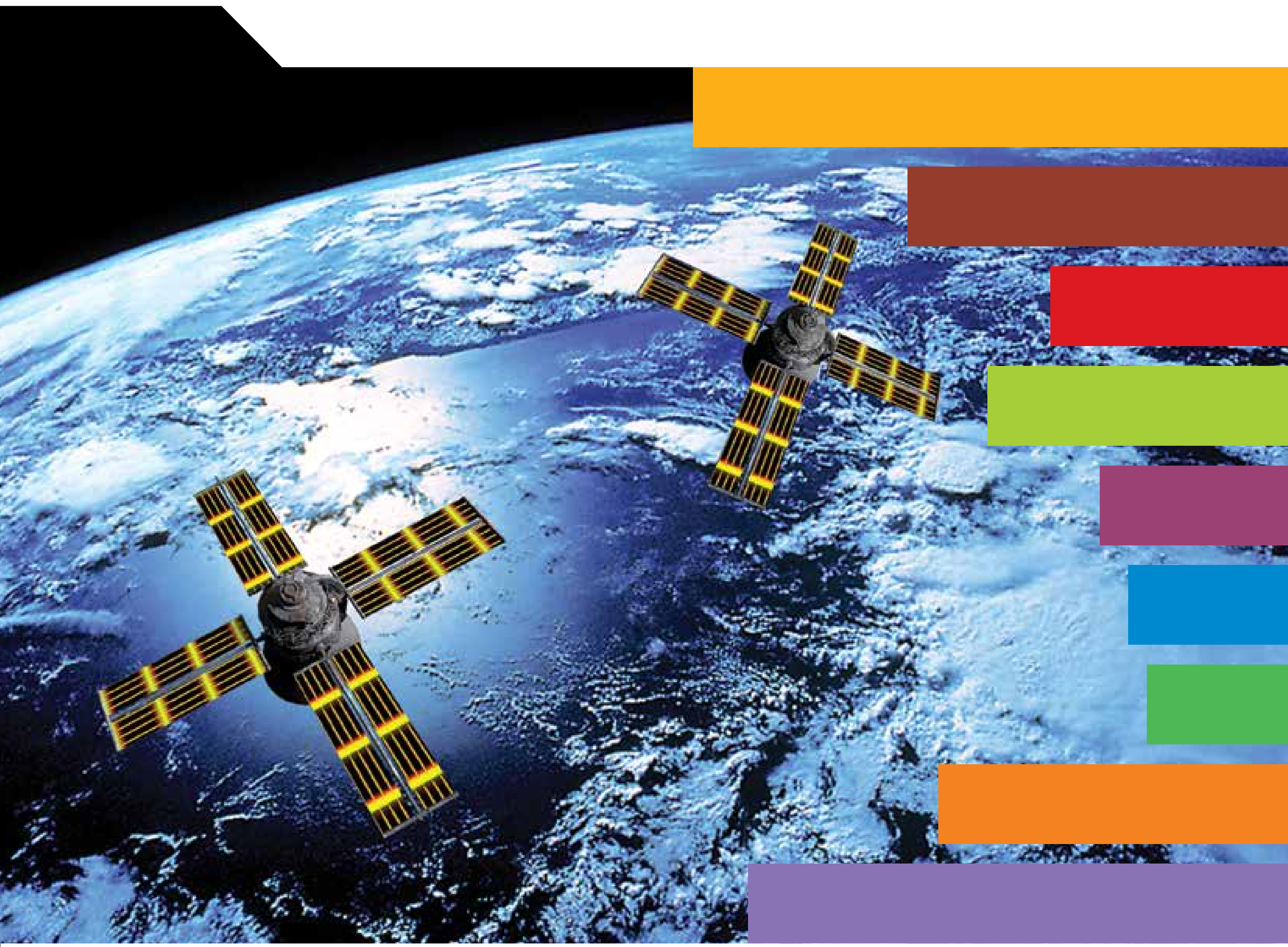
The Space Economy at a Glance 2014



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The Space Economy at a Glance 2014

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Foreword

This publication is part of the OECD's "At a Glance" series which provides snapshots of key policy areas based on data and indicators. The Space Economy at a Glance *(2014) provides a statistical overview of the global space sector and its contributions to economic activity. This new edition provides not only recent indicators and statistics based on both official and private data, but also a strategic outlook that identifies new dynamics in the space sector. The figures cover, for the first time, more than forty countries with space programmes.*

The space sector plays an increasingly pivotal role in the efficient functioning of modern societies and their economic development. The use of satellite technology in navigation, communications, meteorology, and earth observation is giving rise to a growing stream of applications in such areas as air traffic control, transport, natural resource management, agriculture, environmental and climate change monitoring, entertainment and so on, which in turn are creating new downstream uses and new markets. Space is increasingly seen as a contributing lever for economic growth, social well-being and sustainable development.

This publication is the latest output of the OECD Space Forum in the Directorate for Science, Technology and Innovation (STI). The Space Forum assists governments, space-related agencies and the private sector to better identify the statistical contours of the space sector, while investigating the space infrastructure's economic significance, innovation role and potential impacts for the larger economy. In 2014, the Space Forum's Steering Group has nine members, including national space agencies/official bodies in charge of space activities from eight OECD economies: Canada (Canadian Space Agency), France (Centre National d'Etudes Spatiales), Germany (Deutschen Zentrums für Luft-und Raumfahrt), Italy (Agenzia Spaziale Italiana), Norway (Norsk Romsenter and Ministry), Switzerland (Swiss Space Office), the United Kingdom (UK Space Agency), the United States (National Aeronautics and Space Administration), as well as the European Space Agency. The Space Forum benefits from co-operation with a large network of experts in the international space community.

This publication was prepared under the direction and guidance of Claire Jolly, Head of the OECD Space Forum, with support in conducting research and analysis from Marit Undseth, Research Analyst, Sang In Know, Junior Researcher, Anita Gibson, Development and Outreach Co-ordinator, and editorial assistance from Barrie Stevens, Senior Advisor. The team benefited from contributions from colleagues inside the Organisation, particularly Hélène Dernis for patents and Koen de Backer for global value chains, colleagues from the Economic Analysis and Statistics (EAS) Division for industry data, all from STI. We particularly thank the members of the Space Forum for providing instrumental data and comments. We also thank the industry and institutional participants of two special OECD Space Forum workshops that were organised on global value chains and the space sector in Paris and Washington. Finally, several experts from other organisations also kindly contributed some data: Ken Davidian from the FAA, Brad Botwin and Christopher Nelson from the US Department of Commerce; R. Sateesh Kumar from the Indian Space Research Organisation, Isabelle Sourbès-Verger from CNRS, Pierre Lionnet from Eurospace, Claude Rousseau from NSR, and Carrissa Christensen and Paul Guthrie from Tauri Group, as well as many space industry representatives. Our gratitude goes to all the organisations and individuals who contributed to this publication.

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Acronyms

AIA	Aerospace Industries Association
AIS	Automatic Identification System
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
BERD	Business Enterprise Research and Development
BNSC	British National Space Centre
BRIC	Brazil, Russian Federation, India and China
BRIIC	Brazil, Russian Federation, India, Indonesia and China
CAST	China Aerospace Science and Technology Group
CDTI	Centro Para el Desarrollo Tecnológico Industrial (Spain)
CEOS	Committee on Earth Observation Satellites
CNES	Centre National d'Études Spatiales (French Space Agency)
CSA	Canadian Space Agency
DBS	Direct Broadcasting Satellite
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DTH	Direct-to-Home Satellite
EC	European Commission
EPO	European Patent Office
ESA	European Space Agency
FAA	Federal Aviation Administration
FSS	Fixed Satellite Service
FTE	Full-time Equivalent
GBAORD	Government Budget Appropriations or Outlays for Research and Development
GEO	Geostationary orbit
GIFAS	Groupement des Industries Françaises Aéronautiques et Spatiales
GPS	Global Positioning System
GSO	Geosynchronous orbit
IFP	International Futures Programme
INSEE	Institut National de la Statistique et des Etudes Economiques
ISRO	Indian Space Research Organisation
ITAR	International Traffic in Arms Regulations
ITCS	International Trade in Commodity Statistics
ITU	International Telecommunications Union
JAXA	Japanese Aerospace Exploration Agency
KARI	Korean Aerospace Research institute
LEO	Low earth orbit
MSS	Mobile Satellite Service
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSC	Norwegian Space Centre

OECD	Organisation for Economic Co-operation and Development
PCT	Patent Co-operation Treaty
PPP	Purchase Power Parities
Roscosmos	Russian Federal Space Agency
SANSA	South African National Space Agency
SJAC	Society of Japanese Aerospace Companies
SME	Small and medium enterprises
SSO	Sun synchronous orbit
SSO	Swiss Space Office
UKSA	United Kingdom Space Agency
USGS	United States Geological Survey
USPTO	United States Patent and Trademark Office

Executive summary

The global space sector is a high-technology niche with a complex ecosystem, which employed at least 900 000 persons around the world in 2013, including public administrations (space agencies, space departments in civil and defence-related organisations), the space manufacturing industry (building rockets, satellites, ground systems); direct suppliers to this industry (components), and the wider space services sector (mainly commercial satellite telecommunications). But these estimates do not take into account universities and research institutions, which also play a key role in R&D, as receivers of public contracts and initiators of much of the space sector's innovation.

The acquisition and development of space capabilities remains a highly attractive strategic goal, and the number of countries and companies investing in space systems and their downstream applications continues to grow. Despite the economic crisis, institutional funding remained stable in 2013 on a global scale, with increased budgets in several OECD countries and emerging economies. Space often has a reputation for being expensive, but national investments represent only a very small percentage relative to GDP in all G20 countries. In the United States, the largest programme in the world, space represents only 0.3% of GDP and in France, less than 0.1% of GDP.

Although OECD countries accounted for the largest space budgets globally in 2013 (USD 50.8 billion, using purchasing power parities or PPPs), an increasing part of global space activities takes place outside of the OECD, particularly in Brazil, the Russian Federation, India and China (around USD 24 billion PPPs).

The space economy represented some USD 256.2 billion in revenues in 2013, divided between the space manufacturing supply chain (33%), satellite operators (8.4%) and consumer services (58%), including actors who rely on some satellite capacity for part of their revenues, such as direct-to-home satellite television services providers.

Globalisation of the space sector is accelerating

Globalisation is affecting the space economy at different levels. In the 1980s, only a handful of countries had the capacity to build and launch a satellite. Many more countries and corporate players across a wide range of industrial sectors are now engaged in space-related activities, a trend that is expected to strengthen in the coming years. Supply chains for the development and operation of space systems are also increasingly evolving at the international level, even if the space sector remains heavily influenced and shaped by strategic and security considerations. Many space technologies are dual use, i.e. employed for both civilian and military programmes, which tends to constrain international trade in space products. Nonetheless, as evidenced by recent OECD research on global value chains, product and service supply chains for space systems are internationalising at a rapid pace. While the mode of interaction between space actors may vary (e.g. in-kind co-operation among space agencies, contracting out to foreign suppliers, industrial offset programmes), the trend towards globalisation is having an impact right across the space economy – from R&D and design, to manufacturing and services.

As more actors seek to enter global value chains, competition on the relatively small commercial open markets for spacecraft, launchers and parts is getting stronger for incumbents. In parallel, the expansion of aerospace and electronics groups to address new national markets, where fresh public investments in space programmes are being made, is affecting human resources. As new opportunities arise, in the form of scientific co-operation, technological innovations, new applications, emerging markets etc., so too do new risks – the growing vulnerability of widely stretched supply chains to various kinds of disruption is just one example. Balancing these new risks and opportunities over the next few years will prove challenging for policy makers and industry players alike.

The "democratisation" of space is gaining ground

New dynamic forces are being unleashed in the space sector, with some technological innovations coming increasingly into use (e.g. electric propulsion systems on-board large telecommunications satellites, 3-D printing used by industry and tested in orbit on the International Space Station) and others just around the corner (e.g. advances in miniaturisation making small satellites even more affordable). Scientific and technological innovations are making space applications more accessible to more people. It still takes years of R&D, with sustained funding, to develop leading-edge sensors and new spacecraft. However, it is now possible for universities to buy off-the-shelf technologies and equipment to build micro-satellites with ever-growing functionality. Innovative industrial processes are also promising to potentially revolutionise space manufacturing, for example the adaptation of the automobile industry's mass production techniques to selected space systems. These new dynamics, coupled with globalisation, could increasingly impact the way space activities are conducted around the world, particularly for incumbent industrial actors.

Many of the socio-economic impacts from space investments are becoming more visible

Socio-economic impacts derived from space investments are diverse. Impacts of using space applications can often be qualitative (e.g. improved decision-making based on satellite imagery) but also monetarily quantifiable in documented cases, such as cost-efficiencies derived from using satellite navigation tools. However, the flow of evidence-based information to decision makers and citizens needs to be improved. When assessing the net benefits of space investments, more effort is needed internationally in building the knowledge base and devising the mechanisms for transferring know-how and experience to practitioners worldwide. This can improve the provision of evidence-based information on the benefits and limitations of space applications, while at the same time reducing the risk of "reinventing the wheel".

Reader's Guide

This reader's guide introduces the contents and structure of The Space Economy at a Glance publication, some general definitions, the sources used and some methodological notes.

What's new in this report?

Published every three years to provide reviews of major trends in the space sector and its contributions to economic activity, *The Space Economy at a Glance* is part of the broader "at a glance" OECD collection of reports. These reports provide indicators on a variety of topics of interest to decision-makers and citizens.

The Space Economy at a Glance 2014 brings several new features:

- As compared to the 2011 version, more countries are included in the graphs, building on new time-series on institutional budget, thanks to co-operation with many countries developing space programmes.
- The country profiles, featuring members of the OECD Space Forum as well as invited economies, have also been enriched with new indicators.
- Original work on global value chains, using the space sector as a case study, has also been feeding many sections, and provides thought-provoking findings featured in the publication. This activity on value chains built on several OECD Space Forum workshops that were held in 2013 and 2014, in Paris and Washington D.C., to discuss definitions, methods, indicators, and industry survey methodologies with stakeholders from public administrations, as well as the private sector.
- New indicators have also been developed and included, thanks to co-operation with different OECD divisions and the space community. They include indicators on patents, with data available now at the regional level, as well as new bibliometric data on scientific publications per country. Improved trade data on space and aerospace are also available with the inclusion of intermediate and final products in some cases.

Structure of the report

The Space Economy at a Glance is structured in several parts:

- The introductory chapter provides an overview of key trends in the space sector in 2014.
- Part I provides a review of "readiness" indicators, i.e. capabilities that are necessary to be able to engage in significant space activities (e.g. budget, infrastructure, human capital).

- Part II reviews a diversity of "intensity" indicators, which illustrate the multiplicity of space programmes and stakeholders (e.g. sectors, industry revenues).
- Part III provides selected illustrations of the impacts of space investments.
- Part IV offers a global overview of the aerospace sector.
- Part V presents selected country profiles, using a common framework to present key information on the space activities of selected OECD economies that are members of the OECD Space Forum, as well as invited emerging economies.

From Part I, each indicator presented in the report is preceded by a short text that explains in general terms what is measured and why, followed by a brief description of the main trends that can be observed. A paragraph on methodologies highlights those areas where some caution may be needed when comparing indicators across countries or over time.

Basics about space technologies

Launching a satellite into space to orbit the earth, or a probe to visit another celestial body, remains a formidable challenge. Major progress has been achieved over the past few decades, including notably the successful development of several families of rockets (e.g. Soyuz, Ariane, Atlas, Delta), but access to space remains costly and risky. Satellites are essentially platforms that can carry instruments used for diverse applications. They are often very sophisticated R&D objects with a lengthy development time (several years), although the greater recurring use of standard satellite platforms is reducing that time (six months or less for some small satellites). These satellites are launched in different orbit, depending on their missions.

Basics about satellites' orbits

Orbit	Description
Low earth orbit (LEO)	Satellites in LEO orbit the earth at altitudes of between 200 km and 1 600 km. Compared with higher orbits, LEO satellites can capture images and data with better detail (better resolution), have speedier communications with earth (less latency), and require less power to transmit their data and signals to earth. However, due to friction with the atmosphere, a LEO satellite will lose speed and altitude more rapidly than in higher orbits.
Polar orbit	A majority of satellites never "see" the poles, as more often than not they are positioned in equatorial orbits to cover large populated areas. Satellites that use the polar orbit – particularly meteorological satellites – go over both the North and the South Pole at a 90-degree angle to the equator. Most polar orbits are in LEO, but any altitude can be used.
Geosynchronous/Geostationary orbit (GSO/GEO)	The satellites in geosynchronous orbit (also known as geostationary when it has an inclination of zero degrees) are at a higher altitude, around 36 000 kilometres, forming a ring around the equator. Their orbits keep them synchronised with the earth's rotation, hence they appear to remain stationary over a fixed position on earth, and provide an almost hemispheric view. Their advantage is the frequency with which they can monitor events (three GEO satellites placed equidistantly can together view the entire earth surface, but with less precision than LEO satellites). They are ideal for some types of communication and global meteorological coverage.
Sun Synchronous Orbit (SSO)	When in sun-synchronous orbit, the satellite orbital plane's rotation matches the rotation of the earth around the sun and passes over a point on earth at the same local solar time each day.

Note: Orbital mechanics (also called flight mechanics) deal with the motion of artificial satellites and space vehicles moving under the influence of forces such as gravity, atmospheric drag, thrust, etc. There are many types of orbits other than the ones described above [e.g. medium earth orbit for some navigational and communications satellites, Molniya orbits, etc.].

The economic and strategic significance of these complex systems come primarily from their capacity to function as enabling technologies in communication, earth observation, navigation and positioning. They contribute to:

- Communicate anywhere in the world and disseminate information and data over wide areas, whatever the state of the ground-based network.

- Observe any place on earth accurately and in a broad spectrum of frequencies, in a non-intrusive way.
- Locate with increasing levels of precision a fixed or moving object anywhere on the surface of the globe.

Space technologies therefore boast unique capabilities. However, there are a number of technical constraints that may lessen the usefulness of satellite signals or data for specific applications. For example in terms of earth observation for land-use or climate monitoring, one key aspect is the geographic area that a sensor can cover in one satellite pass and the level of detail that can be seen (it is a function of the satellite swath width, orbit and sensor's resolution – as with a telescope, the more one zooms, the less global coverage one gets). Another aspect is the satellite's revisit time over one specific area (from many times a day to only once a month depending on the orbit chosen for the satellite). And finally, the adequacy of the on-board sensors for a particular element that needs to be observed (this depends on the choice of sensors carried on the satellite, optical or radar, and on the bands that figure in the electromagnetic spectrum).

Methodological notes

The indicators in this report build on data provided regularly by member countries' authorities and on data available from other OECD and international sources. The data primarily come from official sources (such as OECD databases, statistical offices, national space agencies), as well as industry sources in some cases. Figures have been chosen based on the reliability and the timeliness of available data.

A number of currency conversions have been conducted for purposes of comparison, and the methods are always cited. The GDP figures used are expressed in USD. Purchasing power parities (PPPs) are also used. PPPs are the rates of currency conversion that equalise the purchasing power of different countries by eliminating differences in price levels between countries. For some calculations, this report also makes use of the Consumer Price Index (CPI) – all items as a deflator, from the OECD Main Economic Indicators (MEI) database. The CPI measures the average changes in the prices of consumer goods and services purchased by households. It is compiled in accordance with international statistical guidelines and recommendations, as there is no space industry-specific consumer price index. This allows interesting comparisons between countries. The report also uses OECD's Monthly Monetary and Financial Database for the calculation of exchange rates. Exchange rates are monthly averages, calculated by the OECD as averages of daily interbank rates on national markets. Data are averages of daily closing rates.

The tables below provide information on the country acronyms and grouping used throughout the publication.

Selected ISO codes

AUS	Australia	ISR	Israel
AUT	Austria	JPN	Japan
BEL	Belgium	KOR	Korea
CAN	Canada	LUX	Luxembourg
CHE	Switzerland	MEX	Mexico
CHL	Chile	NLD	Netherlands
CZE	Czech Republic	NZL	New Zealand
DEU	Germany	NOR	Norway
DNK	Denmark	POL	Poland
ESP	Spain	PRT	Portugal
EST	Estonia	SVK	Slovak Republic
FIN	Finland	SVN	Slovenia
FRA	France	SWE	Sweden
GBR	United Kingdom	TUR	Turkey
GRC	Greece	USA	United States
HUN	Hungary		
ISL	Iceland		
IRL	Ireland	EU	European Union
ITA	Italy		

BRA	Brazil	IDN	Indonesia
CHN	China	RUS	Russian Federation
COL	Colombia	TWN	Chinese Taipei
IND	India	ZAF	South Africa

Country aggregates

OECD Europe	All European member countries of the OECD, i.e. Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom.
OECD	All member countries of the OECD, i.e. countries of OECD Europe plus Australia, Canada, Chile, Israel, Japan, Korea, Mexico, New Zealand, United States.
EU15	European Union countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.
G20	Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, the Russian Federation, Saudi Arabia, South Africa, Turkey, United Kingdom, United States and European Union (which is not included in the G20 average).
BRIC	Brazil, Russian Federation, India, China.
BRIICS	Brazil, Russian Federation, India, Indonesia, China, South Africa.

Sources

OECD (2014), *Main Economic Indicators (MEI)* (database), *www.oecd.org/std/mei*.

OECD (2014), *International Trade by Commodity (ITCS)* (database), *www.oecd.org/std/its/itcsinternationaltradebycommoditystatistics.htm*.

OECD (2014), *STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*, *www.oecd.org/sti/btd*.

Chapter 1

The space sector in 2014 and beyond

Chapter 1 reviews major trends in the space sector. It first provides a review of the "space economy" in 2014. It then focuses on an original analysis of global value chains in the space sector, including a spotlight on fifty years of European space co-operation. The chapter also looks at new dynamics in the sector, which may impact incumbents and new entrants, with a focus on innovation in industrial processes and the development of small satellites.

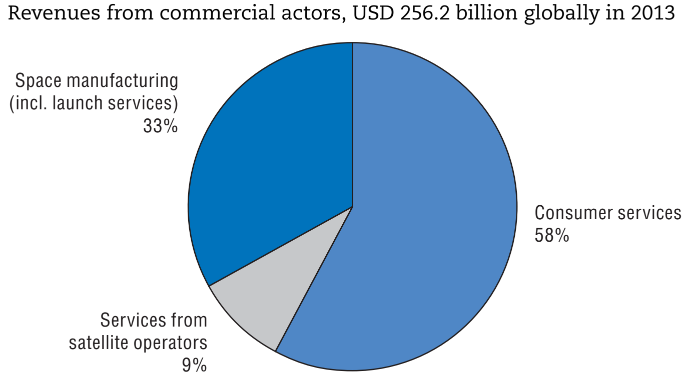
Defining the "space economy" in 2014

Straddling the defence and aerospace industries, the space sector has for decades been a relatively discrete sector, developed to serve strategic objectives in many OECD and non-OECD economies, with security applications, science and space exploration. The space sector, like many other high-tech sensitive domains, is now attracting much more attention around the world, as governments and private investors seek new sources of economic growth and innovation. The "space economy" has become an intriguing domain to examine, bringing interesting innovation capacities as well as new commercial opportunities.

Over the past decade, the number of public and private actors involved in space activities worldwide has increased, spurring even further the development of the nascent space economy. Despite strong headwinds in many related sectors (e.g. defence), the space sector overall has not been significantly affected by the world economic crisis. It remains a strategic sector for many countries, relatively sheltered because of national imperatives (e.g. rising security concerns in many parts of the world feeding the needs for more satellite surveillance), its long lead time to procure, build and launch satellites (i.e. current activities are a reflection of projects planned a number of years ago), but also because of an ever stronger demand in its main commercial branches, particularly satellite telecommunications. When examining other sectors, the highest proportion of internal value creation for firms is often found in certain upstream activities (new concept development, R&D or the manufacturing of key parts and components), as well as in certain downstream activities, such as marketing, branding or customer service. Such activities involve "tacit, non-codified knowledge in areas such as original design, the creation and management of cutting-edge technology and complex systems, as well as management or organisational know–how" (OECD, 2014). This is also true for space products and services chains overall.

Figure 1.1. **Main segments of the space economy**

Revenues from commercial actors, USD 256.2 billion globally in 2013



StatLink http://dx.doi.org/10.1787/888933141646

The global space economy, as defined by the OECD Space Forum, comprises the space industry's core activities in space manufacturing and in satellite operations, plus other consumer activities that have been derived over the years from governmental research and development. In 2013 commercial revenues generated by the space economy amounted to some USD 256.2 billion globally (i.e. including actors in Europe, North America, South America, Asia, the Middle East). The breakdown was as follows:

- The space manufacturing supply chain (described in details below, from primes to Tiers four, from assembly of complete spacecraft systems to components) represents conservatively some USD 85 billion globally. This number is probably relatively underestimated since there are institutional programmes in many countries that are the sources of unreported contracts to national space industries (e.g. defence activities). This important segment is often characterised by largely captive markets, since much of the demand for institutional satellites, launchers and ground segment is often directed at national industries. However, as we will see in the next section, more actors than ever before are involved in supplying space products.
- As a second segment, services from satellite operators -which own and operate satellites- are included for some USD 21.6 billion (i.e. revenues from the satellite telecommunications operators: fixed and mobile satellite services, satellite radio services, and commercial remote sensing operators). These are important actors, as they have to service governmental and commercial customers outside the space sector (e.g. providing bandwidth, imagery), so they tend to push space manufacturing suppliers for more innovation to respond to market needs at lower cost (e.g. development of broadband via satellite).
- Finally, the consumer services include actors, usually outside the space community, which rely on some satellite capacity for part of their revenues. These downstream activities are an integral part of the space economy, although their share is the most difficult to assess, as valuable satellite signals or data need to be tracked in equipment and services. They include direct-to-home satellite television services providers, satnav consumer equipment and value-added services, and very-small apertures terminals providers (e.g. data handling, banking), with revenues estimated at some USD 149.6 billion.

All measurements are of course beset with definitional and methodological issues, and so estimates may vary. For example, using a slightly different scope and more limited national data, the space economy was valued in 2011 at USD 150-165 billion (OECD, 2011). By way of comparison, the institutional budgets for space activities amounted to some USD 64.3 billion (current) for 40 economies in 2013. In all countries, the role of governments remains essential as a source of initial funding for public R&D, as well as a major anchor customer for many space products and services. When national space budgets are converted using purchase power parities to allow better international comparisons, the United States, China, India and the Russian Federation are among the top-four investors on space in 2013. The United States has the highest space budget per capita, representing some USD 123 PPP per habitant, followed by the Russian Federation, France, Luxembourg, Japan, Belgium, Germany and Norway (see 3. *Institutional space budgets* for more data).

Table 1.1. Space budgets in PPP and per capita for selected countries

	Space budget in USD millions (PPP), 2013	Budget per capita
USA	39 332.2	123.2
CHN	10 774.6	7.9
RUS	8 691.6	61.0
IND	4 267.7	3.3
JPN	3 421.8	26.9
FRA	2 430.8	38.0
DEU	1 626.6	20.1
ITA	1 223.3	20.7
KOR	411.5	8.2
CAN	395.9	11.5
GBR	338.9	5.3
ESP	302.9	6.7
BRA	259.2	1.3
BEL	244.8	21.9
IDN	142.0	0.6
CHE	133.0	16.6
SWE	122.0	12.7
NDL	110.5	6.6
TUR	104.3	1.4
NOR	89.6	18.5
ISR	89.3	11.1
POL	80.7	2.1
ZAF	76.4	1.5
AUT	73.0	8.6
FIN	53.9	9.9
DNK	38.2	6.9
PRT	32.2	3.0
GRC	30.3	2.7
CZE	25.4	2.5
IRL	25.3	5.6
AUS	24.9	1.1
LUX	17.0	34.5
HUN	8.9	0.9
MEX	8.5	0.1
EST	5.4	4.0
SVK	4.8	0.9
SVN	2.9	1.4

Source: OECD calculations based on national data and OECD MEI data.

When examining the many actors involved in space products and services, the respective roles of public sector agencies, universities and industry can be more or less pronounced in the research and development phases, and in the actual production of space systems. The companies that form the core of the supply chains for the space industry in OECD economies range from major multinationals, to small and medium size enterprises (SMEs) in Europe, North and South America and Asia. Elsewhere, the model can be slightly different. In India for instance, the Indian Space Research Organisation (ISRO) centres dominate the supply chain. According to their respective speciality, these are manufacturers and assemblers of space systems, with the Indian industry providing only selected equipment and components. Zooming in a typical space manufacturing supply chain, it is divided in "Tiers" like the automobile or the aeronautic sectors, where many players are often involved in several segments at the same time. The US Department of Commerce found for example, via a large industrial survey conducted on the space sector's industrial base, that some 71% of respondents were serving more than one market segment (i.e. aircraft, electronics, energy, missiles, ground vehicles, ships…) (DoC, 2014).

The main segments of what can be called the space manufacturing supply chain (selected companies are cited for illustration purposes, many have subsidiaries around the world) look like this:

- "Primes" are responsible for the design and assembly of complete spacecraft systems, which are delivered to the governmental or commercial users (e.g. telecommunications, earth observation satellites, launchers, human-rated capsules). Selected companies include Airbus Space and Defence (FRA, DEU), Thales Alenia Space (FRA, ITA), Orbitale Hochtechnologie Bremen (OHB System) (DEU), MacDonald, Dettwiler and Associates (MDA) (CAN), Lockheed Martin (USA), Boeing (USA), Space Systems/Loral (USA), Orbital Sciences Corporation (USA); Northrop Grumman Space Technology (USA), Mitsubishi Heavy Industries (JPN), Alenia Spazio (ITA), Surrey Satellite Technology Ltd (GBR), China Aerospace Science and Technology Corporation (CASC) (CHN), Krunichev State Research and Production Space Center (RUS), Israel Aircraft Industry (ISR)…
- "Tier 1" actors intervene in the design, assembly and manufacture of major sub-systems (e.g. satellite structures, propulsion subsystems, payloads). The division between primes and Tier 1 actors is sometimes blurred, as some subsystem manufacturers have been taken over as subsidiaries by multinationals in North America and Europe over the past five years. Yet more vertical consolidation is expected over the next two years. Selected Tier 1 actors include therefore most of the primes indicated above, which may even provide sub-systems to their competitors in some cases, and other firms with specific expertise (in terms of propulsion, structures…): Snecma (FRA), OKB Fakel (RUS), L-3 ETI (USA), Aerojet Rocketdyne (USA), Com Dev (CAN), UTC Aerospace Systems (USA), Teledyne Brown Engineering (USA), Ruag (CHE)…
- "Tier 2" actors are manufacturers of equipment to be assembled in major sub-systems. Again, some companies may be involved in both equipment and subsystems design and manufacturing. As the equipment costs, overall reliability and timely-availability are to a significant extent driven by their components, these companies can play a middle-man role for others, as "Central Parts Procurement Agent" with components' suppliers in the lower tiers. Many space agencies and companies do not deal with the lower tiers' component suppliers directly, and have lists of approved agents (e.g. ESA approved agents include the Alter Technology Group (Hirex Engineering, FRA; Tecnologica and TopRel, ESP), and Airbus' Tesat-Spacecom, DEU). Selected equipment manufacturers include: Sodern (FRA), APCO Technologies (CHE), Bradford Engineering B.V (NDL), Selex ES (ITA), Airbus' Space Engineering (ITA), Aeroflex (USA), Raytheon (USA), Kongsberg Gruppen (NOR)…
- "Tier 3 and 4" actors include producers of components and sub-assemblies, which tend to specialise in the production of particular electronic, electrical and electromechanical (EEE) components and materials (e.g. cables, electrical switches). They tend to be either small specialised firms or large electronics groups with only a minor activity linked to space programmes. This "tiers" also includes providers of scientific and engineering services, acting as contractors to space agencies and the space industry. They include specialised or generalist engineering firms, as well as universities and research institutes. Examples are Composite Optics (USA), M/A-COM (USA), Thales Electron Devices (FRA)…

In terms of customers, the space manufacturing supply chain addresses government and commercial satellite operators' demand for spacecraft, launchers and satellites. Depending on the country, the institutional demand may be much more important in terms of revenue generation, as compared to the commercial demand. Typically, space manufacturing activities are more developed where strong institutional customers are established (e.g. United States, China, Russian Federation). The satellite and launchers manufacturers' other customers (i.e. the commercial operators, providing commercial satellite telecommunications services or earth observation and geospatial data to third parties) play a key role in enhancing competition and innovation in the space industry. There are more than 50 satellite telecommunications operators established around the world, e.g. Eutelsat (FRA), Intelsat (USA/NDL), Inmarsat (UK), Telenor (NOR)... For earth observation, smaller satellite operators are generally involved, although some of them have been taken over recently by larger groups. Selected operators with satellite constellations include: BlackBridge's Rapid Eye (DEU), Airbus's Spot Image (FRA), DMC International Imaging Ltd (UK), DigitalGlobe (USA), ImageSat (ISR)…

At the final end of the space industry supply chain, "downstream" actors are the companies providing commercial space-related services and products to the final consumers. They are generally companies that are not connected to the traditional space industry, and are only using space signals and/or data in their own products. Typically, their services concern communications, satellite television (e.g. BskyB, Dish and DirectTV), geospatial products and location based services (e.g. Trimble, Garmin). Often only a small part of their revenues and employment are derived directly from their space-related activity. They are included in the "space economy" as far as a share of their activity directly depends on the provision of satellite signals or data.

The manufacturing supply chain is discussed in more detail in the next sections, particularly its internationalisation, as new actors are positioning themselves in specific sub-segments. The table below provides an overview of selected products and services in the broader space economy.

Major challenges lie ahead both for the incumbents and for the new entrants into the space economy. In a globalised world, few sectors are sheltered from competition as the rapidly evolving global value chains in the space sector demonstrate. In addition a new industrial revolution is looming on the horizon which holds out the prospect of deep-seated change in the traditional space industry. Some of these major disruptive innovations will also presented.

Table 1.2. **Overview of the supply chain in the broader space economy**

Positioning	Actors	Selected products and services
Tiers Three and Four	Scientific and engineering consulting	• Research and development services. • Engineering services (design, testing…)
	Material and components suppliers	• Materials and components for both space and ground systems: passive parts (around 70% of components in space sub-systems: cables, connectors, relays, capacitors, transformers, RF devices…) and active parts (e.g. diodes, transistors, power converters, semiconductors).
Tiers One and Two	Designer and manufacturer of space equipment and subsystems	• Electronic equipment and software for space and ground systems. • Spacecraft/satellite platform structure and data handling subsystem (e.g. on-board computer, interface unit, satellite and launcher electronics). • Guidance, navigation and control subsystems, and actuators (e.g. gyroscopes, sun and star sensors rendezvous- and docking sensor). • Power subsystems (e.g. electrical propulsion, power processing unit, solar array systems, photo voltaic assembly). • Communications subsystems (e.g. receivers and converters, fibre optic gyro, solid state power amplifier, microwave power module, downlink subsystem, transponders, quartz reference oscillators, antenna pointing mechanism). • Propulsion subsystems (e.g. mono- and bi-propellant systems, apogee engines, thrusters, tanks, valves, electric propulsion systems). • Other satellite payload's specific subsystems: positioning, navigation timing systems, reconnaissance, surveillance, and target acquisition; weather and environmental monitoring instruments; scientific/R&D demonstrator and human-rated systems (e.g. payload data handling electronics, navigation clock electronics, cryo cooler, scanning mechanism).
Primes	Space systems Integrators/ full systems supplier	• Complete satellites/orbital systems. • Launch vehicles (and launch services provision in some cases). • Control centres and ground stations.
Operators	Space systems operators	• Launch services provision. • Satellite operations, including lease or sale of satellite capacity (telecom: commercial FSS and MSS operators; earth observation operators).
	Ground system operators	• Provision of control centres services to third parties.
Downstream	Devices and equipment supporting the consumer markets	• Chipset manufacturers. • Satnav and telecom equipment and connectivity devices vendors.
	Space-related services and products for consumers	• Direct-to-home providers. • Very Small Aperture Terminal (VSAT) network providers. • Location-based signals services providers.

Global value chains in the space sector

In the 1980s, building and launching a satellite was the remit of relatively few developed countries with massive industrial complex, co-operating and competing with each other. Since then, globalisation has been impacting all sectors of the economy, including largely protected high-technology sectors, like the space sector. This section builds on OECD work on global value chains to examine key trends in the space sector, making particular use of case studies. As the supply chains for space systems evolve, new opportunities open up for all actors involved, public and private, as well as new inherent risks for incumbents and new entrants. This section provides several angles to review these globalisation aspects, notably the advances in international joint institutional space programmes and the evolutions of the international production networks for space programmes.

More international joint institutional space programmes

Joint space exploration and scientific missions have been an important source of international co-operation over the past decades, contributing to increased linkages between national space agencies and industries around the world.

Box 1.1. **The concept of global value chains and the space sector**

World trade, investment and production are increasingly organised around global value chains (GVCs), also called international production networks. A value chain is the full range of activities that organisations engage in to bring a product to the market, from conception to final use. Such activities range from design, production, marketing, logistics and distribution to support to the final customer. At each step – design, production, marketing and distribution – value is added in some form or other. Driven by offshoring and mounting interconnectedness, those activities have become increasingly fragmented across the globe and between organisations. Many sectors now include complex supply chains with many organisations involved in different countries.

The fragmentation of production and services across countries is not new. What is new is its increasing scale and scope for many sectors of the economy. As demonstrated by work conducted at OECD, global value chains are deepening the process of globalisation along three different lines: geographically (by including a larger number of countries, including emerging economies), sectorally (by affecting manufacturing but also increasingly services industries), and functionally (by including not only production and distribution but also R&D and innovation). Integrating a regional value chain is often a first step for many organisations.

As a result of these trends, a country's position in international production networks is becoming increasingly important for its competitiveness and overall economic performance. Each stage in the international production networks carries, to varying degrees, opportunities for new local activities, jobs and profits, as well as the associated new skills, technologies and public revenues in the form of taxes. Successful integration into a value chain potentially allows a country to seize a bigger share of those benefits, whilst putting more pressure on the incumbents.

To provide an accurate picture of a country's position in value chains, its trade with the rest of the world needs to be measured in value added whenever possible, rather than in gross terms (i.e. OECD work on Trade in Value Added or TiVA). But detailed trade statistics are not available for all economic sectors. As a first step, case study-based evidence can be sought, as for the space industry in this publication.

Source: To learn more about GVCs: OECD (2013), *Interconnected Economies: Benefiting from Global Value Chains*, OECD Publishing, *http://dx.doi.org/10.1787/9789264189560-en*

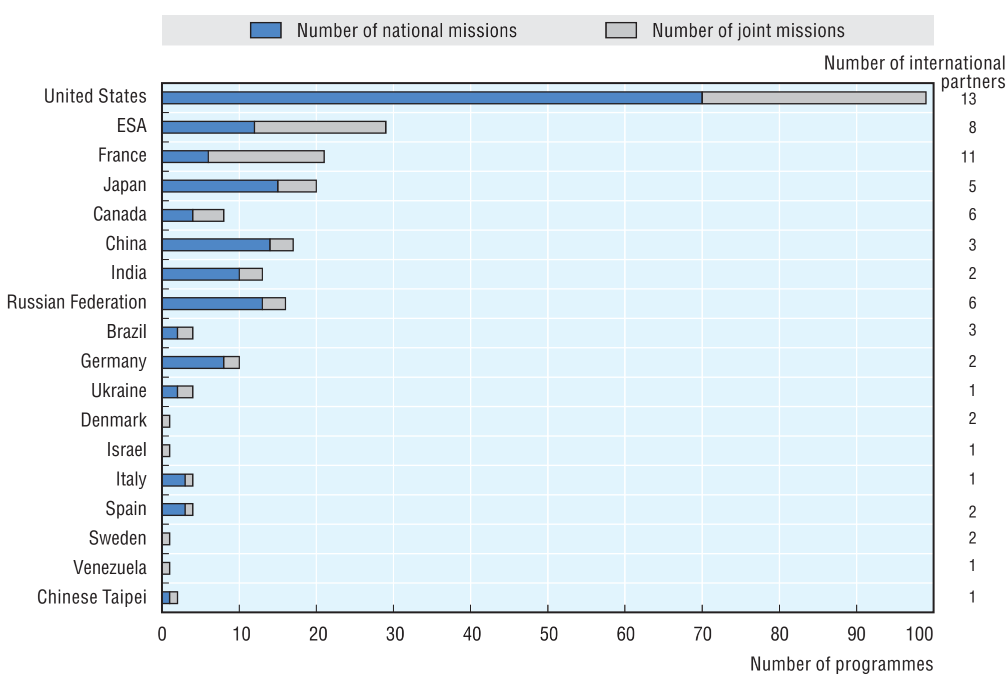
During the cold war, major scientific and engineering breakthroughs took place in different parts of the world, often in isolation, as military research and development and industrial secrecy forced economies to preserve their own technological advances. As international conferences of scientists have prospered since 1991, allowing researchers to collaborate on and disseminate scientific advances, knowledge flows and dual-use technological transfers have also increased from OECD countries and the Russian Federation to other parts of the world (see *16. Scientific production in the space sector*). This has sometimes caused tensions concerning the illegal transfer of sensitive technologies (i.e. space launchers are based on missile technologies), and a tightening of technology export controls. One of the first emblematic joint space missions took place in 1975, when an American Apollo spacecraft, carrying a crew of three, docked in orbit for the first time with a Russian Soyuz spacecraft with its crew of two. In addition to the political significance of the event, it was a major engineering accomplishment as at the time both the US and the Russian industrial chains relied entirely on domestic hardware and national standards. Bilateral working groups were set up for the first time to develop compatible rendezvous and docking systems in orbit, which are still in use today.

Joint institutional space programmes still provide an excellent way to develop and use national expertise and scientific capabilities, while sharing financial burdens in common large-scale projects that would have been impossible to launch individually. The International Space Station (ISS) is a case in point, as it relies on barter agreements between all the different partners, with no direct exchange of funds. For example, as part of the NASA-ESA ISS agreement, the current Orion deep-space capsule manufactured by Lockheed Martin Space Systems for NASA should include a European propulsion service module, based on the European Space Agency's Automated Transfer Vehicle, an unmanned capsule which was used to carry cargo to the ISS. This module, built by Airbus and paid by ESA, could fly for Orion tests in 2017.

Another example of joint institutional space programmes concerns environmental satellite missions in low-earth orbit. Around 160 environmental satellite missions in low-earth orbit are currently measuring selected climate parameters, and around 30% of these are bilateral or multilateral missions, with different countries providing key instruments on-board satellites (Figure 1.2). The United States, the European Space Agency and France have established the most joint operations for environmental satellite missions (e.g. NASA is co-operating with Japan's Aerospace Exploration Agency on the Tropical Rainfall Measuring Mission (TRMM); ESA and NASA cooperate on the Solar and Heliospheric Observatory (SOHO), while the French CNES is co-operating with India on the Megha-Tropiques mission to study the water cycle) (see *10. Satellite weather and climate monitoring*).

Figure 1.2. **Environmental satellite missions in low-earth orbit**

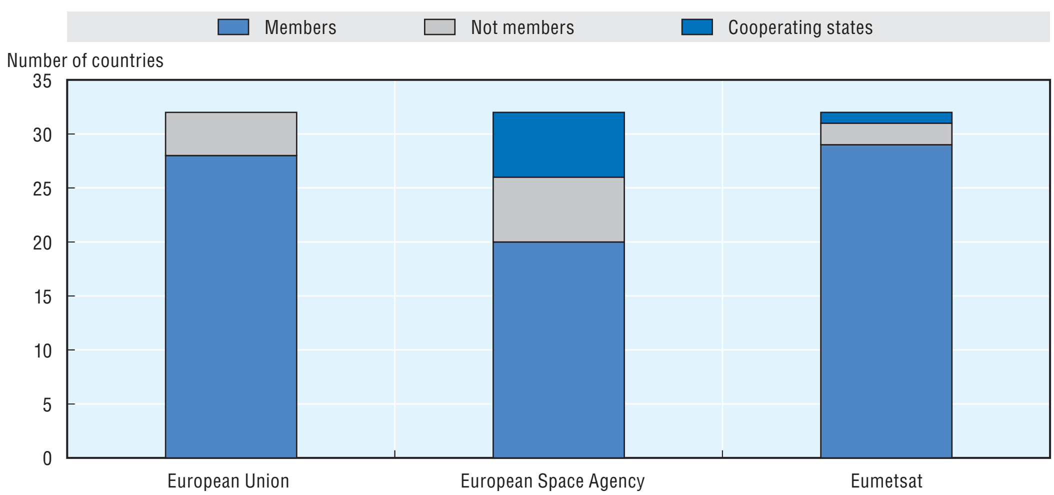
Number of national and joint missions, 2013



Note: Only economies (ESA is an intergovernmental organisation) with joint missions are included. Eumetsat also contributes to selected joint missions with ESA, France and the United States (e.g. Jason missions).
Source: Adapted from WMO, Oscar database, 2014.

Globalisation in the space sector can be particularly illustrated by zooming in on the European regional level. A number of European countries have been involved in space activities since the beginning of the space age with their national programmes, and have decided to join capabilities and funding for specific programmes. When looking at Europe as a whole, there are different European intergovernmental organisations that have responsibilities in European space programmes. There are currently some overlaps in terms of memberships, but also some noticeable differences (Figure 1.2). In recent years, an increasing number of European countries have shown an interest in investing in space programmes. For relative newcomers, this often means adhering to or co-operating with the European Space Agency, joining the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and/or supporting the Copernicus and Galileo programmes of the European Union. For these countries, the yearly contingent or programme payments account for the bulk of their space R&D budgets and industry support.

Figure 1.3. **Membership in European intergovernmental organisations**



Note: Eumetsat is an intergovernmental organisation supplying weather and climate-related satellite data, images and products to the National Meteorological Services of its Member and Cooperating States in Europe, and other users worldwide. Countries included in this graph: Austria, Belgium, Bulgaria, Croatia, Cyprus[1, 2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Netherlands, Poland, Portugal, Romania, Spain, Sweden, United Kingdom, Norway, and Switzerland. Canada has a co-operation agreement with ESA.

1. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".
2. Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

StatLink http://dx.doi.org/10.1787/888933141665

There are several major ongoing European space programmes, most of them co-ordinated by the European Space Agency and two under supervision of the European Union, with technical support from ESA.

- The European Space Agency has some 17 scientific satellites in operation as of spring 2014. It has also designed, tested and operated in flight over 70 satellites, and has developed six types of launchers with its member states and their industry.

- The European Union is managing two programmes, with support from ESA: the Copernicus earth observation programme, which aims to provide "access to full, open and free-of-charge information in the areas of land, marine, atmosphere, climate change, emergency management and security", with five Sentinel satellite missions (Sentinel-1 successfully launched in April 2014); and the Galileo satellite navigation programme (European Union Parliament, 2013).

In terms of budget, the ESA's annual budget is around EUR 4 billion per year, funded by its Member States. The European Union, also funded by its Member States, has dedicated around EUR 6.3 billion to the Galileo satellite navigation programme and EUR 4.3 billion to the Copernicus earth observation programme (2014-20). In addition, the 7-year European research and development programmes (Framework Programmes) have had in recent years a dedicated budget line for space. The Framework programmes FP6 received EUR 0.24 billion for space R&D (2000-06), for FP7 it increased to EUR 1.43 billion (2007-13) and in the Horizon 2020 programme (2014-20) it will reach EUR 1.73 billion. The key objective of the Horizon 2020 programme on space research and innovation is "to foster a competitive and innovative space industry and research community to develop and exploit space infrastructures to meet future Union policy and societal needs". It comes in complement to the space research activities of its European Member States and the European Space Agency. Although overall funding for space seems to be on the increase, some industrial actors worry that European R&D funding may be too disparate, making it increasingly difficult to establish clear returns on investments.

In that context, aside from exports outside the continent, the European space industry has in essence three types of government customers: national European governments, the European Space Agency, and the European Commission. Procurement rules differ though, with the European Commission promoting competitive bidding procurements, and ESA using geographic return rules as a compulsory system to ensure that member governments' investment automatically returns to their national territories in the form of contracts. These policies have had the effect of creating more suppliers throughout Europe, thus increasing the benefits of investing in space programmes by developing national -if limited- space industries (in terms of qualified jobs, industrial and scientific capacities). For example, ESA's funded SmallGEO programme aims to create in collaboration with industry a new general-purpose small geostationary satellite platform. SmallGEO is being developed by an industrial team managed by the German OHB System AG, which includes its subsidiaries LuxSpace (Luxembourg) and OHB Sweden (formerly Swedish Space Corporation), as well as RUAG Space (Switzerland). In total, twelve countries are involved, eight with one industrial contractor in the supply chain, three with two contractors, and Germany with six contractors, as it provides the most funding to this ESA programme. Contracting out foreign suppliers is a mechanism that contributes to information and know-how transfers throughout Europe, as well as providing activities to a large number of suppliers.

Evolutions in international production networks for space programmes

As countries cooperate and compete more in space activities, space industries and operators located on their territory are also being impacted by globalisation trends. The international supply chains for the automotive and electronics sectors have become more complex, and the defence and aerospace sectors – home to many space manufacturers – have only followed the same patterns, although a bit differently when comparing countries. The ownership structures of some groups and mergers are contributing to ambitious international expansion strategies on regional and global scales, and the multiplication of suppliers is making the production lines more complex, as illustrated by case studies on commercial satellites and launchers.

The impacts of ownership structure of space-related companies: Even if governments retain an omnipresent role in space affairs, as funders of major institutional R&D programmes and as customers, the private industry supply chains are getting more complex, influenced by the multinational nature of major space companies. The late 1990s saw a wave of major aerospace and defence company mergers in North America, Europe, Japan, mainly intended to deal with the industry's post-Cold War overcapacity. Large groups active in the space sector are now mostly held by international private shareholders, although governmental bodies still hold a few shares for strategic reasons in selected firms. As in any other economic sector, this influences corporate expansion strategies, since these groups aim for improved shareholder returns, examining new funding and commercial opportunities that are becoming available in different parts of the world. As an example, Airbus Defence and Space (formerly Astrium), which is part of the larger Airbus Group N.V. based in the Netherlands, has a complex structure of national "space primes", systems- and sub-systems manufacturers, in-house equipment departments and subsidiaries in seven European countries and the United States (one subsidiary in Houston). Following initial mergers, the establishment of new companies and the acquisition of smaller firms, the group has a presence throughout Europe, allowing it to bid in countries that invest heavily in the space sector: France (six companies including one in Kourou, French Guyana), Germany (five), Spain (two), the United Kingdom (three), the Netherlands (one), and since 2010 Poland (one) and the Czech Republic (one). Another European group, Thales Alenia Space, is following the same strategy: it announced in April 2014 an expansion of its presence in Europe with the creation of a new British subsidiary. This has been spurred by the United Kingdom government's commitment to fund space activities and create new initiatives to foster growth in the space industry. The third main European satellite manufacturer OHB has six main business units dealing with space activities, two in Germany (Bremen and Munich) and others located in Belgium, Italy, Luxembourg, and Sweden.

Linked to ownership issues, mergers are also continuing in the space sector, with established actors creating larger groups aiming to increase the vertical integration of their production lines. In the past two years, many mergers occurred and more are announced for 2014-15. Canada's MDA Corporation acquired the US commercial satellite builder Space Systems/Loral in 2013. In propulsion, GenCorp's Aerojet and Pratt & Whitney's Rocketdyne were merged also in 2013 forming a new goup called Aerojet Rocketdyne. The US satellite and rocket builder, Orbital Sciences Corporation, may merge with the rocket engine manufacturer ATK. In the Russian Federation, the 49 organisations and companies involved in space activities were merged in February 2014 within a centralised public holding, the United Rocket and Space Corporation (ORKK). The objective is to streamline the Russian supply chains, to enhance economies of scale and quality control, following several launch failures. But even at lower tiers, equipment manufacturers need to address their customers' requirement that they provide full systems, such as complete antenna systems (including antenna, gimbals, waveguide, cables, etc.). This necessitates developing strategic alliances with other vendors, which are often located in different countries. This complex and lengthening supply chain for space products is often not well traced by primes and governmental customers alike.

For industry, internationalisation can be both an opportunity (e.g. cheaper labour in production processes, access to technologies and/or better components from foreign countries), as well as a source of inherent risks (e.g. longer supply chains, susceptible to

Box 1.2. **Mexico entering global value chains in the space sector**

Recent Mexican developments are good illustrations of how an economy can enter global value chains. The national Mexican space agency (Agencia Espacial Mexicana, AEM), was established in 2010, after its creation was adopted unanimously in November 2008 by the Mexican Senate. One of the agency's main objectives is to co-ordinate and build on different existing Mexican efforts, particularly in terms of international scientific and satellite remote sensing co-operation. The development of small satellites to help train engineers and for future institutional missions is also underway. Concerning evolutions in the commercial space sector, Mexico has concentrated since the 1990s, on developing commercial communications services, via a domestic satellite telecommunications system with some 120 earth stations. Mexican satellites are operated by Satélites Mexicanos (Satmex), a private company created in 1997, which provides broadcast, telephone and telecommunication services to some 40 countries in the Americas, with an 11% market share in Latin America. In July 2013, the European operator Eutelsat acquired the Mexican company, valued at a little more than USD 1 billion. Today, the Mexican space sector may follow the approach of key stakeholders in aeronautics. The Mexican aerospace industry increased intensely its development in the early 2000s, attracting major multinational companies. From about 65 manufacturing plants in 2004, the industry reached 150 in 2007 and 240 in 2010. Major Original Equipment Manufacturers (OEMs), such as Boeing, Airbus and Rolls-Royce, have developed joint ventures to develop their supply base in Mexico. Other actors such as Cessna, Bell, Hawker Beechcraft, MD Helicopters, Eurocopter and Triumph have also recently located subsidiaries in Mexico, to move closer production to the North American market. The annual foreign direct investments have grown from about USD 250 million in 2004 to over USD 1 billion in 2011. Aside from the United States, Mexico had the highest level of foreign investment of the aerospace sector that year.

regulatory complications). Two case studies are provided below with satellite and rocket manufacturing illustrations. The information is based on two workshops conducted in 2013 and 2014 by the OECD Space Forum with industry participants and governmental stakeholders (space agencies, ministries, governmental departments) involved in space programmes, as well as on consultation with actors in the space community.

Where is my satellite coming from? More than a hundred satellites were launched in 2013, mostly for institutional missions. Some 29% of these satellites were launched for commercial telecommunications, representing around USD 2 billion in revenues for manufacturers (FAA, 2014). The open market for satellites remains therefore quite small, and the dominant position of just a few companies in space manufacturing markets has been weakening.

In a 2012-13 survey of the US space industrial base, 78% of the US organisations surveyed considered they were not the sole manufacturer or distributor of a given space product, based on the total number of product areas identified. Respondents identified critical suppliers from 56 countries (DoC, 2014). The most prominent non-U.S. suppliers were located in Japan, Germany, Canada, France, and the United Kingdom, providing materials, structures, mechanical systems, electronic equipment, and communications systems. Russian hardware is also often procured by US manufacturers, particularly propulsion systems integrated on US rockets and satellites.

So when private operators buy large telecommunications satellites today, they have a much larger choice in terms of manufacturers internationally, with their main criteria being costs, time-to-market and reliability; rarely do they need to care about the provenance of the satellite and its parts, except if it affects relations with their customers. As of end-2013, American satellite builders have built around 60 commercial telecommunications satellites in the past five years, while European manufacturers have sold around 50. And in that context, although the bulk of commercial satellites are still produced in North America and Europe, more actors from emerging economies are entering the already competitive market as commercial satellite manufacturers, i.e. the Russian Federation, China and India. They accounted in the 2000-10 timeframe for only 13% of the insured telecommunications satellites launched into geostationary orbit. In 2013, the Russian and Asian builders' share of the market rose to 27%, demonstrating in only three years an inclination of private satellite operators to now go to manufacturers they would not have gone to previously.

When examining a standard commercial telecommunications satellite built in the United States or Europe for geostationary orbits (16-20 commercial satellites launched per year), the main subsystems and equipment are all manufactured in different locations before being assembled by the space manufacturing prime. And these subsystems and equipment include themselves components produced in the United States, Europe and increasingly Japan. Although this provides only rough orders of magnitude, according to different industry sources: around 95% of a standard Loral telecom satellite is built in the United States; around 75% of a Thales Alenia Space's telecom satellite is built in France (with some sub-systems coming from its subsidiary in Italy); and around 25% of an Airbus standard telecom satellite is built in France, with most of the other equipment manufactured in European subsidiaries (Germany, Spain).

Deconstructing these commercial satellites further, their subsystems often consist of a large share of US components, still not manufactured elsewhere (e.g. selected oscillators, radio-frequency passive devices, some fuses). Originally many of these components were based on heavy-duty military standards (MIL) developed by US manufacturers, which are still used extensively in the space sector. The global market for space qualified components is difficult to estimate, although there is an important competition in some segments between American and European components manufacturers, particularly on capacitors and resistors. Other actors are getting involved and exporting components, like Japan, South Korea, Turkey and Israel. The European components market is largely divided equally between American and European manufacturers in 2013 (ESCIES, 2013). In the case of Japan, the market for space–qualified components represented roughly YEN 3 billion in 2012 (around EUR 23 million), with 52% of parts coming from the US, 36% from Japan and 12% from Europe (ESCCON, 2013).

In general the electronic, electrical and electromechanical (EEE) components' suppliers with some activity in the space sector are either small specialised firms with unique know-how, or divisions in large multinational groups dealing with many other sectors (e.g. automotive, aeronautics, defence). Very few EEE parts, ranging from cables to electrical switches, up to semiconductors, are designed specifically for space applications, due to the relatively low volume and sporadic manufacturing requirements. Some unique characteristics are required of space quality parts (i.e. high resistance to low temperature and high heat; extremely long reliability; high vibration capability, extremely low defect levels, etc.). The issue of "space qualification" is therefore an inherent cost driver, as it takes time to qualify selected components before they are deemed to be integrated in equipment which eventually will fly to orbit (two to four years, or much longer in some cases). As many companies seek to limit as much as possible the non-recurring engineering (NRE) costs, which represent the one-time cost to research and develop components and equipment, relatively few invest in non-profitable R&D. For example, out of around 25 commercial manufacturers of Static Random Access Memory (SRAM) components, used in almost every industrial sector, internationally there are only six manufacturers of SRAM specifically designed for use in space. Still, EEE parts represent 40% to 70% of the value (and also quantity in average) of a space equipment (ESCCON, 2013). The space manufacturer Loral estimates, for example, that around 50 000 EEE parts are to be found in recent communications satellites. As another example, the centralised procurement for the ESA Automated Transfer Vehicle (an unmanned and expendable module bringing cargo to the International Space Station) covered for seven flight sets, 45 major equipment composed of over a million EEE parts.

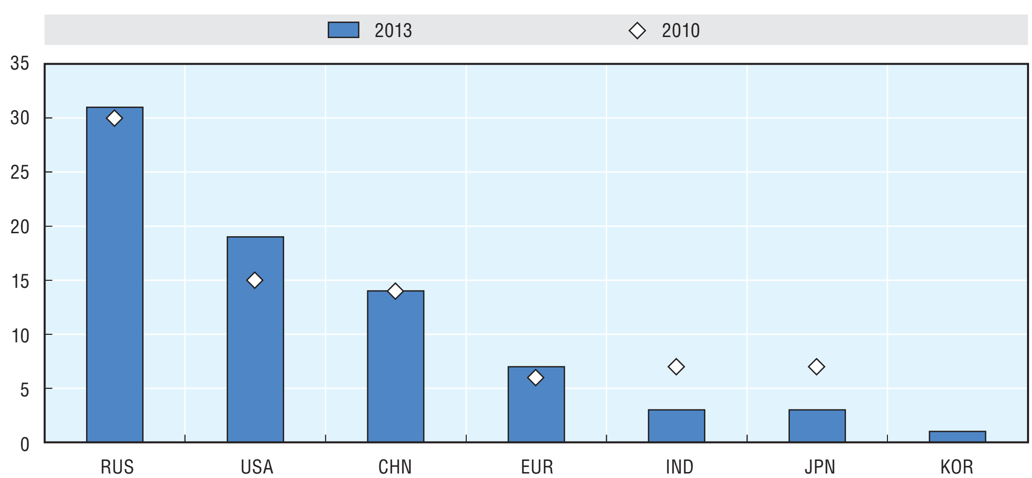
The long-standing reliance on American satellite components and equipment, subject to strict technology transfers and re-export restrictions from the United States (i.e. the US International Traffic in Arms Regulations regime, ITAR), has been a key reason for European, Israeli and Japanese industries' moves to develop home-base alternatives. ESA's European Components Initiative (ECI) also had the objective within a few years to turn Europe from a net importer of components into a net exporter, as well as to secure access to strategic components. The ECI entered recently its fourth Phase (2013-16), focussing on strengthening the European supply chain, with already around 40 qualified manufacturers registered. In Japan, some 27 qualified manufacturers are registered and supported by the Japanese space agency. Manufacturing commercial "ITAR-free" satellites (i.e. satellites with components not subject to US government authorisation for export and re-exports) have been a selling-point of several manufacturers for a decade now with some effects on the US industry. The impacts of the ITAR regime affected the US industry with lost sales opportunities of between approximately USD 988 million and USD 2 billion from 2009 to 2012 according to a recent US Department of Commerce survey (DoC, 2014).

Where is my rocket made? At first glance, the rocket business may not seem very impacted by globalisation. Satellite launchers are related to missile technology, and are therefore kept under tight government control worldwide. The open market to launch commercial satellites remains relatively narrow, about USD 2 billion in revenues in 2013 with six companies able to compete internationally (see *7. Space launch activities*). However, access to space remains an important source of income and jobs for domestic ecosystems of companies and public organisations, as the requirement to launch many institutional satellites for civilian and military missions offer *de facto* captive national markets in many countries (e.g. earth observation, military satellites...). Governmental satellites are typically launched domestically in the United States, China, India, and the Russian Federation. In Europe, there is no policy imposing the utilisation of the European Ariane launcher for ESA Member States' institutional satellites.

Despite these captive domestic markets and tight regulations on missile technology transfers, globalisation has permeated the industry. Korea joined recently the small club of countries with space launch capabilities, thanks to initial active international co-operation in the 1990s. In the case of Europe, the different Ariane launchers were conceived from the start as complex international systems, bringing together parts and equipment manufactured all over Europe, so as to involve as many countries as possible in the funding and development of a sustainable independent European access to space. With current European negotiations about the future of the Ariane family of launchers and its long-term economic viability, the current supply chains spanning many countries are being challenged.

This co-dependence on launcher development can be found in other countries also for political and economic reasons. As soon as the cold war ended, contractual arrangements for commercial technology transfers were set up between the Russian industry and many national space industries, contributing to not only sustain the Russian sector, but also offering its Western and Asian customers the possibility to benefit from long-proven technologies. China and the Russian Federation have had for instance a very fruitful co-operation on space technologies transfers, which assisted the Chinese space administration in developing the first elements of its human spaceflight programme. The US space sector has also developed industrial co-operation, by acquiring Russian engines for several US rockets. The joint-venture United Launch Alliance (ULA), which merged in 2006 Lockheed Martin's and Boeing's US government space launch services, has been using a Russian engine, the RD-180 for more than a decade on its Atlas heavy-lift rocket, which is dedicated to US governmental launches. Similarly, the satellite and rocket builder Orbital Sciences Corporation is using a Russian-sourced first stage engine for its Antares medium lift launcher. This AJ-26 engine is built in the Russian Federation and refurbished by Aerojet Rocketdyne, another US company.

Figure 1.4. **International distribution of successful space launches in 2010 and 2013**



Source: Adapted from the US Federal Aviation Authority, 2014.

In parallel, the US-Japanese industrial co-operation in terms of rocket engines is also indicative of close bilateral technological co-operation. The collaboration started back in the late 1970s, with the Delta N rocket which was a licensed version of the US Delta rocket, built in Japan but using both US and Japanese components. More recent industrial co-operation concerns the Japanese H-IIA and American Delta IV launchers, which share the same second-stage propellant tanks' configuration. In exchange for Mitsubishi Heavy Industry's LH2 (liquid hydrogen) fuel tanks, ULA gets LOX (liquid oxygen) fuel tanks to fly on its rocket. In addition, Mitsubishi exports to the US several components (e.g. valves, heat exchangers) and propellant tanks for Delta IV's RS- 68 engine. More joint engine development is currently underway, as both companies work on new upper stage engines for future launchers. For instance, the MB-XX engine under development since 1999 targets both the Japanese and US markets. Each company will be the prime contractor for the use in each country. On a more commercial launch services' level, Mitsubishi Heavy Industry has recently signed a memorandum of understanding with the European launch provider Arianespace to investigate possibilities for joint business opportunities.

Based on these illustrations, starting with limited exchanges, the situation has evolved so much that almost no launchers in activity today are composed solely of indigenous parts and equipment. Aside from developing bilateral co-operation axis, one of the main drivers for this international fragmentation of produced parts comes from evident cost-savings (i.e. no need to develop a multi-billion dollar engine for a rocket, when you can buy one off-the-shelf) and the possibility of accessing technologies already developed elsewhere to improve your own launcher. According to industry sources, propulsion systems can, for example, account for up to 40% of a launcher cost. These exchanges between companies and joint R&D projects are some of the opportunities available to the sector to reduce the cost of production.

So although restrictions in space technology transfers are still important in most parts of the world, including Europe, Japan, the United States and the Russian Federation, competition in major niche markets may soon intensify further at all levels of the space manufacturing supply chain. The US Department of Commerce published in May 2014 new regulations that will facilitate the US exports and re-exports of commercial, scientific, and civil satellites and their parts and components, by moving many items from the strictly controlled State Department's US Munitions List (USML) back to the Commerce Control List. The items moving to Commerce jurisdiction include communications satellites that do not contain US classified components, selected remote sensing satellites, as well as spacecraft parts, components, equipment, systems, and all radiation-hardened microelectronic microcircuits, that are essential for space systems. This will probably impact trade in components, equipment and subsystems around the world.

What are the impacts of these trends for policy-makers?

The more countries invest in space programmes, the more the overall market will be stimulated and the global value chains strengthened, but many nations will keep some control over sovereign interests and sub-sectors (e.g. defence space programmes). The key drivers for more globalisation will include sustained institutional support from new sources worldwide, double sourcing guaranteed on the market offering new commercial opportunities, and a wider global addressable market size for all actors. Globalisation can benefit a large number of countries in terms of economic development and innovation capabilities, but this will increasingly come with more challenges for incumbents and newcomers alike. To better face these trends, two avenues could be pursued by policy makers: better tracking of who is doing what, and sustaining value-creating industries.

Tracking who is doing what – A major challenge faced by national administrations, which are often customers of many space products and services, and their industrial primes concerns the need to have an overview of the complete supply chain, to allow a better visibility of procurement and handling of subsystems and equipment throughout the chain. There is a difference in the globalisation aspects of upstream and downstream segments in the space sector. The upstream segment is still influenced by R&D policy decisions of national governments, a situation that is likely to remain. Meanwhile, the downstream segment is increasingly addressing global markets. However, the segments are interdependent. The more lucrative applications of the downstream segment cannot exist without the infrastructure provided by the upstream segment, although the funding mechanisms and revenue generation between upstream and downstream are increasingly disconnected.

Europe is in a particular situation. As more countries join ESA, more national centres of space expertise can be expected to develop. ESA's geo-return policies, whereby a country's institutional funding provided to ESA programmes leads to contracts to the space industry on its territory, have historically contributed to the creation and support of several national hubs of expertise in space research and development throughout Europe. Many European countries would not have invested in space if it were not for the principle of geo-return. This industrial policy is at the core of many of the successful scientific, institutional and commercial space programmes developed in Europe. With an enlarged ESA, the system could successfully endure without detrimental effects on incumbents, only if the European budget grows with sustained national budgets from both old and new members, to recoup enough industrial contracts on a national basis and keep a level of expertise in selected space fields. Otherwise, like in any other sector, know-how and capabilities could inevitably move where new national funding becomes available. This will need to be taken into account by policy-makers, if they wish to support a dynamic space industry and workforce on their territory, especially as the European Commission, an increasingly important player in the European space sector, defends a different set of contractual rules based on open competition.

To better track who is doing what in the space industry, a number of initiatives can be taken by national administrations. In addition to working with industry associations, promoting and conducting regular industry surveys, other information sources in governmental agencies could be better exploited to provide a better picture of the actors involved in space-related activities (e.g. analyzing administrative data on firms, information on contracts). This would be conducive to improving the quality of national industrial policy evaluations, with detailed information on the structure, positioning along the value chain and competitiveness of the space industry and other actors involved in the larger space economy.

Sustaining value-creating industries - Many producers of space products and services are still regulated by national regimes that limit foreign ownership of their activities. However there are a number of recent instances where entire firms and activities have been bought out by competitors, with international technology transfers taking place. Multinational groups have also been moving low-key activities from one subsidiary to another, with impacts on local employment. These practices can be expected to continue, in a more competitive world for the space industry, on regional and global scales. However, a major difference for the space sector as a whole, as compared to other high-tech sectors, still lies in the important role of national agencies, laboratories and universities in fundamental research and development. This is, for example, the case for the United States, with several NASA and Department of Defense research centres, for France with CNES, ONERA and DGA centres, and India with major ISRO centres distributed throughout the country. These R&D capacities under governmental control have still important impacts on employment and future public innovation capabilities for the space sector that should not be underestimated.

So as economies get more interdependent and interconnected, all countries and all firms have the opportunity to participate and benefit from global value chains in the space sector. However, this situation puts new competitive pressures on governments to adopt reforms that enable their producers to find or to try retaining niches in which they may make the most of their capabilities. There is a need for complementary policies, such as those that boost education and skills, as well as ensuring long-term investments in research and development capabilities, leading to future innovation (OECD, 2014).

Space is still not a "business like others", despite the many globalisation patterns it follows. The more countries are investing in space, the more the global market will be stimulated, and global value chains will be strengthened. Even if companies involved in space activities seem to be freer than ever to pursue growth strategies internationally, many countries will unsurprisingly keep a level of control over sovereign interests and strategic technologies. In order to benefit from global value chains, countries will increasingly have to balance their strategic and industrial interests with further growth. Economies willing to develop and sustain an active national space programme in a more competitive world will need to remain key driving forces, as reliable customers and R&D enablers of their national space industries, as well as be promoters of more open markets for the industry as a whole.

Dynamic innovations in the space sector

The section briefly presents some of the new dynamic innovations within the space sector. Technological innovation and new industrial processes are particularly impacting the space industry in OECD economies. More globally, a new space era seem to be opening up with the development of "small satellites for all".

A revolution pending in industrial processes?

A number of innovations are currently taking place in the space sector that may impact the strategies of many incumbents and newcomers in the industry: the promotion of new production processes, the rise of advanced manufacturing in the space sector, and the launch of new all-electric satellites.

Industrial organisation is an essential element of competitiveness and quality for all economic sectors. It is of course also true for the space manufacturing sector, which has been for decades a highly specialised industry, where precision and verification procedures remain essential, since once a spacecraft is launched there is no way to service it. In that context, satellites and expendable launchers have been treated like prototypes for decades, even if over the years standard platforms have been developed by many manufacturers to gain processing efficiencies and reduce production costs.

To further lower costs, adaptation of new industrial qualification procedures are being pursued, to try and use existing experience and data from high volume industries to mass produce spacecraft and launchers (e.g. automobile, aeronautics). This process has been promoted by SpaceX, a California-based U.S. company. The billionaire Elon Musk, founder of PayPal, funded a few years ago a new space manufacturing company SpaceX. The business model is based on vertical industrial processes (i.e. more than 70% of each Falcon launch vehicle is manufactured at the SpaceX production facility) and mass production, inspired by the automobile sector, not used before in the space industry. It has also benefited from supportive US institutional contracts to develop the activity. The company's fabrication volumes are constantly increasing, with production to grow more than five times year-over-year, with 2 Falcon rocket cores produced in 2012, 3 in 2013, and 17 to be produced in 2014 and 2015 as discussed during a recent OECD Space Forum workshop. The company's factory is configured to achieve a production rate of up to 40 cores annually. These new industrial processes and governmental support allow the company to sell space launch services of its Falcon rocket for around USD 60 million, at a price less expensive than its established competitors.

The European Ariane launcher currently dominates the market for commercial satellite launches (see *7. Space launch activities*) and its production supply chain is spread out on 25 industrial sites throughout Europe. As a reaction, major actors in the European space industry decided in spring 2014 to merge some of their activities to gain in efficiency. Airbus Group, the prime contractor for the Ariane European rocket and Safran, which produces its engines, signed a memorandum of understanding to create a joint venture that could facilitate the development of the Ariane launcher and make it more competitive.

Other established actors in the United States are also reorganising their activities to adapt to increased competition. Overall, streamlining space manufacturing production and concentrating it in a few places follows a rational economic model, but it may impact incumbents over the next couple of year in terms of R&D and industrial employment.

In addition to these evolutions in the space sector's industrial processes, new developments in information technologies, computing power and molecular research in materials are all contributing to advanced manufacturing, an anticipated new chapter in industrial revolution. Additive manufacturing, or three-dimensional (3D) printing, is increasingly used in the space industry, and direct-write technologies may also have major impacts for several space applications.

Additive manufacturing is one mass production technique currently under study in several space agencies and industrial actors alike. The technologies have been tested for almost a decade in the space sector, mainly to produce models and prototypes. However space agencies and industry are looking at integrating fully these capacities in industrial processes, testing different metal alloys to build parts and full equipment. A large number of space-related components have been already produced in North America and Europe with various types of 3-D printers, and they continue to grow in size and complexity.

Despite stringent need for quality control, the first tests seem to indicate significant time- and cost-savings, with expected repercussions on the industry as a whole. In the United States, Lockheed Martin and its RedEye contractors manufactured in late 2013 a couple of two-meter long fuel propulsion tanks to test a new satellite design, by printing independently polycarbonate pieces and bonding them together. The process took approximately three months, or half the time Lockheed Martin anticipated for traditional space manufacturing techniques, and only one-fifth the price (RedEye, 2014). Further research and development in metal alloys and use of 3-D printing may also have long-term impacts on space exploration, as future generations of astronauts may be able to "print" equipment they need, out of material taking less mass at launch. Experiments took place already on the International Space Station, and more are planned by late 2014 to produce and test plastic parts with a new 3-D printer.

Another advanced manufacturing advance is based on direct-write technologies, also known as digital printing or digital writing. Using this process, it is possible to print or rather deposit on the surface of equipment a nano-scale structure with mechanical and electrical properties, which can be controlled. In other words, it becomes possible to place sensors on almost any surface including hard-to-reach places. This opens entire new fields of applications for many sectors, including the space industry for which sending low mass to orbit is critical. Being able to detect and even control changes in structures, and in the environment of commercial satellites and space stations opens up many development axes.

Finally in terms of innovation, according to many industry actors, the market for commercial satellites will be divided by 2020 between satellites with conventional chemical propulsion and satellites with electric hybrid propulsion. In 2012, two relatively new satellite telecommunications operators (Mexico's Satmex, bought by France's Eutelsat since then, and Hong Kong's Asia Broadcast Satellite) bought four commercial fully-electric satellites, developed by Boeing Space and Intelligence Systems. The first two satellites were launched in late 2013.

Electric propulsion technologies are classified into three categories: electrothermal, electrostatic and Plasma. These are types of propulsion that have been under study for more than thirty years in several countries, particularly the United States, France and the Russian Federation to save mass on interplanetary probes. On a satellite, the propulsion system aims to ensure the transfer of the satellite from its injection orbit to its final orbit. Once the satellite has reached its position, the propulsion system is necessary to modify the orbital moves induced by natural disturbances, and correct the orientation of the satellite when needed. Satellites often carry several propulsion systems, using solid propellant (i.e. chemical system) for transfer manoeuvres, and using electric thrusters for more precise control of orbit and orientation. The main constraint for electric thrusters is that the thrust force is less important, compared to chemical engines, so it takes more time to move a satellite or an interplanetary probe. The first probe to use an ion engine for main propulsion was NASA’s Deep Space 1 launched in 1998. NASA’s Dawn probe, which is currently exploring the asteroid belt, also uses one. The European Space Agency’s satellite SMART-1, launched in 2003 to orbit the moon, used a Hall thruster, a type of ion thruster in which the propellant is accelerated by an electric field.

As much R&D has been conducted over the years, it is not surprising to see fully-electric commercial satellites becoming available. The main advantage of electric propulsion used for commercial satellites is that due to the relatively lower weight of the satellite an operator can embark more marketable capacity (i.e. transponders on board telecommunications satellite to lease to its customers), in place of the fuel the satellite would have needed if it used a classic chemical propulsion system. Since the satellite’s mass to be launched is also smaller, it reduces the launch costs. Several space manufacturers are now offering or planning to offer all-electric satellites or hybrid solutions for satellite operators. But the market is still nascent, as despite the lower costs, an important constraint from using fully-electric propulsion for operators is the length of time it takes to reach the satellite’s final operating orbit (several months) before being able to start commercial operations.

The era of small satellites for all?

As a possible result of some of the innovative trends seen in previous sections, small satellites have become in the past five years very attractive, due to their lower development costs and shorter production lead times.

There is still a natural trade-off to be made between a satellite’s size and its functionality, i.e. the smaller a satellite is, the fewer useful instruments it can carry, and the shorter its lifetime will be since it carries less fuel. However advances in both miniaturization (e.g. increased utilisation of micro-electromechanical systems or MEMS; reduction of Attitude Determination and Control components) and improved satellite integration technologies have dramatically diminished the scope of that trade-off (NASA, 2014). Small satellites are also becoming much more affordable. Commercial off the shelf (COTS) components and consumer electronics are now commonly used to build small satellites at the lower end of the cost range. Several commercial companies fabricate structures for a large variety of small satellite missions, and it is even possible to buy online most of the components and subsystems to build a nano-satellite in-house (e.g. Pumpkin, ISIS and SSTL lead the market). The main cost barrier remains the access to space, although significant progress may occur in that domain.

There are different types of satellites, mainly sub-categorised by their mass. Developers increasingly work on complex system architectures, to get small satellites to interact in constellations. Whole new classes of missions for navigation, communications, remote sensing and scientific research for both civilian and military purposes are being designed in universities, research centres and industry.

Table 1.3. **Types of small satellites**

Type of spacecraft	Mass
Mini satellite	100-180kg
Microsatellite	10-100kg
Nanosatellite (Cubesat)	1-10kg
Femto and picosatellite	Less than 1kg

Cubesats are very popular in universities, as technology demonstrators. They are less than twenty years old, with their standardization realized in 1999 by academics at CalPoly and Stanford University in California. The US Defense Advanced Research Projects Agency (DARPA) was one of the first promoters of these satellites as technology demonstrators, contracting out American universities (Woellert et al., 2011). Usually it takes years, even a decade or more, for major scientific missions to actually move from paper studies to operational satellite missions. In that context, the use of small satellites by universities can help students put into practice much faster their engineering and scientific competences, and small satellites can be launched when excess capacity is available on diverse rockets.

As of spring 2014, almost a hundred universities worldwide are pursuing cubesat development. Some 200 cubesats have been launched. The first launch occurred in 2002. From 2009 to 2011, there have been around 10 per year, but more than 100 were launched in 2013 alone. Twenty six countries have developed cubesats so far, with the United States launching over half of the satellites, followed by Europe, Japan, Canada, and several South American countries.

In terms of future developments, fractionated mission architectures are being studied in several countries. This involves research in networked systems of distributed, co-operating small-satellites, away from the current traditional, large, multifunctional satellites. Some experts see this as an evolution similar to computers, i.e. large mainframe computers of the 1970s have evolved into networks of small computers connected via Internet. This is leading to new commercial ventures. The firm Skybox Imaging, launched in 2013 its first satellite (SkySat-1) of a planned constellation of 24 small satellites, is focusing on making cheap high resolution satellite imagery available, with continuous refreshed data. In January 2014, the company Planet Labs launched the "Flock 1" constellation, with 28 nano-satellites in low-earth orbit, with also the aim to provide frequently updated satellite imagery. As a potential indicator of commercial interests linked to these small satellites' developments, Google acquired in spring 2014 the Skybox firm for some USD 500 million.

Small satellites are thus attracting a lot of interest around the world, and this interest will probably increase as lessons learned are shared in scientific conferences by hundreds of developers. Many countries have decided to fund their first space programmes with the development of small satellites. Overall, aside from the mandatory requirement to secure a launch seat for these satellites on current commercial and governmental rockets, one major challenge will concern the issue of space debris, especially if some systems are not following best practices and end-up in wrong orbits. As the population of small satellites in low earth orbits augments, particularly in the sun-synchronous belt, a very busy orbit for commercial satellite constellations and institutional missions, so will the inherent risks need to be addressed more effectively by the international space community.

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I. READINESS FACTORS: INPUTS TO THE SPACE ECONOMY

2. Civilian space R&D programmes budgets
3. Institutional space budgets
4. Regulatory framework
5. Human capital

Part I examines the factors that enable space activities, notably the institutional budgets that underpin capital-intensive and high-technology sectors. The first indicators provide details on two aspects of government budgets dedicated to space activities: civilian space programmes as presented annually in Government Budget Appropriations or Outlays for Research and Development (GBAORD) and public institutional space budgets, covering both civilian and military budgets. After reviewing trends in human resources, the regulatory framework of space activities is also examined.

2. Civilian space R&D programmes budgets

Institutional budgets are critical in starting-up and developing capital-intensive and high technology sectors such as space. Government Budget Appropriations or Outlays for R&D (GBAORD) data are assembled by national authorities analysing their budget for R&D content and classifying them by "socio-economic objective". These diverse objectives represent the intention of the government at the time of funding commitment, and a special category "exploration and exploitation of space" exists. Although the data provide only a partial picture of space investments (see note below), the long-term time-series provide useful trends on policy orientations.

In 2013, total civil GBAORD for space programmes for all OECD countries amounted to USD 19.2 billion PPP. The United States had the highest GBAORD for space programmes at USD 10.6 billion PPP, followed by the Russian Federation (USD 3.3 billion PPP), Japan (USD 2.2 billion PPP) and France (USD 1.7 billion PPP). The United States was also the country in which space programmes took the highest percentage of total civil GBAORD, at 16.9%, followed by France (10.4%) and Belgium (8.7%). The OECD-wide mean average represented 7.7% in 2013.

Compared to trends seen in previous editions of *The Space Economy at a Glance*, there is a global 2% decrease in GBAORD for space programmes for the OECD area in 2013. The share of space programmes in total civil GBAORD also decreased from 9.1% to 7.5%, mostly due to a decrease in the United States. However, there are no strong negative trends for a majority of countries, with a number of economies (France, Germany, Japan) having actually increased their outlays for space R&D in the last couple of years.

Methodological note

GBAORD data have the advantage of reflecting up-to-date government priorities, since they use budget provisions and not actual spending, although data delays are sometimes an issue. The breakdown in socio-economic objectives brings some limitations (i.e. the "exploration and exploitation of space" category excludes military space programmes, which are included in a specific "defence" category), but GBAORD data provide trends, which can be usefully complemented by other data (e.g. institutional budgets). USD Purchasing power parities (PPPs) have been used to make budgets comparable between countries. New budgetary procedures introduced in the Russian Federation in 2005 have resulted in items previously classified as GBAORD being attributed to other headings and have affected the coverage and breakdown by socio-economic objective.

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Note

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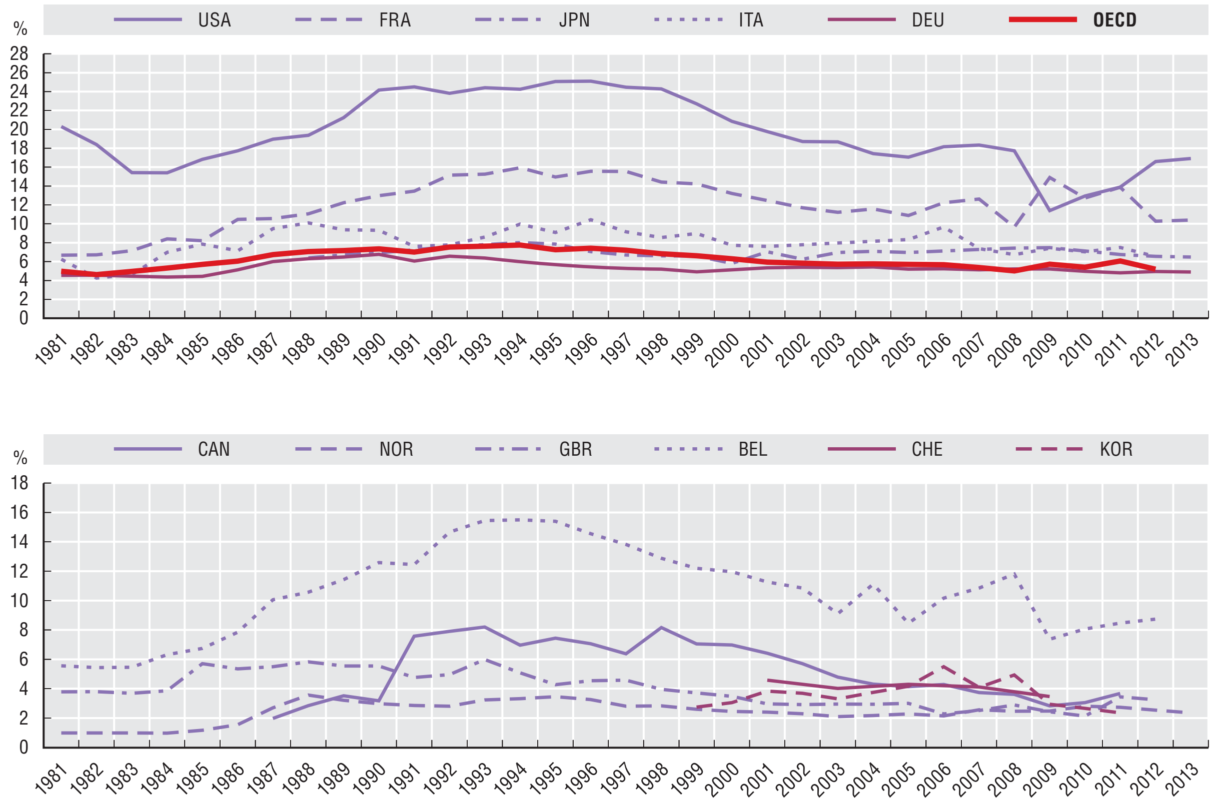
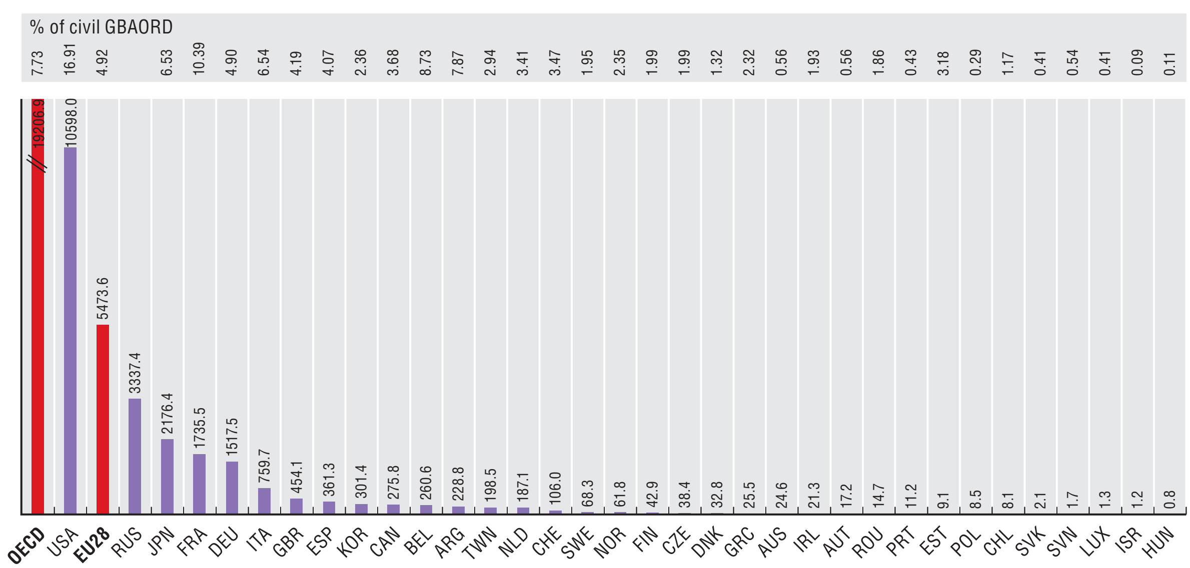
2.1. Evolutions of civil space budgets in government budget appropriations or outlays for R&D (GBAORD) for selected countries, 1981-2013

As a % of GBAORD (or latest available year)



StatLink http://dx.doi.org/10.1787/888933141684

2.2. Civil space budgets in GBAORD, 2013



Source: *OECD Main Science and Technology Indicators Database.*

StatLink http://dx.doi.org/10.1787/888933141703

3. Institutional space budgets

In most countries, institutional space budgets fund a large range of activities in space research, development and applications in both civilian and defence domains. Budgets are usually spread across several government agencies (including defence), which makes them sometimes difficult to track in national accounts. The estimates provided here should therefore be considered as conservative.

Although OECD economies account for the largest space budget globally in 2013, an increasing part of global space activities takes place outside of OECD. When comparing OECD and BRIC economies' space budgets in 2008 and 2013 (using USD purchasing power parities or PPPs), budgets from OECD countries have remained resilient to the economic crisis, with only a slight decrease overall. A number of European Union countries (EU15) have seen their national budgets augment in the period, while BRIC's budgets have shown a strong increase. The Russian space budget for instance rose 144% between 2008 and 2013, taking into account inflation. When national space budgets are converted from USD current to USD PPP, China, India and the Russian Federation are among the top-four investors on space in 2013. Still using PPP to allow better international comparison; the United States has the highest space budget per capita, representing some USD 120 PPP per habitant, followed by the Russian Federation, France, Luxembourg, Japan, Belgium, Germany and Norway (see Chapter 1, Table 1.1).

In current US dollars, five countries have budgets above 2 billion USD in 2013, with the highest budget in the United States (USD 39 billion), covering the space activities of NASA, NOAA, USGS as well as other selected governmental Defence organisations. China had the second-biggest space budget, estimated at around USD 6 billion (based on the intensity of its programmes and trends in its official defence budget), followed by the Russian Federation (USD 5.3 billion), Japan (USD 3.6 billion) and France (USD 2.7 billion). When looking at space budgets' shares in GDP, the percentages remain relatively modest. Only three countries' space budgets represent more than 0.1% of GDP (Russian Federation, United States and France).

Methodological note

Figures reflect all national space investments (civil and military budgets) including national contributions to the European Space Agency and other organisations where applicable. Some countries have fiscal periods stretching over two years, thus making comparison more challenging. Evolutions in a space budget's share of GDP may be affected by both an increase/decrease of space budgets, but also by changes in GDP itself, which may have been hit by the economic crisis. Purchasing power parities (PPPs) are statistical constructs used to allow better international comparisons, in order to compensate for lower price levels in emerging economies (data missing for Chile, Iceland, and New Zealand). The PPP data are complemented by budget data in current USD, where exchange rates fluctuations may impact comparability.

Sources

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Note

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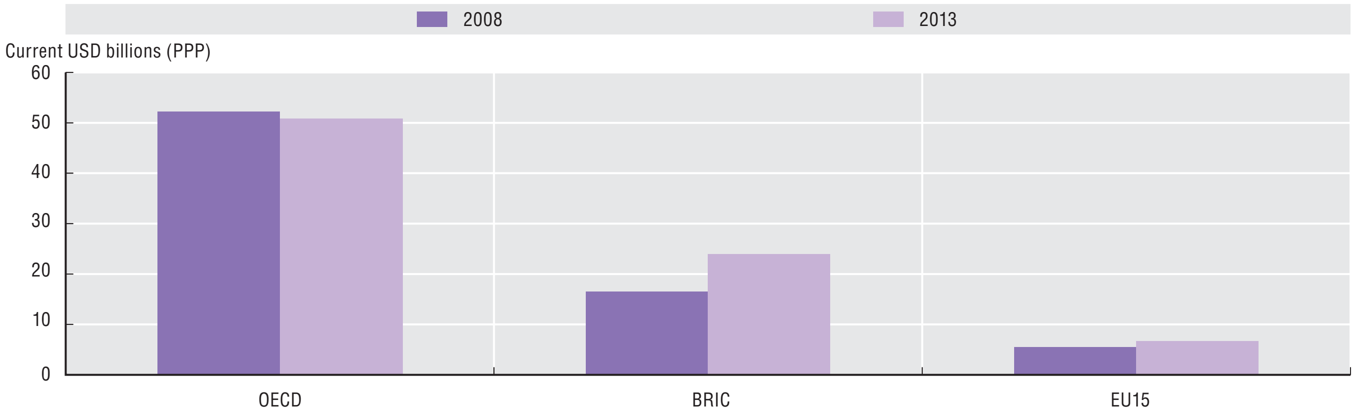
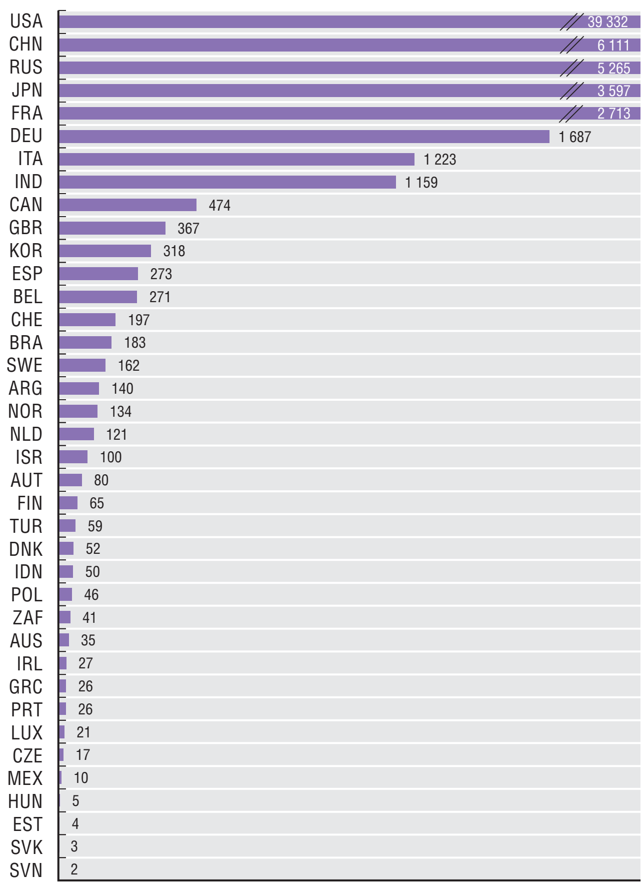
3.1. OECD, BRIC and EU15 space budgets



StatLink http://dx.doi.org/10.1787/888933141722

3.2. Space budgets of selected OECD and non-OECD countries in current USD, 2013

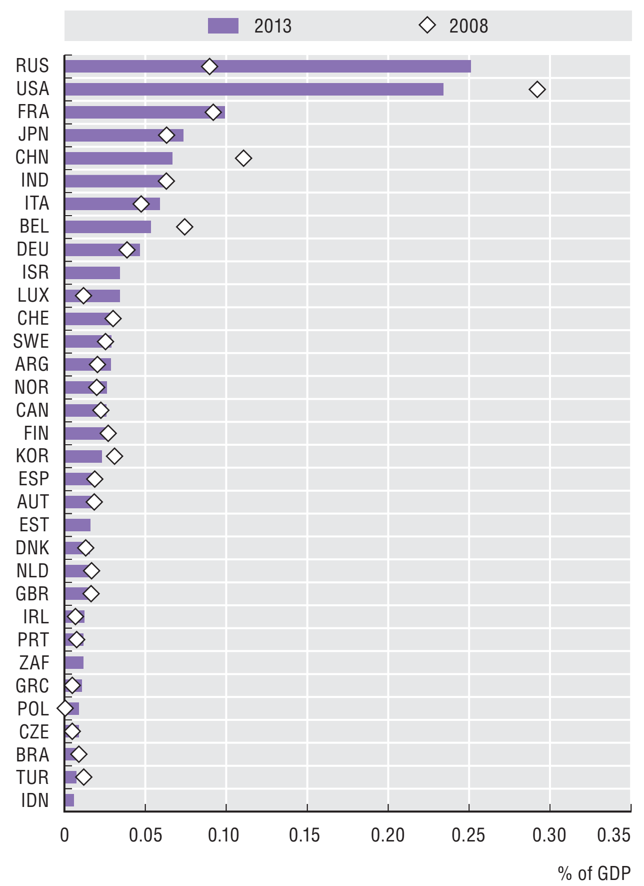


Source: OECD calculations based on national data and OECD MEI data.

StatLink http://dx.doi.org/10.1787/888933141741

3.3. Space budget as a share of GDP for selected countries

% of GDP (based on current USD), 2008 and 2013



Source: OECD calculations based on national data and OECD MEI data.

StatLink http://dx.doi.org/10.1787/888933141760

4. Regulatory framework

The legal and regulatory framework determines the rules according to which space actors operate. During the 1960s and 1970s, a set of international treaties and principles was enacted establishing the peaceful uses and non-appropriation of outer space. Based on this regime, governments are liable under international space law whenever a space object is launched from their territory, even if it is by a private entity. This international regime is therefore complemented by national space laws, to mitigate the risks for governments involved in space activities with an appropriate national licensing structure that regulates institutional and private space activities taking place on their soil.

Since the 1980s, the rapid progression of commercial space activities that followed the privatisation of international telecommunications organisations, such as Intelsat and Eutelsat, has spurred the swift development of national laws and regulations worldwide. A diversity of governments are developing space laws, not only long-established space-faring nations, but also countries with limited space activities wishing to either attract new investments from abroad, or to cater to the needs of their own fledging space industry (e.g. supporting development of small satellite missions). The enactment of a national legal and regulatory regime for space activities can be an important component when trying to develop a competitive space industry.

In parallel, the International Telecommunication Union (ITU) co-ordinates with national administrations the use of the radio spectrum internationally and plays a crucial role in assigning satellite orbits to avoid interferences. Since the 1990s with deregulation and privatisation in satellite telecommunications, with new access to commercial and private funding, the co-ordination has become more challenging with ever more actors. Some 72 national administrations indicated to the ITU their intent to launch satellite networks in 2013 in geostationary and low-earth orbits. Operators have seven years to bring the network into use when the first submission is accepted. France and the United States have the largest shares of total ongoing ITU requests (14.5% and 13.4%). Many countries in Asia and the Middle East have also recently submitted projects planned to be brought into use over the next four to five years (i.e. satellite networks in "advanced publication stage": China, Japan, Israel, Qatar, Saudi Arabia, United Arab Emirates).

Another relevant indicator is the list of operating administrations/agencies in operational control of the ground stations. More than 20 new operating agencies have been submitted to the ITU Radiocommunication Bureau since 2008, underlining the internationalisation of actors in the space sector. Satellite operators face in parallel strong pressure to share their frequencies with terrestrial mobile networks, with increased harmful interferences for some services. This will be one major issue discussed at the World Radiocommunication Conferences to be held in 2015.

Methodological note

The data on legal and regulatory instruments come from national reporting done via the United Nations Office for Outer Space Affairs. The ITU data are extracted from the organisation's World Telecommunication/ICT Indicators database, based on the count of unique filings (satellite networks) per administration. Only countries with more than 50 filings are identified.

Sources

International Telecommunication Union (ITU), Space Services Department, *www.itu.int/en/ITU-R/space*.

United Nations Office for Outer Space Affairs (UNOOSA), *www.oosa.unvienna.org/*.

Notes

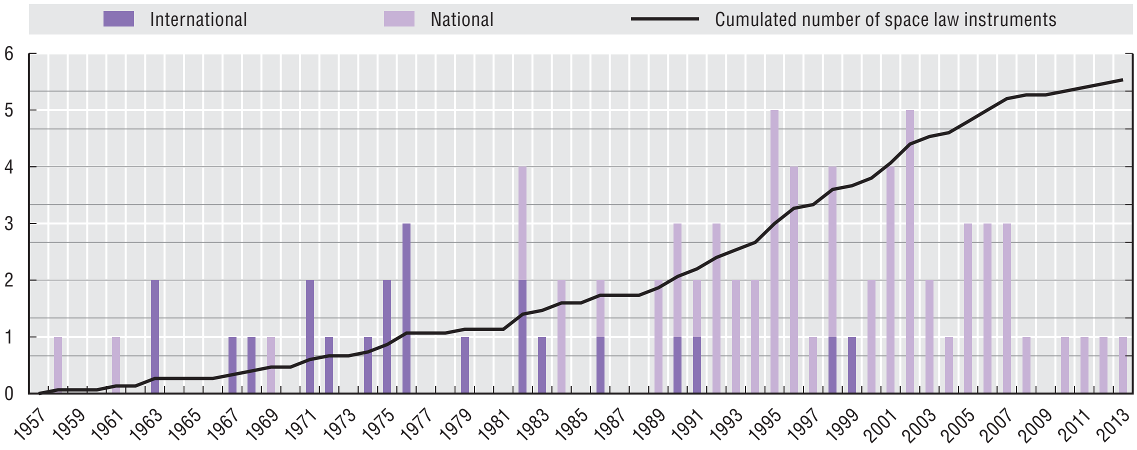
4.1: International instruments include United Nations space-related treaties and principles, international conventions creating multilateral organisations (ESA, Intelsat…) and other international agreements. National space laws and regulations include several instruments (in some cases major updates to existing regulations), as referenced by UNOOSA.

4.3: There are three ITU regulatory stages when developing a satellite network: network in Advance Publication of Information stage (operators have seven years maximum to set up their network) (A), network in co-ordination stage (C), and network in notification stage (the final step before frequency assignments can be recorded into the Master International Frequency Register or MIFR) (N).

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

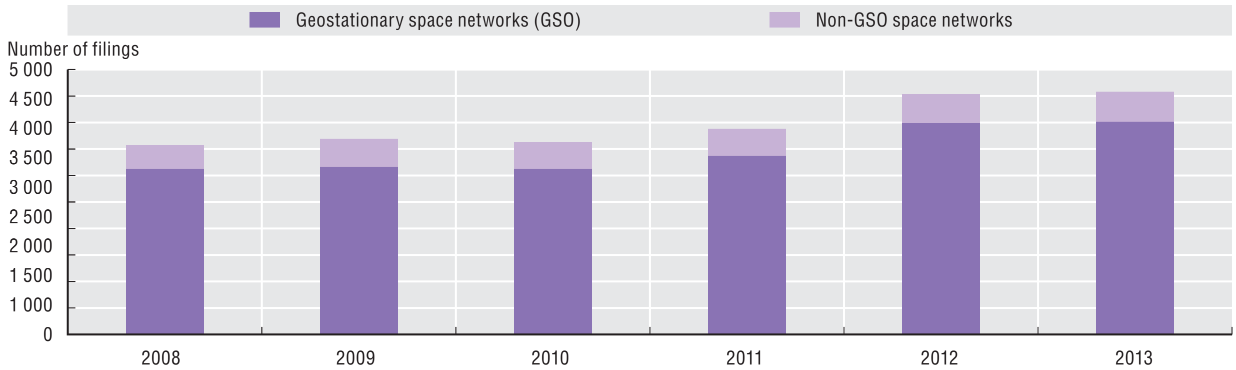
4.1. Development of national space laws and regulations

Number of treaties, national space laws and regulations per year, 1957-2013



Source: OECD calculations based on United Nations data (2014).

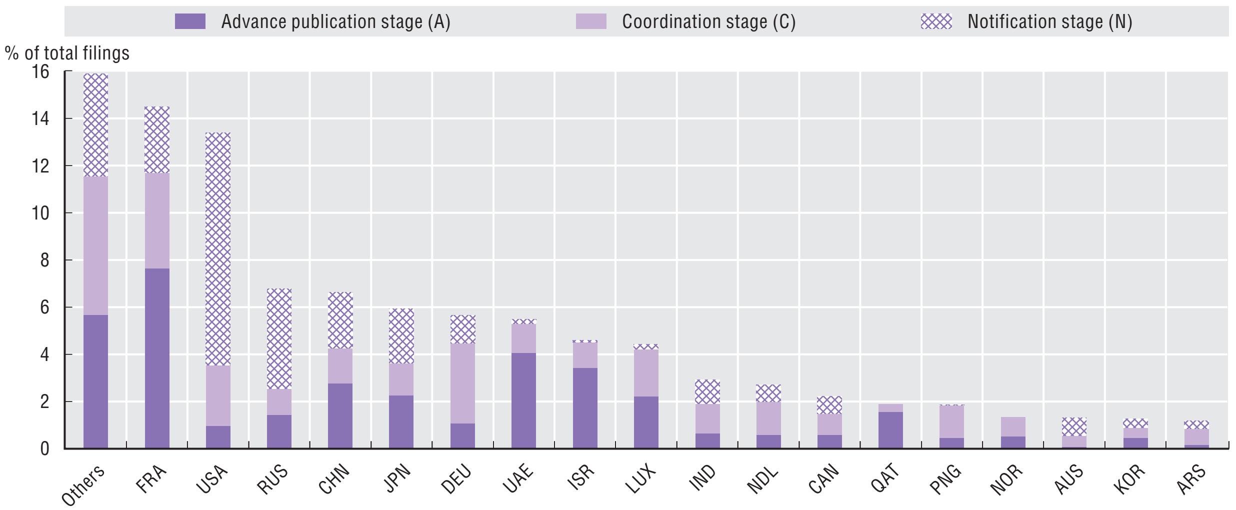
4.2. ITU filings for satellite networks



Source: OECD calculations based on ITU data (2014).

4.3. Share of satellite networks filings per national administration

% of total filings by country, with % of satellite networks' regulatory stage



Source: OECD calculations based on ITU data (2014).

5. Human capital

Human capital is instrumental for the development and sustainability of the space sector. The sector is home to highly skilled professionals, mainly technicians, scientists and engineers. The global space sector employs at least 900 000 persons around the world in 2013, including public administrations with responsibilities for managing space activities and publicly-funded research and development programmes (space agencies, space departments in civil and defence-related organisations), the core space manufacturing industry (building rockets, satellites, ground systems), direct suppliers to this industry and the wider space services sector (mainly commercial satellite telecommunications). Not included in this estimate are other major actors, which play a direct or indirect role in space programmes (e.g. universities, military personnel working on classified programmes). To give orders of magnitude, around 350 000 full-time employees are active in the United States, 200 000 in the Russian Federation, around 60 000 in Europe. A focus on the essential but narrower space manufacturing industry is provided in other indicators (see 6. *Space manufacturing activities*).

When examining human capital, it is important to consider the next generation of employees, who may get involved in space programmes. The majority of jobs available in the space sector can be found in the scientific and engineering fields The OECD Programme for International Student Assessment (PISA) evaluates the quality, equity and efficiency of school systems by tracking the evolution of student performance over time and across subjects. Based on recent surveys, space remains overall an attractive sector for young students. When asked to choose a field of research which 15-year-old students would pursue as a scientist, most students chose the treatment and cure of diseases, or space science. The first one is much more popular with girls than boys but the difference is much narrower in the case of space. The two most common reasons for cited field of research involve references to curiosity, interest, excitement, and to helping people. Other OECD PISA results show differences between countries in the knowledge and skills of 15-year-olds in mathematics, reading and science. On average across OECD countries, science performance has remained broadly stable since 2006. Students from China, Japan and Finland outperform all other countries and economies in science in PISA 2012: Shanghai-China (580 points), Hong Kong-China (555 points), Singapore (551 points), Japan (547 points) and Finland (545 points). Other countries with mean performances above the average include Estonia, Korea, Viet-Nam, Poland, Canada, Liechtenstein, Germany, Chinese Taipei, the Netherlands, Ireland, Australia, Macao-China, New Zealand, Switzerland, Slovenia, the United Kingdom and the Czech Republic. Countries that performed around the average include Austria, Belgium, Latvia, France, Denmark and the United States.

Methodological note

Existing data on space-related human capital are very fragmented. Official employment statistics on the sector are often poor, lacking in both quality and detail. To some extent, the gaps can be filled by micro-data coming mainly from industry associations' surveys, which usually focus on the space manufacturing industry while the larger services sector is not included.

Sources

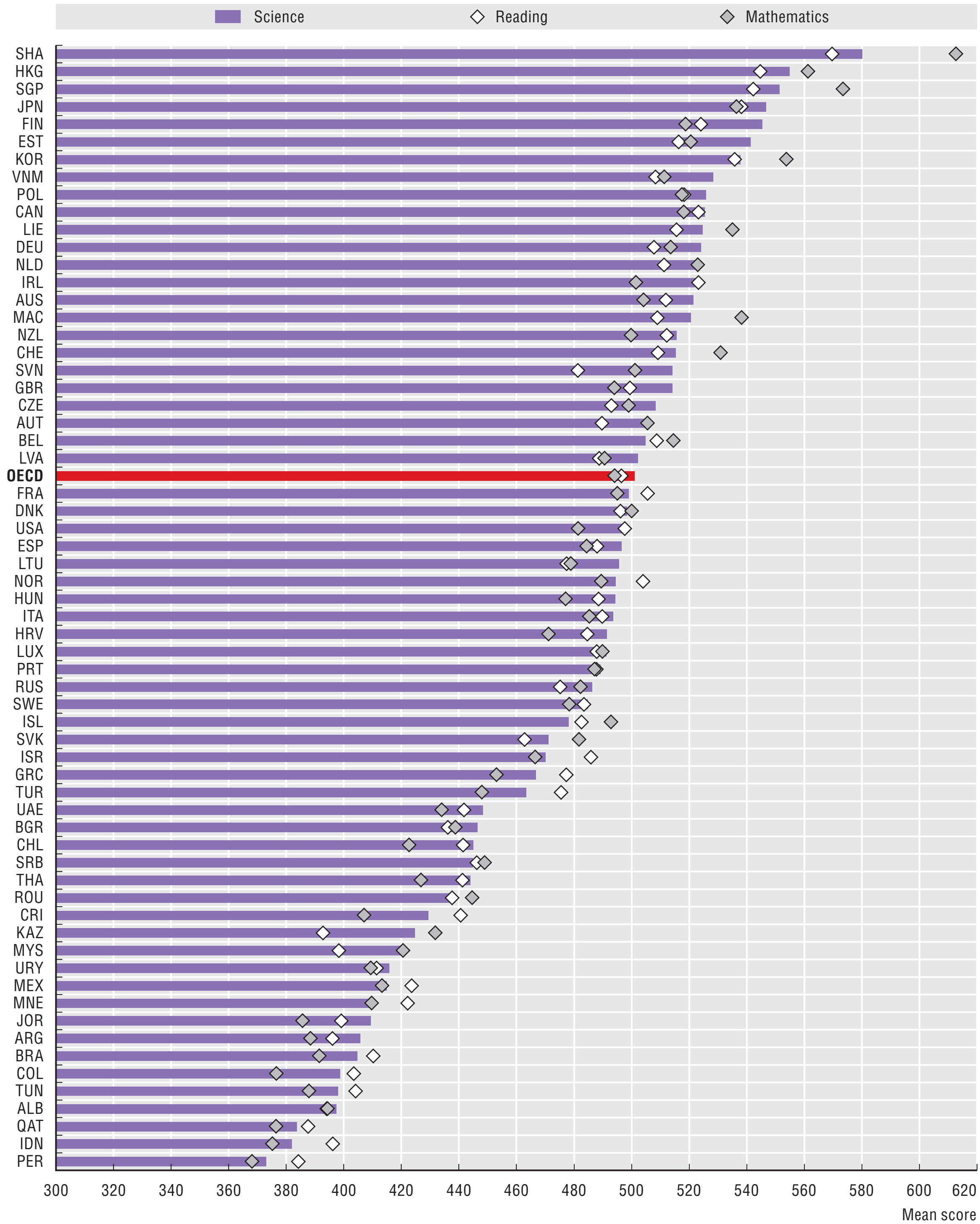
OECD (2014), *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science* (Volume I, Revised edition, February 2014), PISA, OECD Publishing, *dx.doi.org/10.1787/9789264201118-en*.

Note

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

5.1. The next generation of scientists: science, reading and mathematics proficiency at age 15

Mean score from OECD PISA test, 2012



Source: OECD PISA 2012 Results, 2014, *http://dx.doi.org/10.1787/9789264201118-en.*

StatLink http://dx.doi.org/10.1787/888933141779

II. INTENSITY: ACTIVITIES AND OUTPUTS IN THE SPACE ECONOMY

6. Space manufacturing activities
7. Space launch activities
8. Satellite telecommunications
9. Satellite earth observation
10. Satellite weather and climate monitoring
11. Global navigation satellite systems (GNSS)
12. Space exploration activities
13. Human spaceflight activities
14. International trade in selected space products
15. Space-related patents
16. Scientific production in the space sector
17. Insurance market for space activities

Part II provides an overview of the activities derived from space infrastructures, i.e. products or services that are produced or provided by the space sector. Outputs also include the benefits to industries or countries stemming from the production of space products or the performance of space-related R&D. These include financial benefits (e.g. revenues) and indicators of present and future financial benefits (e.g. patents).

6. Space manufacturing activities

Many economies have developed industrial capacities in space manufacturing. This implies industries involved in one or several high-technology value chains ranging from basic research and development, to manufacturing a satellite, its components, launch capabilities, and developing the associated ground-segment to operate these systems. Space manufacturing remains in 2014 a highly specialised high-tech industry, relatively small in size but with highly-qualified human resources. Employment may decrease over the next two years in different parts of the world (Europe, United States, Russian Federation) as several major manufacturers are restructuring their space business after mergers and putting in place vertical integration of their activities.

The US space manufacturing industry is the largest, with almost 80 000 employees and revenues of around USD 36 billion (constant). It relies on strong US government demand, with many institutional satellites (see 36. *United States*). The Department of Commerce found that in total some 348 000 employees were supporting US government space programmes in 2012, taking into account employees in governmental agencies, in the space manufacturing sector, and companies providing services to the manufacturing actors.

With some 36 000 employees in space manufacturing, the European space industry has seen continual revenue growth since 2009, reaching EUR 6.8 billion in 2013 (around USD 8.8 billion). The manufacturing industry is dependent on exports for almost half of its revenues, as compared to other industries in Asia and North America. This figure does not include satellite service operators (i.e. in telecommunications) and the employees in space agencies and other administrations supporting space programmes.

In China, the domestic space programme is keeping the space industry busy, with revenues representing some CNY 135 billion in 2013 even taking into account inflation (around USD 22 billion). The commercial revenues correspond well with the high level of outputs in the Chinese space programmes (satellites, rockets, space station). There are some 25 000 employees in industrial space manufacturing, working in state-owned enterprises and private enterprises, with still the bulk of employees (tens of thousands more) working in governmental bodies, public research centres and administrations (the Chinese space programme is under the supervision of the Chinese Ministry of National Defense).

In Japan, some 8 000 employees work in the space manufacturing industry, again not taking into account other employees working in universities and governmental agencies. After the development of a new launcher and satellite programmes in the late 2000s, the Japanese industry revenues have remained relatively flat, around YEN 260 billion annually (around USD 2.6 billion).

Methodological notes

Four major space manufacturing industries are presented here as case studies. The data are not fully comparable and focus on commercial companies involved in space manufacturing, but they provide an indication of trends in different parts of the world, especially as the key role of domestic institutional markets appears more clearly. International comparability is limited, "space manufacturing" is a broad term used here to reflect specific manufacturing activities conducted in the space sector. It excludes many actors involved in space-related products and services (e.g. commercial operators of satellite communications), while including some non-space activities (e.g. missile production for the US data). Original data come from three industry associations in Europe, Japan (2013 data are estimates) and the United States (with survey inputs from the US Labor Bureau Statistics, 1995 data are estimates), and from the Chinese Bureau of National Statistics (2013 data are estimates). Data for revenues were converted in constant currencies so as to take into account inflation. Producer prices were used for Europe, Japan and the United States, while only consumer prices were available for China.

Sources

Aerospace Industries Association, *www.aia-aerospace.org*.

National Bureau of Statistics of China, *www.stats.gov.cn*.

Eurospace, *www.eurospace.org*.

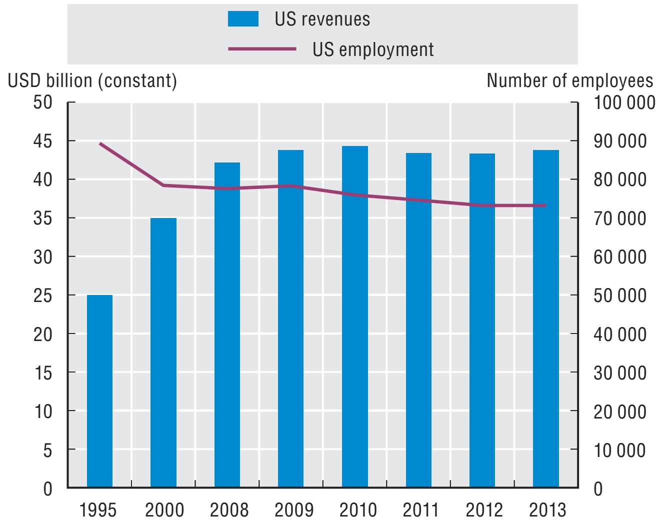
Society of Japanese Aerospace Companies, *www.sjac.or.jp/*.

OECD *Main Economic Indicators (MEI) Database*, *www.oecd.org/std/mei*.

Note

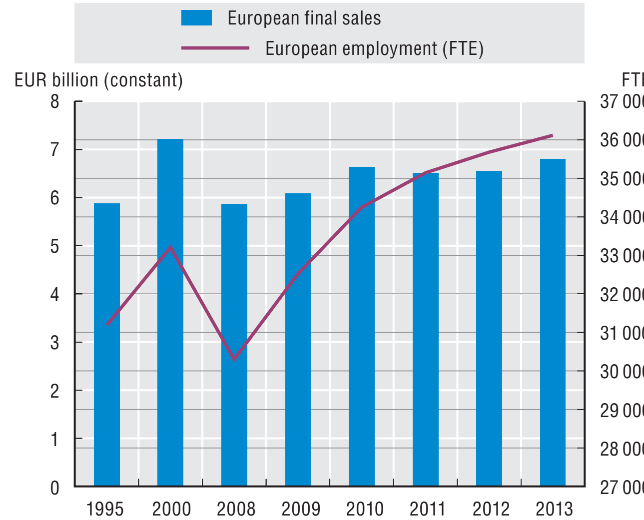
Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

6.1. US space manufacturing revenues and workforce



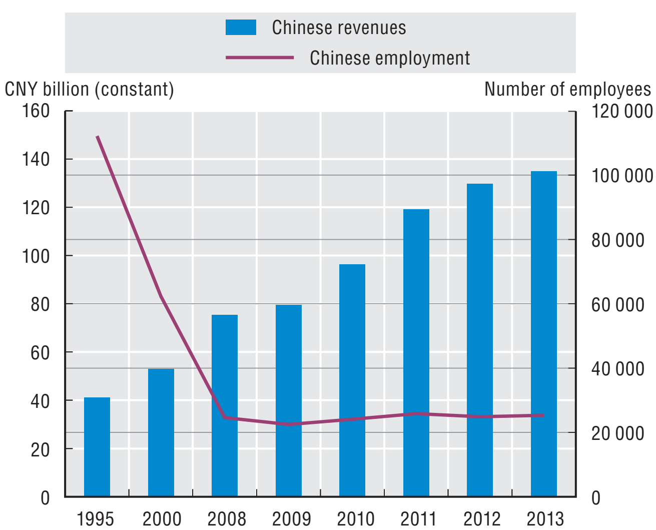
Source: AIA/LBS, 2014.

6.2. European space manufacturing revenues and workforce



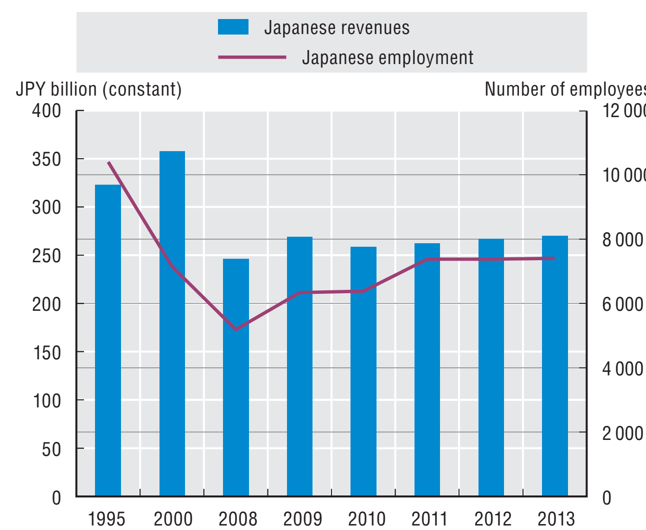
Source: Eurospace, 2014.

6.3. Chinese space manufacturing revenues and workforce



Source: OECD calculations based on the Chinese National Bureau of Statistics, 2013 and *OECD MEI Database*.

6.4. Japanese space manufacturing revenues and workforce



Source: OECD calculations based on SJAC, 2013 and *OECD MEI Database*.

7. Space launch activities

Only a few countries in the world have the technology and facilities to carry out an orbital space launch, or to maintain a fleet of operational launchers. In 2014, this applies to eight countries (United States, Russian Federation, China, Japan, India, Israel, Iran and Korea) and the European Space Agency (ESA). Since 1994, more than 1 300 successful launches have been carried out, with the Russian Federation and the United States accounting for almost 75% of all launches. The launch industry is subject to strong yearly variations (due to the low number of launches per year, satellite life and replacement cycles, etc.). After a drop in the early 2000s, launch numbers are back at 1990s levels, mostly due to increased activity in the Russian Federation and in China, which now has the same number of yearly launches as the United States. In 2013, 78 successful launches were carried out: 31 Russian launches, 19 US, 14 Chinese and seven European. India and Japan had three launches each, and Korea's launch vehicle Naro-1 successfully placed STSAT-2C in orbit. There were three failed launches: one Russian, one Chinese and one commercial launch (Sea Launch).

As most institutional satellites are placed into orbit by national launchers, the market open to international competition is relatively small. It was about USD 2 billion in 2013, a 20% decrease compared to 2012. As of spring 2014, there were six companies able to commercially launch satellites to geostationary (GEO) orbit, which is the most profitable orbit, home to large commercial communications satellites. They include the European Arianespace company (the current market leader, with the Ariane 5 launcher), the Russian Federation's International Launch Services (Proton launcher), the United States' Lockheed Martin (Atlas V) and Boeing (Delta launchers), China Great Wall (Long March launchers) and Sea Launch, an international consortium (Norway, Russian Federation, Ukraine and United States). Other companies can launch satellites in lower orbits, most notably SpaceX (USA), which carried out its first commercial launch in December 2013 with its Falcon 9. It is currently developing its Falcon heavy launch vehicle, with two commercial flights scheduled for 2015 and 2017. India's Polar Satellite Launch Vehicle (PSLV) has a long track record. India is also developing and has successfully tested a heavy-lift cryogenic engine for its Geosynchronous Satellite Launch Vehicle (GSLV) with the ambition to enter the commercial GEO launch market. Launch demand in the next 10 years is expected to remain robust, with stable or increasing demand from institutional and commercial actors driven primarily by growth in emerging economies.

Methodological notes

Data are based on the Federal Aviation Administration's Office of Commercial Space Transportation (FAA/AST) and other public sources. The data include worldwide orbital launch events that are conducted during a given calendar year.

Sources

US Federal Aviation Authority (2014), *Commercial Space Transportation: 2013 Year in Review,* Washington, DC, January.

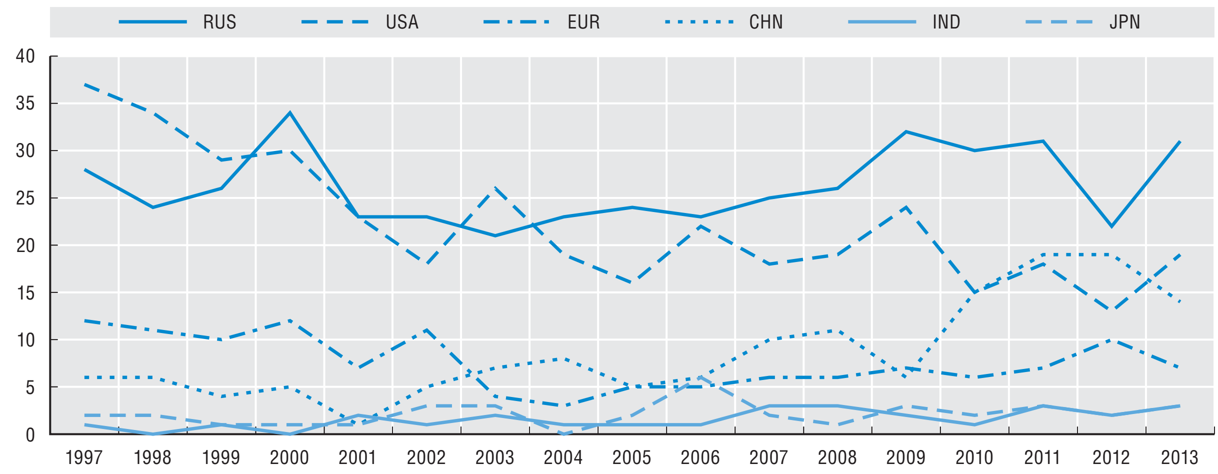
US Federal Aviation Authority (2013), *2013 Commercial Space Transportation Forecasts*, Washington, DC, May.

Satellite Industry Association (2014), *State of the Satellite Industry Report 2013*, Prepared by The Tauri Group, Washington, DC.

Note

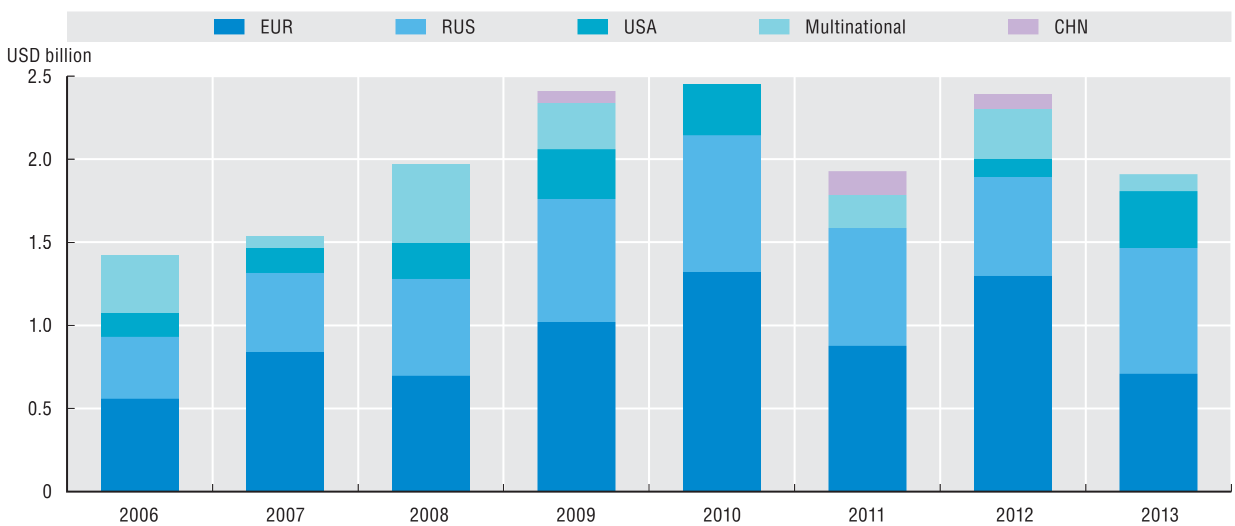
Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

7.1. Number of successful space launches for selected actors, 1997-2013



7.2. Launch industry revenues estimates

In USD billion (current), 2006-13



Source: Adapted from the US Federal Aviation Authority, 2014 and previous years

8. Satellite telecommunications

Satellite services are a growing part of the global communications infrastructure. Through unique capabilities, such as the ability to offer point-to-multipoint communications distribution with small receivers, to effectively blanket service regions, and provide a flexible architecture in hard to reach places, satellite services constitute an important complement to terrestrial telecommunications services.

Satellite networks have been the backbone of the intercontinental telephone network from the 1960s to the 1980s, and although fibre cables have supplanted their uses on routes with highest traffic volume, satellite communications remain a highly profitable business. It branches out traditionally between providers of fixed satellite services (i.e. leasing capacity on geostationary-orbiting satellites for video, voice and data traffic) and providers of mobile satellite services (i.e. data services for mobile users, such as ships at sea and aeronautical markets). This distinction is increasingly losing its relevance, as operators are increasingly entering each other's markets. Another closely-linked ecosystem assembles the providers of satellite ground segment equipment and very small aperture terminals (VSATs), which provide communication receivers and full network solutions to public agencies (including defence) and private companies in banking, retail, oil and gas, rural communities.

The top 25 actors in the fixed satellite services generated revenues of around USD 12 billion in 2013, a 29% increase as compared to 2008, with more than 300 commercial satellites in geostationary orbit. The top 5 actors (Intelsat and SES in Luxembourg, Eutelsat in France, Telesat in Canada, Sky Perfect Jsat in Japan) have some 4 600 employees and represent around 70% of the revenues, a continuing declining share as compared to 2008 (76.5% of revenues), as competition has grown and national satellite operators have set up business. On top of the fixed satellite services operators selling capacity, large media groups are providing the contents and actual satellite broadcasting, broadband and telephone services to every-day consumers (e.g. Dish Network and DirectTV in the United States, BskyB in the United Kingdom, CanalSat and TPS in France). Although it remains challenging to disassemble the revenues streams, some estimates point to a market of around USD 92 billion in 2013 for these satellite broadcasting services (SIA, 2014).

Mobile satellite operators have traditionally provided communications to the narrower but profitable aeronautical and maritime markets. In 2013, their revenues are estimated at around USD 2.6 billion, with three actors leading the market (Inmarsat in the United Kingdom, Iridium in the United States, Thuraya in the United Arab Emirates). Satellite radio is also a market segment representing more than USD 1 billion. Finally, the VSATs and ground equipment providers represent more than USD 7 billion in revenues (Comsys, 2014), with most actors developing vigorous international subsidiaries networks (e.g. Hughes Network Systems, ViaSat Inc., iDirect in the United States, Advantech Satnet in Canada, Gilat Satellite Networks in Israel, Thales in France).

In this context, satellite television remains the most profitable space business. Direct-to-home satellite television broadcast is almost universally available in OECD economies via one or more services, where the signal is received by satellite dishes and set-top boxes. Countries' uptake of satellite services varies widely, in New Zealand and Poland 50% of television households use satellite, but less than 10% in Belgium and Finland. Finally, broadband via satellite is becoming more common and cheaper, although it still remains a confidential market, representing only 0.2% of wireless broadband subscriptions by access technology in OECD economies in 2012 (OECD, 2013).

Methodological notes

Industry data mainly stem from OECD analysis and calculations based on annual reports of publically-traded companies and media reports. VSATs industry data stem from Comsys (*www.comsys.co.uk*) and satellite television broadcasting estimates from the Satellite Industry Association (*www.sia.org*).

Sources

OECD (2013), *OECD Communications Outlook 2013*, OECD Publishing., *dx.doi.org/10.1787/comms_outlook-2013-en*.

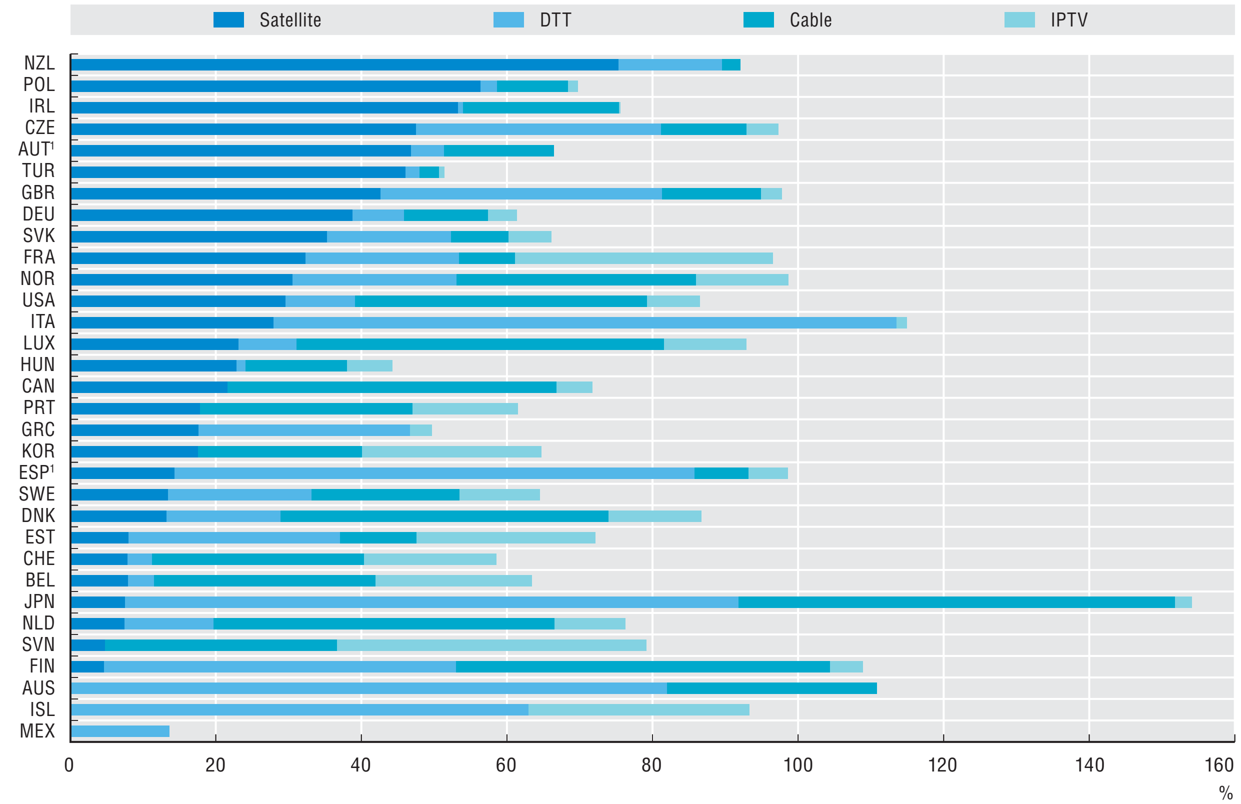
Notes

8.1: DTT: Digital Terrestrial Television, and IPTV: Internet Protocol Television.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

8.1. Penetration of digital satellite television by country

As a % of television households, 2012

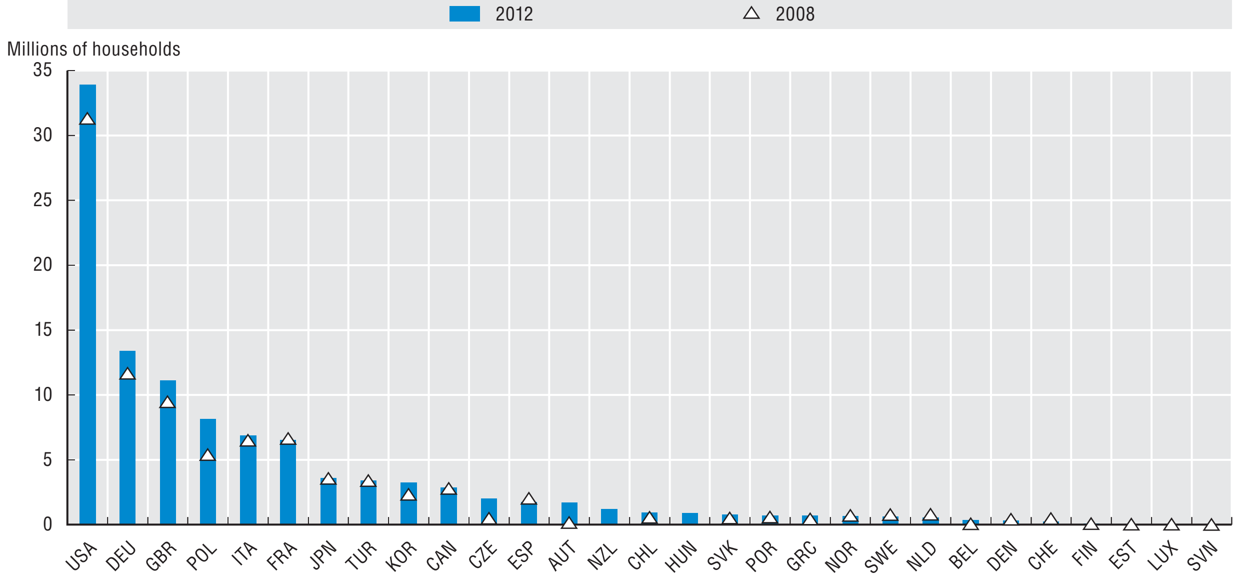


Source: OECD Communications Outlook 2013.

StatLink http://dx.doi.org/10.1787/888933141798

8.2. Number of households using satellite platforms for digital television in selected OECD countries

Millions of TV households, 2008 and 2011



Source: OECD Communications Outlook 2013.

9. Satellite earth observation

Satellite earth observation (EO) systems are playing an increasingly important role in the global economy. They provide unique capabilities in close association with ground-based sensors to generate the data and information needed to manage and monitor natural resources, land-use and to better understand and cope with major societal issues (pollution, impacts of climate change).

There are currently about 120 operational civil earth observation satellites in orbit (not including weather satellites), and around 40 military satellites. Out of these, more than 50 civilian missions are dedicated to gathering multi-purpose land imagery (CEOS, 2013). The United States, China, India, Europe and France lead the number of ongoing satellite missions. In terms of specific scientific instruments onboard satellites, the United States, China, and France have the most instruments flying (on their national missions and in joint satellite missions). As of late 2013, more than 100 civilian missions are planned or are under consideration until 2030 to monitor land-use and oceans (CEOS, 2013). However, the total number of earth observation satellites could already double by 2021 to more than 300, according to different analyses, as an increasing number of countries are interested in possessing their own remote sensing satellites (e.g. Malaysia, Myanmar, Pakistan). One major earth observation initiative concerns the *International Charter: Space and Major Disasters*, which provides satellite imagery free of charge for disaster response purposes around the world. Initiated in 2000 by the European and French space agencies (ESA and CNES), twelve other organisations joined the Charter and agreed to provide data from their earth observation systems (from Argentina, Brazil, Canada, China, Germany, India, Japan, Korea, Russia, United Kingdom and the United States). This co-ordination mechanism has been activated over 400 times in the past 15 years, providing imagery and maps to disaster-affected countries.

The commercialisation of earth observation data remains a niche area, with relatively few commercial satellite operators (e.g. Airbus' Spot Image, DigitalGlobe, MDA Geospatial Inc.). Their revenues are mainly derived from institutional customers. It is estimated that the security and military sectors account for about two-thirds of the commercial market. One example is the "Enhanced View" contract between DigitalGlobe and the US National Geospatial Agency, which accounted for 60% of the company's revenues in 2012 or about USD 250 million (DigitalGlobe, 2014).

Overall, the commercial satellite earth observation represents a market valued at some USD 1.5 billion in 2013, a doubling of revenues compared to 2008 (Satellite Industry Association, 2014). The share of satellite data sales to private actors is slowly increasing though. According to a survey conducted among European and Canadian earth observation companies, the share of sales directed to private companies has been rising in recent years and accounted for 43% of revenues in 2012 (EARSC, 2013). In that context, US remote sensing companies aim to commercialise higher-definition imagery (better than 50 centimetre spatial resolution), to better compete with international actors and aerial imagery. Finally, several new private initiatives are developing constellations with smaller, low-cost satellites, which may have strong impacts on the earth observation sector over the next decade (see Chapter 1).

Methodological note

Data are based on the Committee on Earth Observation Satellites (CEOS), a group formed by major space agencies to co-ordinate civilian earth observation missions. A satellite mission usually carries several scientific instruments (its "payload"), some of which have been flying for decades onboard different generation of satellites from diverse countries, allowing essential and sustained data times series (e.g. data used for land use planning).

Sources

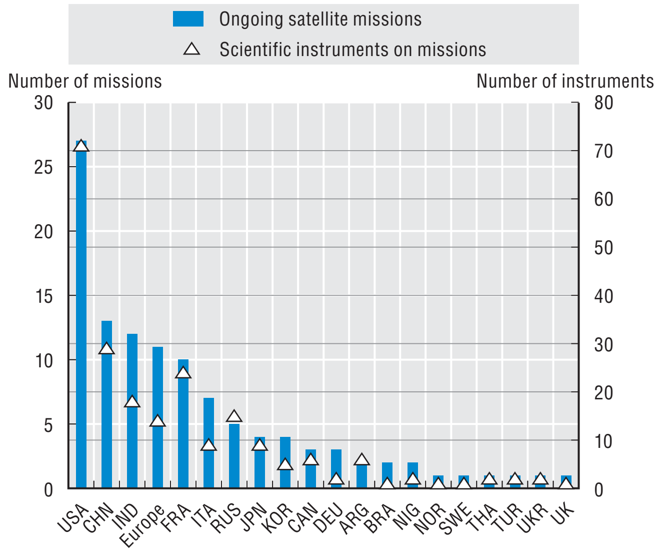
Committee on Earth Observation Satellites (2013), CEOS Missions, Instruments and Measurements database, *www.ceos.org*.

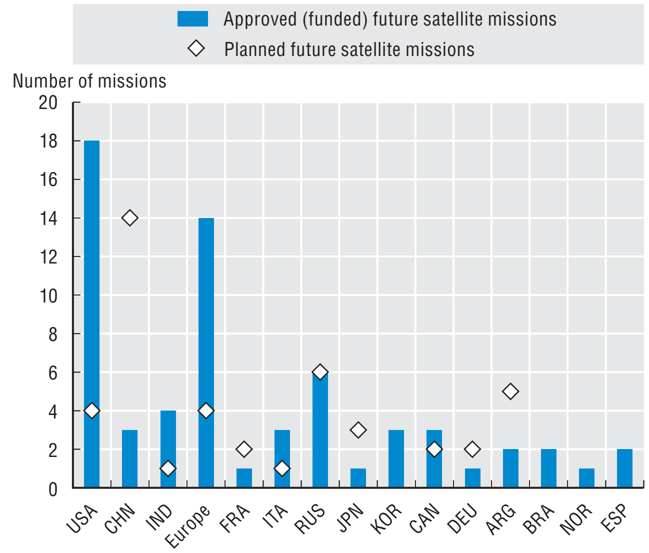
The International Charter "Space and Major Disasters", *www.disasterscharter.org/*.

EARSC (2013), A Survey into the State and Health of the European EO Services Industry, Brussels, August.

Satellite Industry Association (2014), *State of the Satellite Industry Report*, prepared by the Tauri Group, Washington, DC.

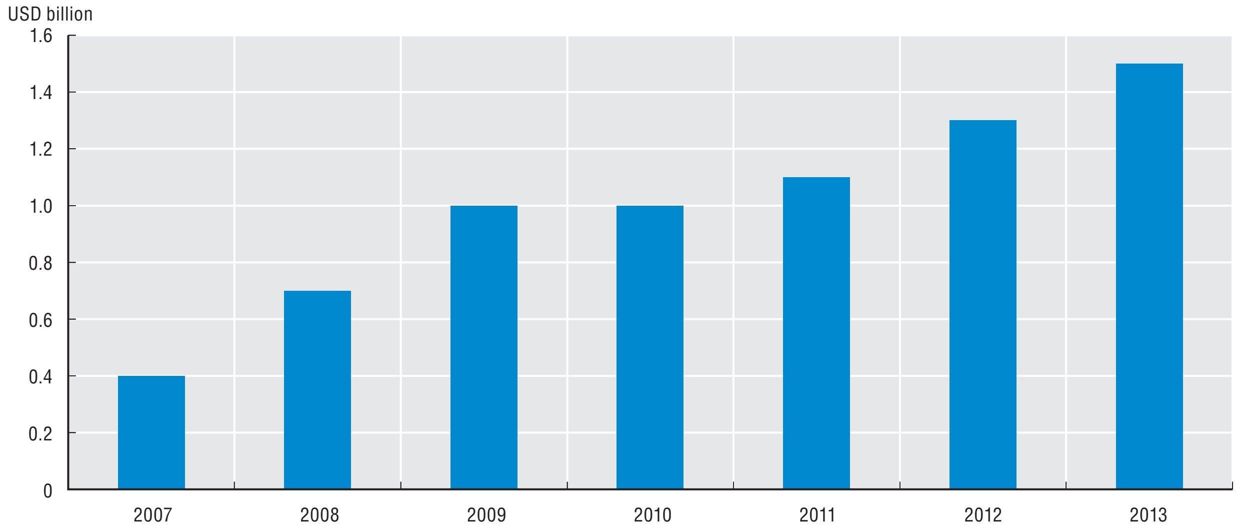
9.1. Selected ongoing and planned institutional earth observation missions by civilian agencies





Source: OECD calculations based on CEOS, 2013.

9.2. Estimates of commercial remote sensing revenues



Source: Adapted from Satellite Industry Association, 2014.

10. Satellite weather and climate monitoring

Meteorology was the first scientific discipline to use space capabilities in the 1960s, and today satellites provide observations of the state of the atmosphere and ocean surface for the preparation of weather analyses, forecasts, advisories and warnings, for climate monitoring and environmental activities. Three quarters of the data used in numerical weather prediction models depend on satellite measurements (e.g. in France, satellites provide 93% of data used in Météo-France's Arpège model). Three main types of satellites provide data: two families of weather satellites and selected environmental satellites.

Weather satellites are operated by agencies in China, France, India, Japan, Korea, the Russian Federation, the United States and Eumetsat for Europe, with international co-ordination by the World Meteorological Organisation (WMO). Some 18 geostationary weather satellites are positioned above the earth's equator, forming a ring located at around 36 000 km (Table 10.1). Their positioning – i.e. American satellites over the West Atlantic, European satellites over the East Atlantic, European and Indian satellites over the Indian Ocean – allows global coverage thanks to international co-operation in weather data exchanges. They share this congested geostationary orbit with more than 300 commercial telecommunications satellites. They are complemented by 17 polar-orbiting weather satellites circling the earth at a much lower altitude (around 850 km) in sun-synchronous orbit, which allows them to revisit a given spot on earth every day at the same hour, making 7 to 16 orbits per day (i.e. "morning" or "afternoon" satellite). The United States, Europe, China and the Russian Federation are so far the only ones operating these essential polar-orbiting satellites, which allow a closer monitoring of the earth's atmosphere (Table 10.2).

In addition to these dedicated weather satellites, around 160 environmental satellite missions in low-earth orbit are currently measuring selected climate parameters (they include both R&D and earth observation satellites, see *9. Satellite earth observation*). Around 30% of these are bilateral or multilateral missions, with different countries providing key instruments on-board satellites (see Figure 1.2). The United States, the European Space Agency and France have established the most joint operations for environmental satellite missions (e.g. NASA is co-operating with Japan's Aerospace Exploration Agency on the Tropical Rainfall Measuring Mission (TRMM); ESA and NASA cooperate on the Solar and Heliospheric Observatory (SOHO), while the French CNES is co-operating with India on the Megha-Tropiques mission to study the water cycle). Paradoxically, although there have never been so many weather and environmental satellites in orbit, funding issues in several OECD countries threaten the sustainability of the provision of essential long-term data series on climate.

Methodological notes

Based on data from the World Meteorological Organisation's database *Observing Systems Capability Analysis and Review* (OSCAR) database, which includes meteorological and environmental satellites.

Sources

Eumetsat, *www.eumetsat.int/*.

National Oceanic and Atmospheric Administration (NOAA), *www.noaa.gov/satellites.html*.

World Meteorological organisation (WMO) Space Programme, *www.wmo.int/pages/prog/sat/index_en.php*.

Notes

10.1 et 10.2 :

1. As of June 2014, some instruments are malfunctioning ("Warning" mode).
2. The satellite is about to become operational ("commissioning" mode)

Note: For the US Defense Meteorological Satellite Program (DMSP) satellites, the US Department of Defense (DoD) is responsible for development and operations, while NOAA provides linkage with the civilian meteorological community.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

10.1. Current geostationary weather satellites

Actors: / Satellites' orbital position:	East Pacific	West Atlantic	East Atlantic	Indian Ocean	West Major Pacific
United States (NOAA)	1 sat. (GOES-15)	2 sats (GOES-13, GOES-14[2])			
Europe (Eumetsat)			3 sats (Meteosat-9, -10 and -11[2])	1 sat. (Meteosat-7)	
India (Indian Space Research Organisation)				4 sats (INSAT-3C, Kalpana-1, INSAT-3D, INSAT-3A)	
Russian Federation (RosHydroMet)				1 sat. (Electro-L N1[1])	
China (China Meteorological Admin.)				2 sats (Feng-Yun-2D, FY-2E)	1 sat. (FY-2F[2])
Korea (Korea Meteo. Administration)					1 sat. (COMS-1)
Japan (Japan Meteorological Agency)					2 sats (Himawari-6 and -7)

Source: Adapted from WMO, *Oscar Database, 2014.*

10.2. Current polar orbiting weather satellites (in sun-synchronous orbit)

	Early Morning Orbit	Morning Orbit	Afternoon Orbit
United States	4 satellites (US Defense Meteo. Satellite Program DMSP-F13[1], DMSP-F16, DMSP-F17, DMSP-F19[2], DoD)	1 sat. (DMSP-F18, DoD)	6 sats (Suomi-NPP (NASA), DMSP-F14[1] and DMSP-F15[1] (DoD), NOAA-15[1], NOAA-18 and NOAA-19 (NOAA))
Europe	-	2 sats (Metop-A and Metop-B, Eumetsat)	-
Russian Federation	-	1 sat. (Meteor-M N1[1], RosHydroMet)	-
China		2 sats (FY-3C and FY-3A[1], CMA)	1 sat.(FY-3B, CMA)

Source: Adapted from WMO, *Oscar Database, 2014.*

Satellites' unique contributions to weather and climate

Since the launch of the first successful weather satellite, TIROS-1, by NASA in 1960, weather satellites are making a major contribution to weather forecasting and climate monitoring. They provide atmospheric measurements: the level of aerosols and greenhouse cases in the atmosphere, monitor the ozone layer, energy capture; atmospheric humidity, temperature (typically by aid of infrared and microwave sounders) and atmospheric winds; as well as measuring cloud cover density, identifying the cloud types and studying cloud particle properties; monitoring of volcanic ash plumes and other particles entering the atmosphere. In addition come other land- and sea-related aspects of climate monitoring, such as land cover (snow/ice, fires) and ocean monitoring (sea level, salinity, currents). Polar-orbiting satellite data feed into Numerical Weather Projection models (NPW), which forecasters use for forecasts 10-12 days in advance. Geostationary satellites provide the images used to identify current weather patterns and carry out shorter-term forecasts. GPS radio occultation is a relatively new technique (first applied in 1995) for performing atmospheric measurements. The technique involves a low-earth orbit satellite receiving a signal from a GPS satellite. The signal has to pass through the atmosphere and gets refracted along the way. The magnitude of the refraction depends on the temperature and water vapour concentration in the atmosphere. Satellite missions have brought on major scientific breakthroughs particularly in climate observation (e.g. satellite detection of long-term damage to the ozone layer leading to the passage of the Montreal Protocol in 1987; and detection and monitoring of the dramatic changes in the extent of Arctic sea-ice coverage). Satellite data are also increasingly used for epidemiology, which combines medical parameters, weather conditions, entomology and general land use information to detect possible tipping points in disease occurrences in many parts of the world (e.g. dengue fever, malaria).

11. Global navigation satellite systems (GNSS)

Like time-keeping, the ability to locate one's position or the position of various objects accurately and reliably is a growing need in our modern economies, with wide-ranging implications for traffic management, security, the environment, the management of natural resources and the provision of personal services (civil and commercial).

As of spring 2014, six regional and global constellations are under development, with the American Global Positioning System (GPS) constellation already fully functional. All these constellations are institutional programmes, with satellites and ground segment systems contracted to national or regional space industries, but under national authority. The only exception is the Galileo programme, which is managed by the European Union. Around 100 navigation satellites could be in orbit by 2020, with at least four different satellite navigation systems with global coverage (GPS, Galileo, Glonass, Beidou), transmitting signals on multiple frequencies.

Many consumer electronics companies are providing devices and services using location-based data. In terms of revenue generation, value-adders involved in satellite positioning, navigation and timing are perfect illustrations of downstream markets, only linked to the space industry by the satellite signals and data they use in their consumer products (e.g. navigation devices in cars, precision faming tools).

When examining top actors in location based services (Trimble, Mitac International, Tom Tom and Garmin), their 2013 revenues represent some USD 8 billion. These actors and others involved in Personal Navigation Device (PND) markets are looking at diversification, as smartphones and tablets are impacting the sale of proprietary PNDs. Other actors involved include manufacturers of receivers, and antennas. Some 47 manufactures surveyed in 2013 captured more than 95% of the market, with 380 receivers available commercially (GPS World, 2013). Although estimates vary, a recent market report published by the European GNSS Agency estimates the global core revenues of the GNSS market around EUR 50 billion in 2013 (European GNSS Agency, 2013).

Methodological notes

Industry surveys are still relatively few concerning the location-based and navigation sectors, especially as technologies have rapidly evolved in the past five years. Estimates provide interesting orders of magnitude, but statistical definitions vary.

Sources

European GNSS Agency (2013),*GNSS Market Report: Issue Three,* October, Prague. *www.gsa.europa.eu*.

GPS World (2013), *gpsworld.com*.

11.1. Satellite navigation constellations

United States	Operational since April 1995, the Global Positioning Satellite (GPS) system is composed of 27 satellites, providing a horizontal accuracy of minimum 3 meters, which can be further enhanced by ground- or space-based augmentation systems. An upgrade of the constellation is currently under way with GPS-III satellites under production.
Russian Federation	Some 29 Glonass satellites in orbit, with 24 operating to provide global coverage. Accuracy is comparable to that of GPS, and commercial use of Glonass is increasing. The Russian Government approved a work programme in March 2012, allocating RUB 326.5 billion (≈ USD 11 billion) for the period 2012-20. The complete constellation would consist of 30 satellites in orbit, including six in reserve.
Europe	As of spring 2014, Galileo has four satellites, with six more satellites scheduled for launch by late 2014, at which point early services could be made available to the public. Galileo could reach full operational capability with 30 satellites around 2020. In 2008, a governance framework was established for the Galileo programme. It provides for the deployment of the full operational capability of the constellation under a public procurement scheme, entirely financed out of the European Union budget. The European Union also operates a GPS augmentation system, EGNOS, with transponders on three satellites, to improve accuracy.
China	The Chinese global positioning system, dubbed Compass/Bei Dou, is currently covering the Asia-Pacific region, with a constellation consisting of 14 operational satellites, as of May 2014. The constellation could reach global coverage by 2020, with 35 satellites.
India	The two first satellites in India's seven-satellite constellation, Indian Regional Navigation Satellite System (IRNSS), were successfully launched in July 2013 and April 2014. India has furthermore launched two out of three satellites that will contribute to the GPS augmentation system GAGAN, the last launch scheduled in 2014-15.
Japan	The Japanese Quasi-Zenith Satellite System (QZSS) is a space-based GPS augmentation system, compatible with GPS, which will consist of four satellites. The first satellite, Michibiki, was launched in 2010 with the remaining three satellites to be launched in the 2015-17 period.

12. Space exploration activities

Space exploration is a key driver for investments in innovation and science, and it constitutes an intensive activity for space agencies and industry. Space sciences and planetary missions have developed markedly over the years, with new actors joining in, although no country can today launch a major exploration mission alone, because of the costs involved and since the supply chains for systems and components have become so internationalised (see Chapter 1). Another factor for co-operation is the need for deep space monitoring systems, based on international arrays of giant radio antennas installed in different countries (e.g. Australia, Chile, United States, South Africa), to keep communication links with interplanetary spacecraft missions.

Out of the over 900 satellites orbiting the earth, a dozen are dedicated to space sciences, including large international space telescopes, and scientific missions searching for earth-like planets outside the solar system. Robotic spacecraft have been sent to all of the planets in the Solar System. As of spring 2014, three satellites are orbiting Mars (Europe, United States) and two more are on their way (US, India), two active rovers are on Mars' surface (US), two satellites are orbiting Venus (China, US) and at least ten probes are flying throughout the solar system, including one to reach and land on a comet for the first time by late 2014 (European mission with China, India, US). One of the more emblematic destinations for future missions is the planet Mars. Reaching Mars remains a challenge, as nearly two-thirds of all spacecraft destined for Mars have failed without completing their missions. Missions to Mars can be launched every two years or so (i.e. the alignment of earth and Mars in their orbits around the sun allows spacecraft to travel between the two planets with the least amount of energy), and the voyage can take up to six months. The next missions to Mars could occur in 2016, 2018 and 2020.

Although scientific missions and joint space exploration strategic planning remain the remit of the public sector, new private actors aim to get engaged in innovative space exploration activities. Supported by successful information-technology entrepreneurs, the Google Lunar XPRIZE calls for privately-funded spaceflight teams to compete to launch by late 2015 a robotic spacecraft that can land and travel across the surface of the Moon. As of spring 2014, some 25 teams from around the world are engaged.

Methodological notes

Space agencies publish key statistics about their current and upcoming space exploration missions. A given space exploration mission can cumulate several tasks, such as a flyby, being an orbiter, carrying a lander or a rover.

Sources

European Space Agency (2014), Space Exploration Activities, *exploration.esa.int*.

NASA (2014), Solar System Exploration, *solarsystem.nasa.gov*.

Google Lunar XPRIZE (2014),*www.googlelunarxprize.org*.

Notes

12.1: 1. Include flyby missions.

Chasing a comet for science

Comets are considered the primitive building blocks of the Solar System and likely helped to "seed" the earth with water, perhaps even the ingredients for life. Several missions have been sent over the years to observe comets from afar. Launched in 2004, the European Space Agency's Rosetta probe has been travelling through the Solar System and arrived successfully at the Comet 67P/Churyumov-Gerasimenko in August 2014. It became the first space mission to rendezvous with a comet since the Giotto European probe's close encounter with Comet Halley in 1986. It will also be the first attempt to land on a comet's surface in Fall 2014.

12.1. Popular extra-planetary destinations

Number of missions, 1958-2013

	Asteroids and comets	Venus	Mars	Moon
Total number of missions[1]	29	45	46	116
Success rate	85%	55.5%	43.4%	50.8%
Successful orbiters	2	10	10	36
Successful landers/rovers	2/-	9/-	6/4	9/3
Successful crewed landing	-	-	-	6
En route missions	3	-	2	-
Operational	3	-	5	5
Planned (funded) missions	4	1	3	6
Comments	ESA's Rosetta mission aims to orbit and deploy a lander on a comet for the first time (Nov. 2014).	Venera 3 (former USSR) was the first spacecraft to reach the surface of another planet in 1966.	NASA's Mariner 9 made the 1st successful Mars orbit, while the USSR's Mars 3 made the first landing the same year.	This is the only extra-terrestrial body visited by astronauts (last flight in 1972).

Source: OECD adapted from space agencies.

13. Human spaceflight activities

More countries than ever are investing in indigenous human spaceflight capabilities, usually in collaboration, by providing scientific experiments and equipment to larger missions through a variety of means: sounding rockets, suborbital flights, and of course orbital spaceflight missions (currently only available via flights to the International Space Station (ISS) or the Chinese Tiangong-1 test-bed space station).

The year 2014 marks the 16th anniversary of the ISS, with six astronauts continuously on-board since 2008. The countries involved in this partnership include: the United States, Canada, Japan, the Russian Federation, and participating ESA country members (Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom). Since the end of the space shuttle missions in 2011, the only way for crews to reach the station is by using the Russian Soyuz capsules. Other means are available to deliver cargo and crew supplies to the station: the Russian Progress (several flights a year), the European Automated Transfer Vehicle (the fifth to be launched in 2014), the Japanese H-II Transfer Vehicle (also the fifth to be launched in 2014) and commercial US capsules, SpaceX's dragon and Orbital's Cygnus. SpaceX and Orbital were awarded resupply contracts worth USD 1.6 and 1.9 billion respectively until 2015. As of May 2014, SpaceX has successfully executed 3 of its 12 planned cargo missions to the ISS. Orbital Sciences Corporation's Cygnus capsule has made its first delivery in January.

Following the retirement of the space shuttle fleet, commercial firms were selected by NASA to develop new spacecraft capable of carrying astronauts to the ISS by 2017-18. These are SpaceX, Boeing, Sierra Nevada and Blue Origin. In parallel, NASA is working on the development of a new heavy-lift launcher with a capsule dubbed Orion, capable of carrying astronauts beyond the earth's orbit, with long-term missions to asteroids and Mars. China has also started building a 30-ton space station, to be completed in the 2016-23 timeframe. In the meantime, the operational Chinese Tiangong-1 space station serves as a technology testbed, visited in June 2013 by Taikonauts for two weeks, China's longest manned space mission to date.

The shift from government to commercial space transportation for cargo and ultimately crews of astronauts to low-earth orbit will be highly dependent on the performance of firms over the next five years. In parallel to these initiatives, space tourism activities are being developed particularly in North America and Europe, with zero-gravity/parabolic flights, sub-orbital flights and orbital space travel offered to private consumers. The company Virgin Galactic is scheduling its first commercial suborbital flight in 2014-15 from the United States.

Methodological notes

Several definitions of "astronaut" co-exist. The International Aeronautic Federation (IAF) calls anyone who has flown at an altitude of 100 kilometres an "astronaut". The US Air Force set the limit at 50 miles altitude (80.45 km), while other organisations consider that a person must have reached orbital velocity and remain in orbit (above 200 km) to be considered an "astronaut". The IAF definition has been used here.

Sources

European Space Agency (2014), Human spaceflight programme, *www.esa.int/Our_Activities/Human_Spaceflight*.

Federal Aviation Administration (2014), Office of Commercial Space Transportation, *www.faa.gov/about/office_org/headquarters_offices/ast*.

NASA (2014), International Space Station, *www.nasa.gov/mission_pages/station*.

Notes

13.1: 1. China, Russian Federation.
2. 7 Russian, 1 American, 1 Chinese, 1 international.

13.2: 1. Since 2011.

13.1. Selected human spaceflight statistics

As of May 2014

Countries with autonomous capability to launch humans into space	2[1]
Number of nationalities who have flown in space	+40
Number of launches with humans on-board	+270
Persons who have flown into orbit	+530
Operational and inhabited space stations since the 1960s	10[2]
Professional astronauts living in orbit (the International Space Station is continuously inhabited since 2003)	6
Number of paying orbital spaceflight participants (“space tourism”)	7
Persons who have flown over the 100 km altitude threshold (including suborbital flights)	484
Astronauts who walked on the Moon (1969-1972)	12

13.2. Human spaceflight capabilities in selected parts of the world

As of January 2014

		Orbital capabilities			Human-rated launchers capabilities		
		1990-2009	2010-2019	After 2020	1990-2009	2010-2019	After 2020
Government	EUR	Spacelab module on shuttle	ISS	ISS	None	None	None
	CHN	None	Tiangong-1 space station	Tiangong-2 space station	Long March	Long March	Long March
	RUS	Mir	ISS	ISS	Soyuz	Soyuz	Soyuz/Angara
	USA	Space shuttle	ISS	ISS	Space shuttle	None[1]	Commercial/ governmental launchers

14. International trade in selected space products

International trade in space products, i.e. satellites and rockets, is relatively limited. It remains highly regulated and subject to government control, with a rather small volume of production and a high degree of custom-made parts and materials. All these factors constrain trade; however, official trade statistics do reveal some notable trends.

There was a significant increase in export volume in the last half of the decade, with a total recorded export value of USD 15 billion for 2007-13. This compares to USD 4.4 billion total export value for 2000-06. This significant growth is due to a more internationalised manufacturing sector and increased intra-firm trade across borders (see Chapter 1). The emergence of new markets in different parts of the world, especially in the telecommunications sector, is also a major factor.

OECD economies are the main exporters of space products. During the 2007-13 timeframe, France, Germany, the United States and Italy were the top exporters of spacecraft and space vehicles. However, exports are increasingly headed to non-OECD economies as compared to the beginning of the decade (57% of exports in 2007-13, as compared to 51% in 2000-06), with the Russian Federation and China as important customers. Kazakhstan is also an important importer because of the Russian-operated launch site in Baikonur. France and Luxembourg's high ranking on the importers' list comes from being home to large satellite telecommunications operators (Eutelsat for France and SES and Intelsat for Luxembourg). These operators procure their commercial satellites internationally.

Methodological notes

Tracking trade volumes of final products of spacecraft (including satellites) and launch vehicles remains challenging. Spacecraft are defined in international classification systems as a manned or unmanned vehicle designed to orbit the earth or travel to celestial objects for the purpose of research exploration. However, statistics can only capture a limited share of space-related trade and the recorded volume is probably considerably under-reported as compared to actual production levels (and/or due to the absence of detailed codes for some systems and equipment, and statistical confidentiality issues). The data come from the International Trade by Commodity Statistics (ITCS) database jointly managed by the OECD and the United Nations. The Commodity Code used is 7925 "Spacecraft (including satellites) and spacecraft launch vehicles". These data need to be completed by industry associations' results, as many of the space manufacturing contracts do not appear in official statistical databases.

Sources

OECD International Trade by Commodity database (ITCS) database, data extracted 13 May 2014. *www.oecd.org/std/its/itcsinternationaltradebycommoditystatistics.htm*.

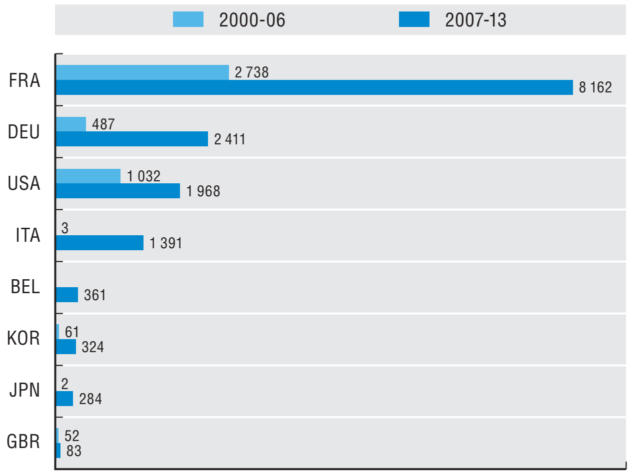
Note

14.3: Data reported by France, United States, Germany and Italy.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

14.1. Top OECD exporters of satellites and launch vehicles

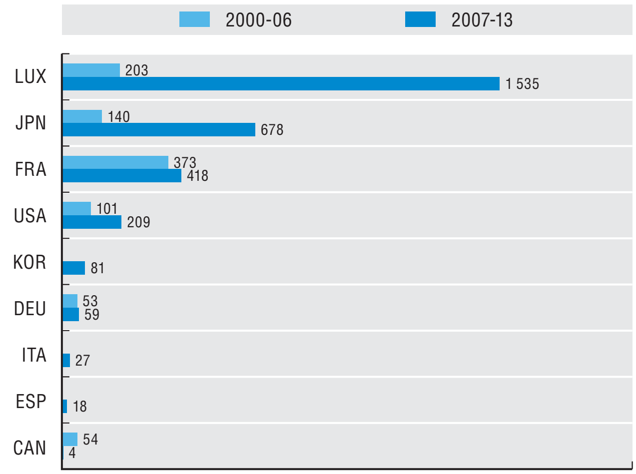
USD million (current), 2000-06 and 2007-13



StatLink http://dx.doi.org/10.1787/888933141836

14.2. Top OECD importers of satellites and launch vehicles

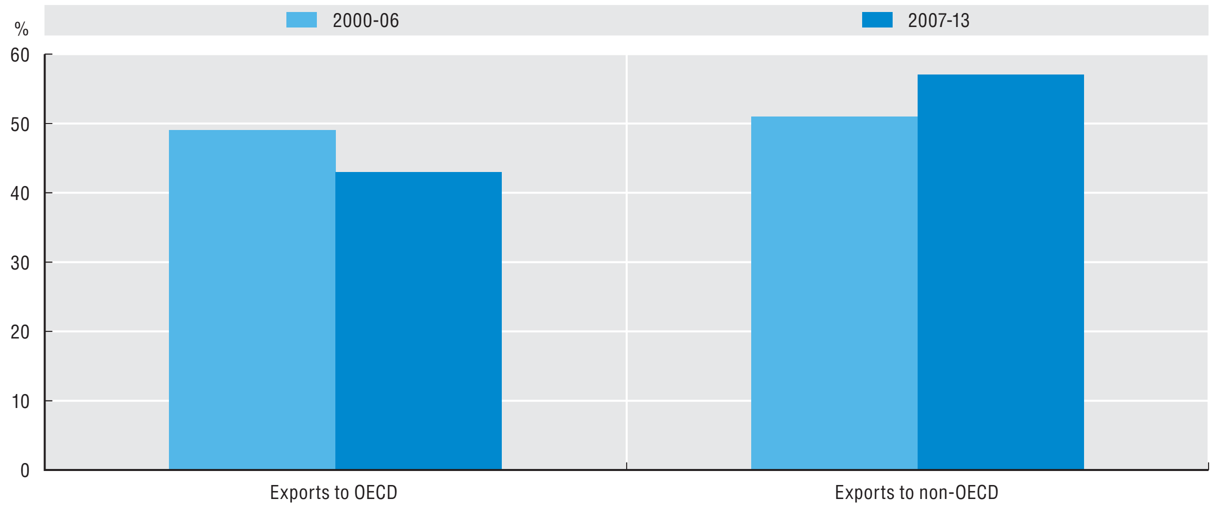
USD million (current), 2000-06 and 2007-13



Source: OECD ITCS Database, 2014.

StatLink http://dx.doi.org/10.1787/888933141855

14.3. Space exports market distribution as reported by top four exporters



Source: OECD ITCS Database, 2014.

StatLink http://dx.doi.org/10.1787/888933141874

15. Space-related patents

Patenting in the space sector is not as common as in other sectors, as commercial discretion and institutional confidentiality are often still priorities for some space systems. There are only a few hundreds patents a year. Still, the number of space-related patents has almost quadrupled in 20 years, as revealed by the applications filed under the Patent Co-operation Treaty (PCT). The space application areas (i.e. satellite navigation, earth observation, telecommunications) have also gained in importance in a decade.

When comparing patent applications for space-related technologies per country over 2001-03 and 2009-11, the United States still leads but its share has shrunk. Other countries have seen their shares of worldwide patents grow in relative terms, noticeably France, Germany, China, Japan and Italy. In terms of revealed technological advantage, eight countries demonstrate a level of specialisation in space technologies. The Russian Federation, France, Israel, Turkey, Chinese Taipei, Canada, Spain, Brazil and the United States show a relatively large amount of patenting in space activities, compared to other economic sectors.

In terms of space-related patenting on a regional scale, the highest shares can be found in a few selected regions: around 12% of worldwide space patenting occurs in California (USA), 6% in Midi-Pyrénées (FRA), 5% in Southern Kanto (JPN) and Ile de France (FRA), and 4% in Guangdong (CHN). Between 2001-03 and 2009-11, California's share has noticeably shrunk, while several European and Asian regions have seen their patenting activities progress (Midi-Pyrénées, Southern Kanto, Capital Region in Korea), with strong growth in some cases (Ile de France, Guangdong, Niedersachsen, Hamburg, Aquitaine, Ontario).

Methodological notes

Space-related patents are identified using a combination of codes from the International Patent Classification (IPC) and key word searches in the patent title. In the first figure, the downturn of USPTO patent grants after 2001 is mainly due to delays in updating patent databases and to the time-lag between the application of a patent and its granting (trends for applications filed were also included for USTO). The "revealed technological advantage" (RTA) index is defined as a country's share in patents in a particular field of technology, divided by the country's share in all patents. The index is equal to zero when the country holds no patents in a given sector, is equal to 1 when the country's share in the sector is equal to its share in all fields (*i.e.* no specialisation), and grows when a positive specialisation is found. For sectoral comparisons, patents in biotechnologies and nanotechnologies are based on a selection of IPC classes. Patents in environment-related technologies are defined using combinations of IPC classes and codes Y02 of the European Classification (ECLA).

Sources

OECD patent databases, May 2014 and calculations based on the Worldwide Patent Statistical Database, EPO, Spring 2014.*www.oecd.org/sti/inno/oecdpatentdatabases.htm*.

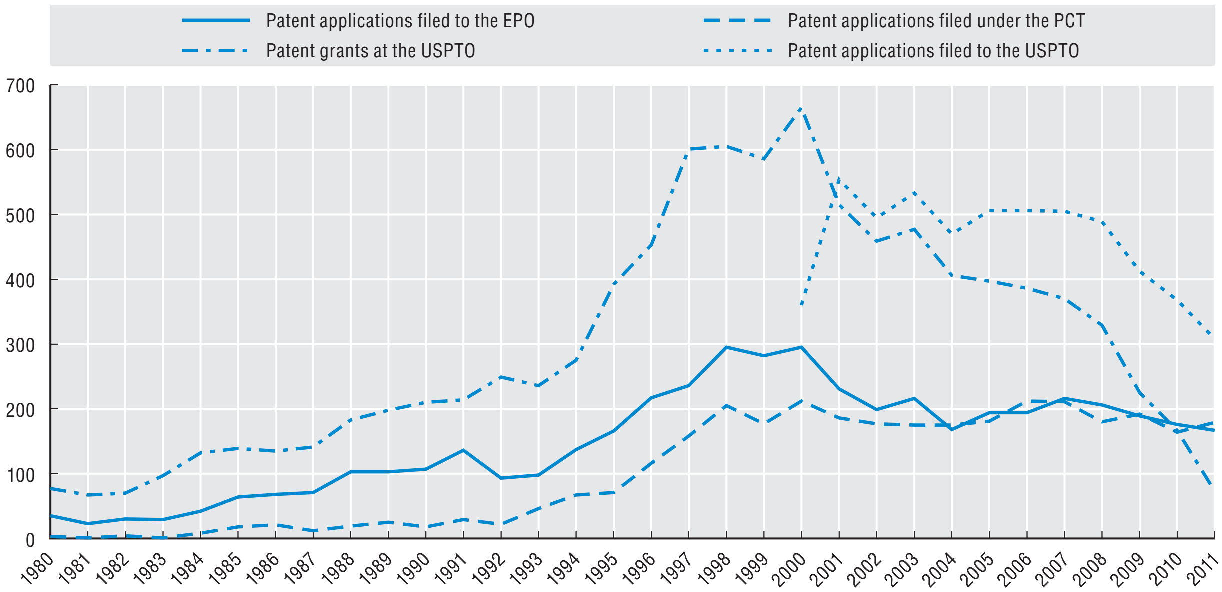
Note

15.2: Patents in space-related technologies can be allocated to more than one domain.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

15.1. Evolution of space-related patents

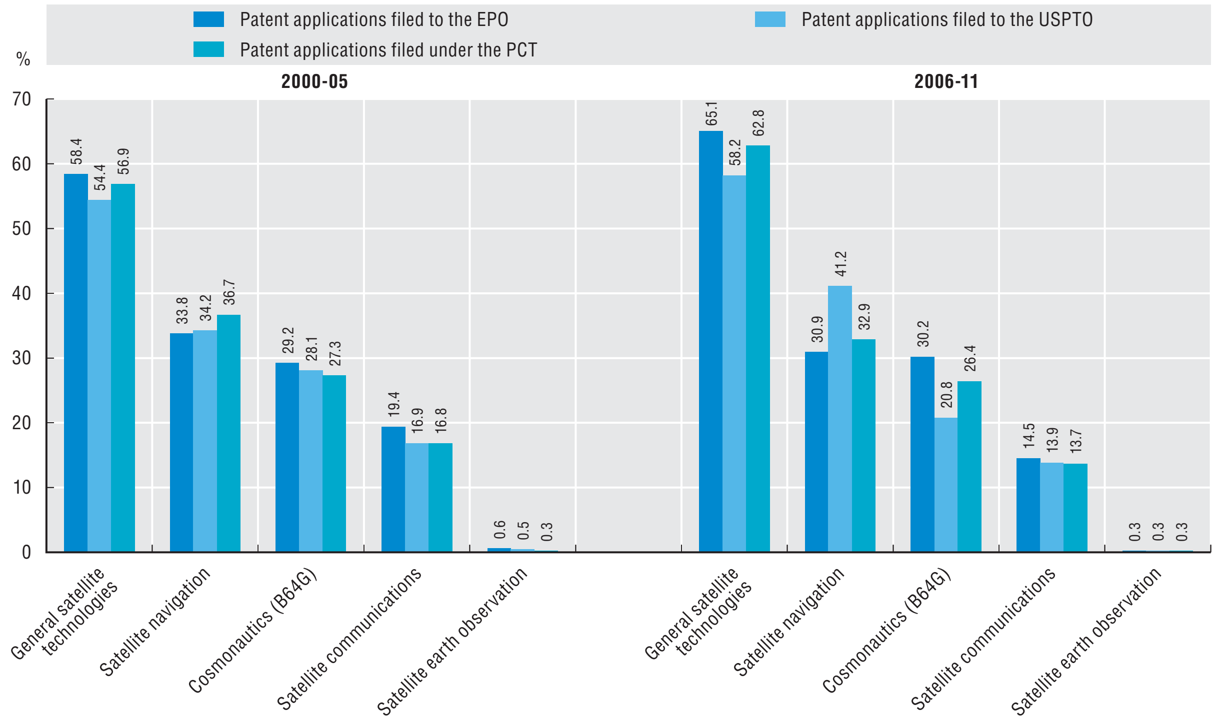
Number of patents, by patent offices and priority date, 1980-2011



StatLink http://dx.doi.org/10.1787/888933141893

15.2. Space-related patents by main domains

% of patents, by patent offices and priority date, 2000-05 and 2006-11

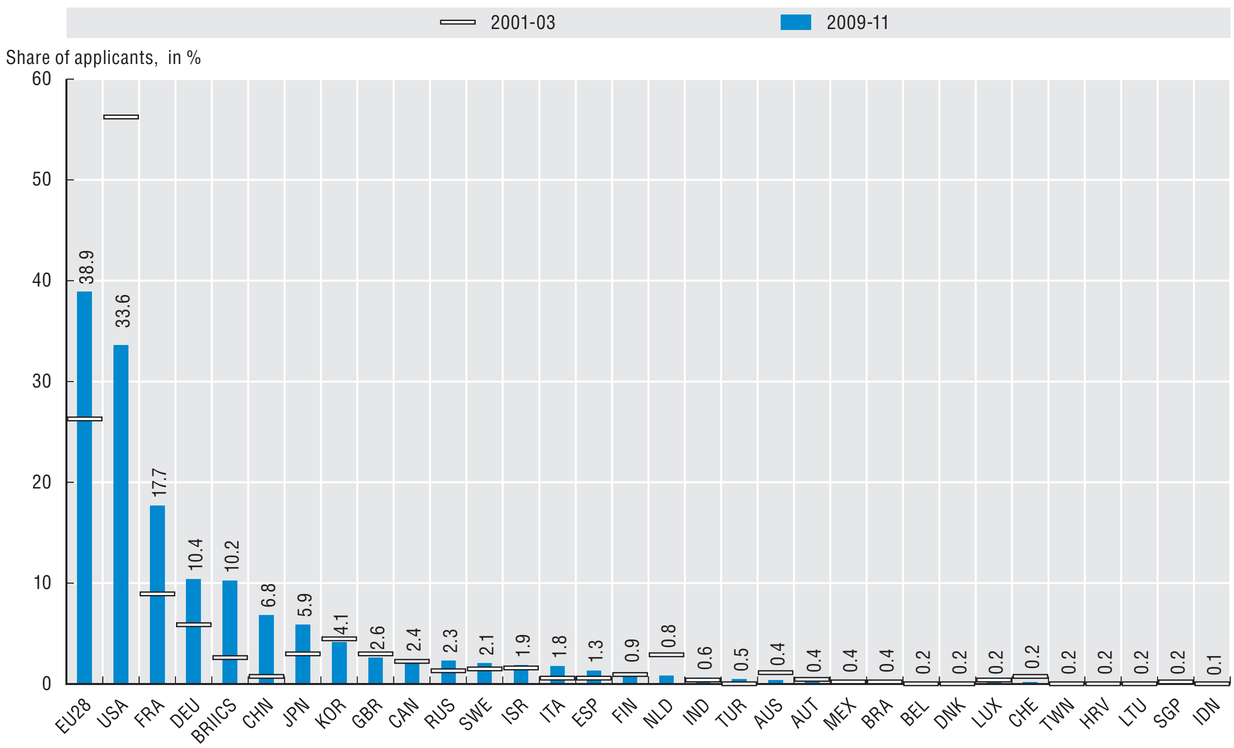


Source: OECD patent databases and calculations, 2014.

StatLink http://dx.doi.org/10.1787/888933141912

15.3. Patent applications for space-related technologies per economy

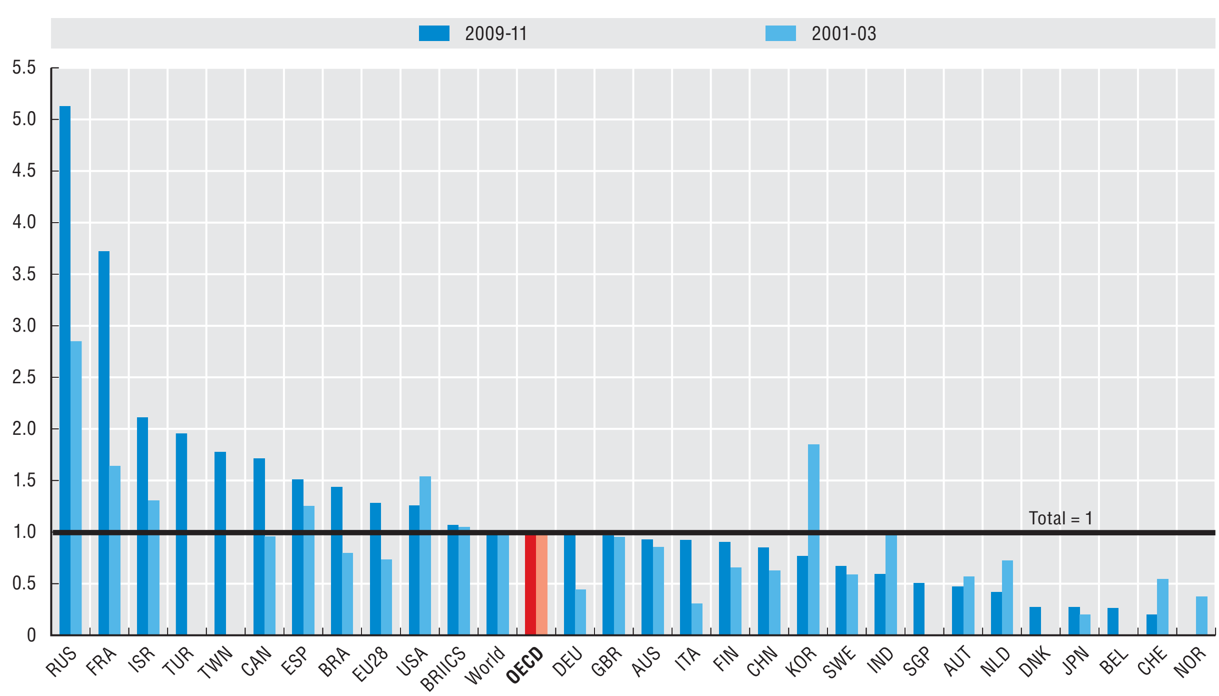
Patent applications filed under the PCT, by priority date and inventor's residence, using fractional counts



StatLink http://dx.doi.org/10.1787/888933141931

15.4. Revealed technology advantage in space related technologies

Patent applications filed under the PCT, by priority date and inventor's residence

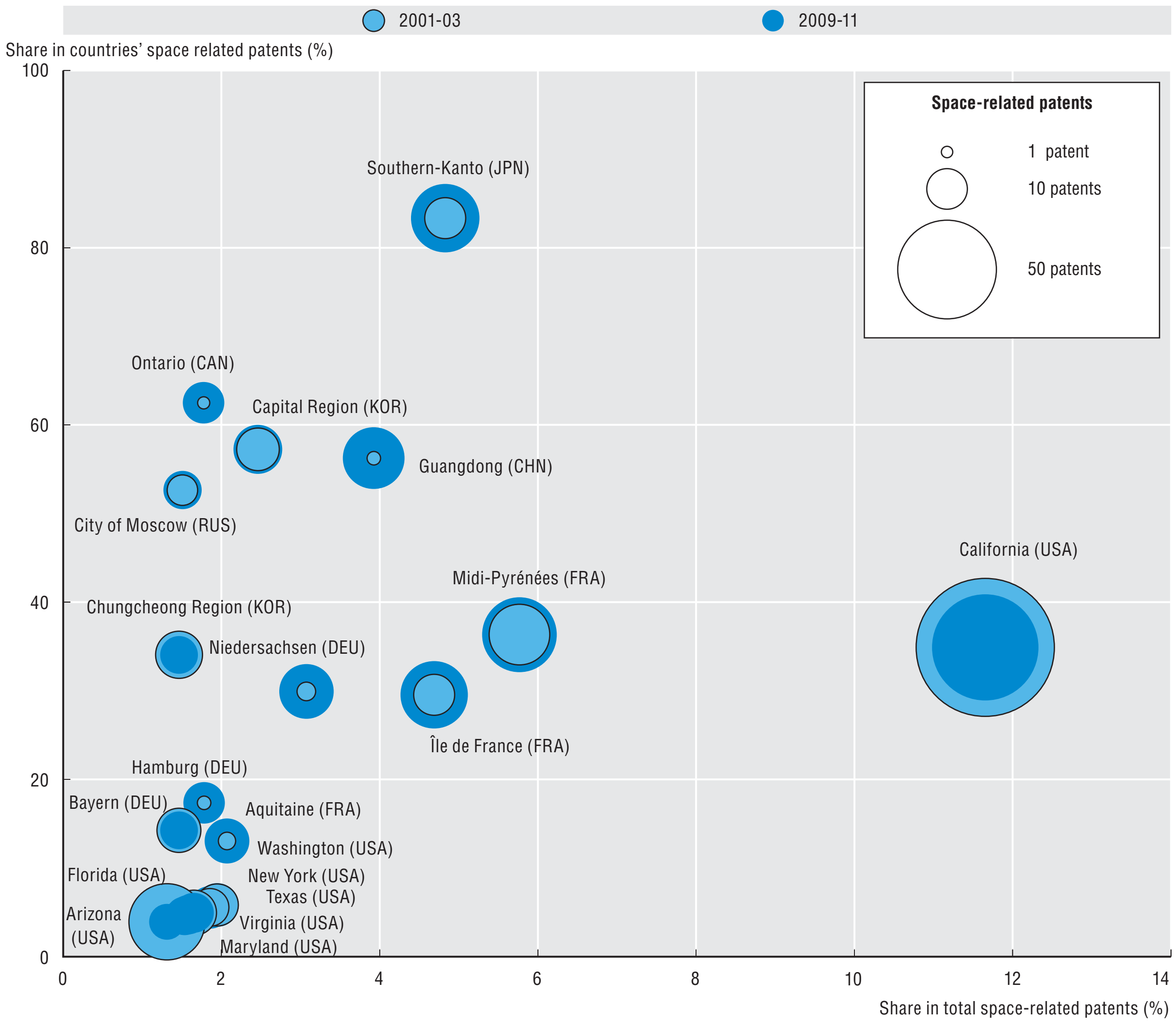


Source: OECD Patent Database and calculations, 2014.

StatLink http://dx.doi.org/10.1787/888933141950

15.5. Top 20 regions in space-related patents

Patent applications filed under the Patent Cooperation Treaty by inventor's region and priority date, 2001-03 and 2009-11



Source: OECD Patent Databases (REGPAT), June 2014.

StatLink http://dx.doi.org/10.1787/888933141969

16. Scientific production in the space sector

Scientific papers on satellite technologies have been published in specialised journals since the late 1950s, but they remained the remit of just a few experts for almost 30 years. After a first rise in the number of publications in the early 1980s, production stagnated until the end of the cold war. Since 1991, the multiplication of specialised journals and international conferences has strongly impacted the diffusion of publications on satellite technologies, growing from 2 000 to more than 6 000 in 2003, and reaching almost 16 000 papers in 2013 alone. This trend parallels the growing number of countries involved in space programmes, especially from the BRIICS.

In terms of subject areas, not surprisingly earth and planetary sciences, engineering, computer sciences, physics and astronomy are the leading topics. The growing role of satellite observations in natural resources management and climate monitoring are key drivers for some of the recent papers using satellite data. In 2013, 73.5% of the considered publications are articles in scientific journals and 26.5% are conference papers. When looking at the scientific production in satellite technologies' papers in 2003 and 2013, the United States leads with 28.2% of the total production of scientific articles in 2013. However a number of countries have seen their respective shares grow over the ten-year period, particularly Brazil, China, and India.

Authors from the top 40 institutions which published the most papers in scientific journals or conference proceedings on satellite technologies in 2008-13 are located in the United States, China, and Europe. Out of the original 160 major institutions selected (universities, research laboratories…), the NASA Goddard Centre leads the number of publications, followed by the Joint Propulsion Laboratory (JPL)/California Institute of Technology. The Chinese Academy of Sciences has leaped into the top three institutions over the period. Several Chinese universities that were not included in the top 160 institutions in 1999 have now entered the top 15 (e.g. Graduate University of the Academy of Sciences, the Wuhan and Beihang Universities), replacing other institutions from North America, Europe and the Russian Federation.

Methodological notes

Indicators based on bibliometrics (i.e. scientific publications) provide valuable information on knowledge production and diffusion in specific fields, including space technologies. Estimates of scientific production are based on whole counts of documents (papers in scientific journals and conference papers) by authors affiliated to institutions. Although some elements of space technologies and their applications still remain confidential (especially in the case of defence programmes), peer-reviewed scientific publications convey the research findings of scientists worldwide and give a good indication of the knowledge production in the field and its growing internationalisation. The data include scientific publications in English (the majority) as well as other languages. A slight decrease in the total of publications reported in 2013 may be caused by technical delays in refreshing databases.

Sources

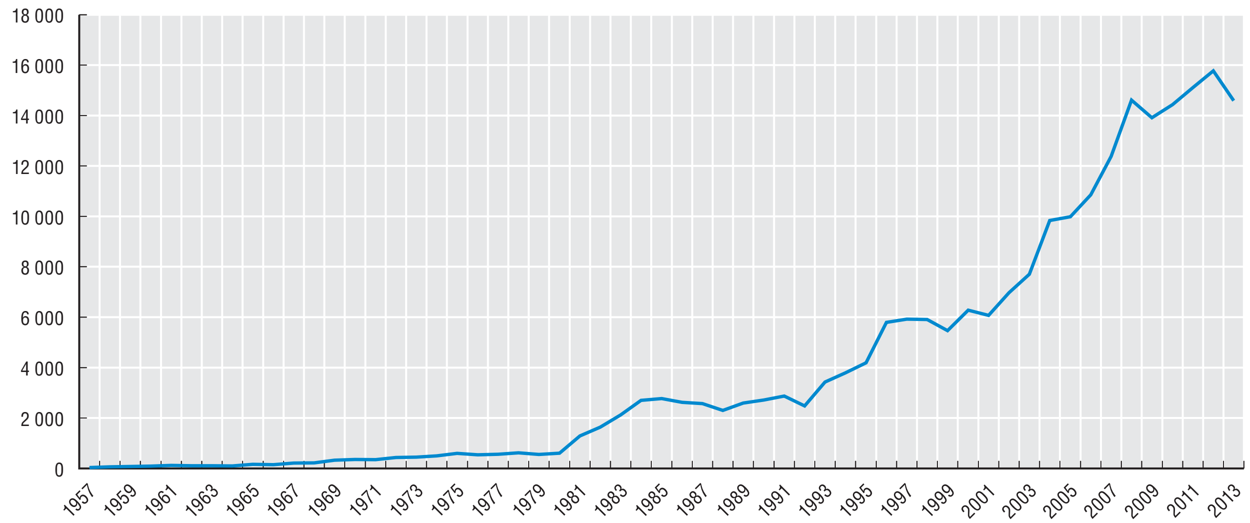
OECD calculations based on SciVerse® Scopus®, Elsevier B.V., accessed April 2014.

Note

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

16.1. Scientific production in satellite technologies since 1957

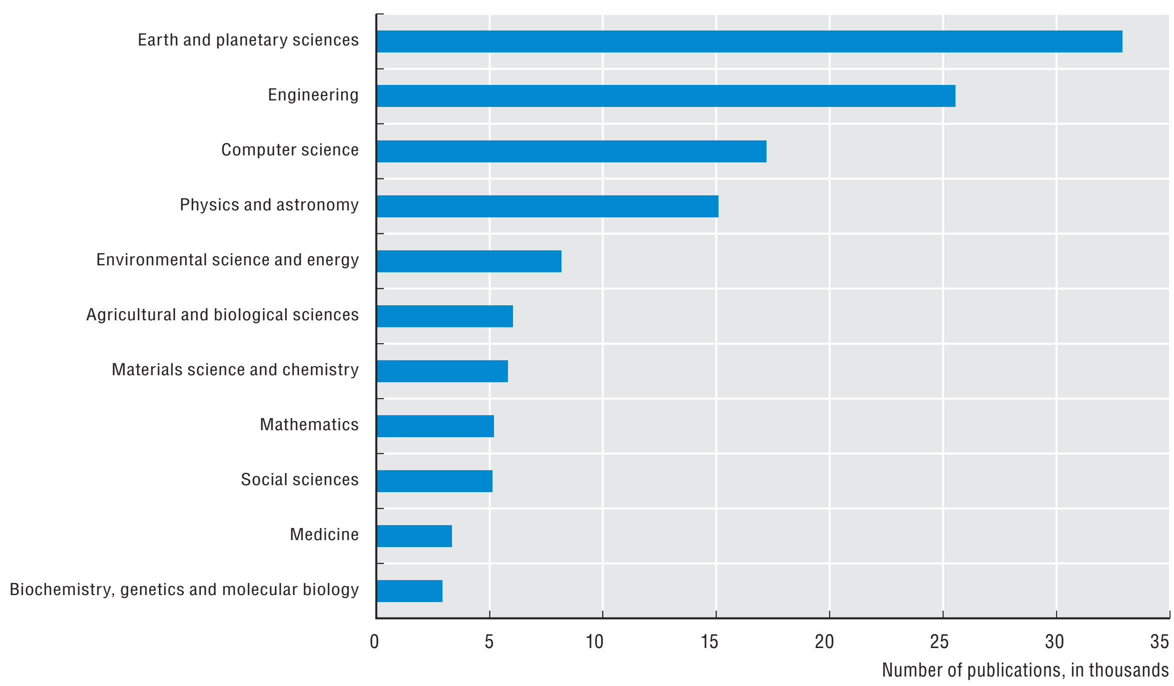
Number of publications



Source: OECD calculations based on SciVerse® Scopus®, Elsevier B.V., accessed April 2014.

16.2. Scientific production in satellite technologies by subject area

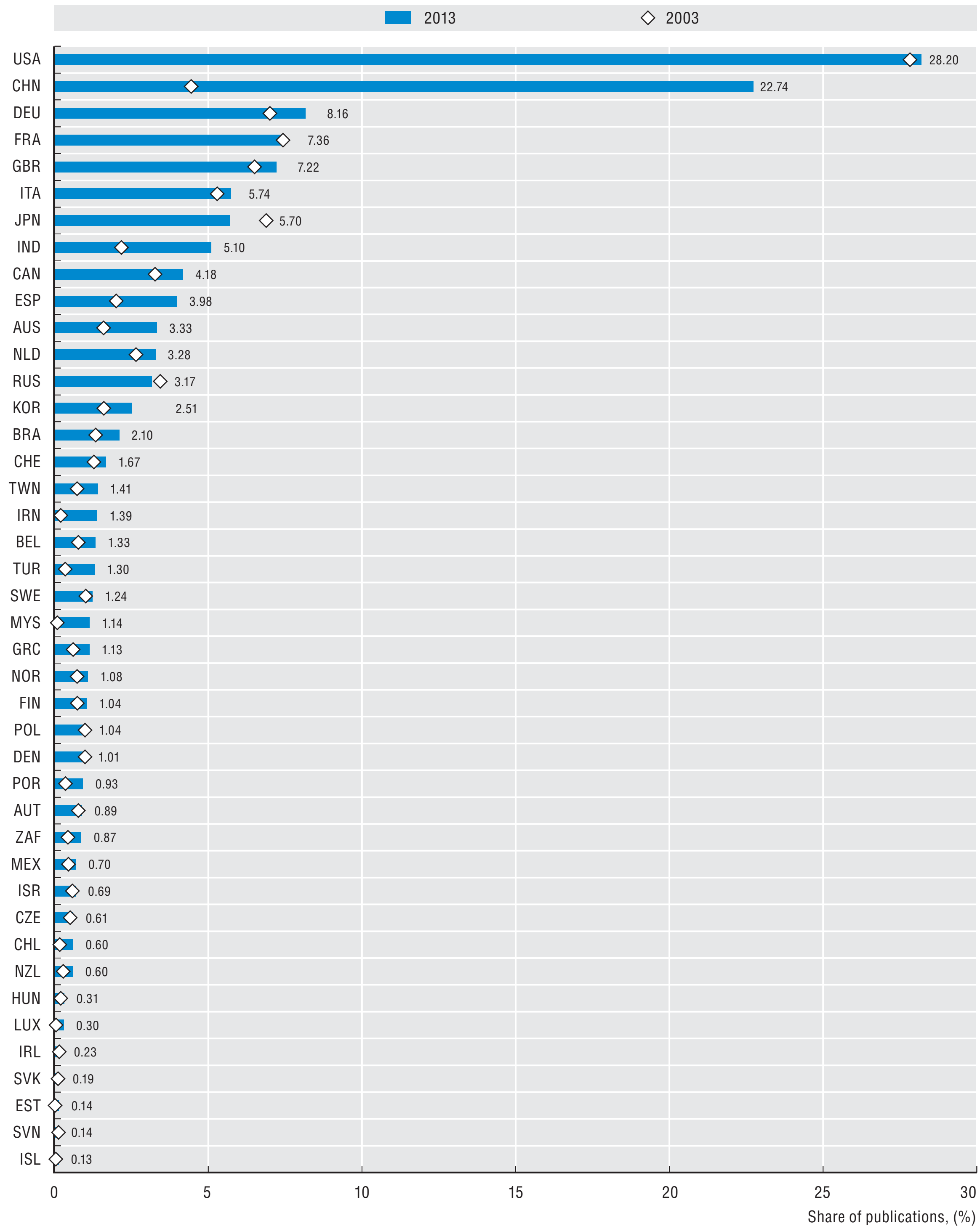
Number of publications, 2008-13



Source: OECD calculations based on SciVerse® Scopus®, Elsevier B.V., accessed April 2014.

16.3. Scientific production in satellite technologies per country

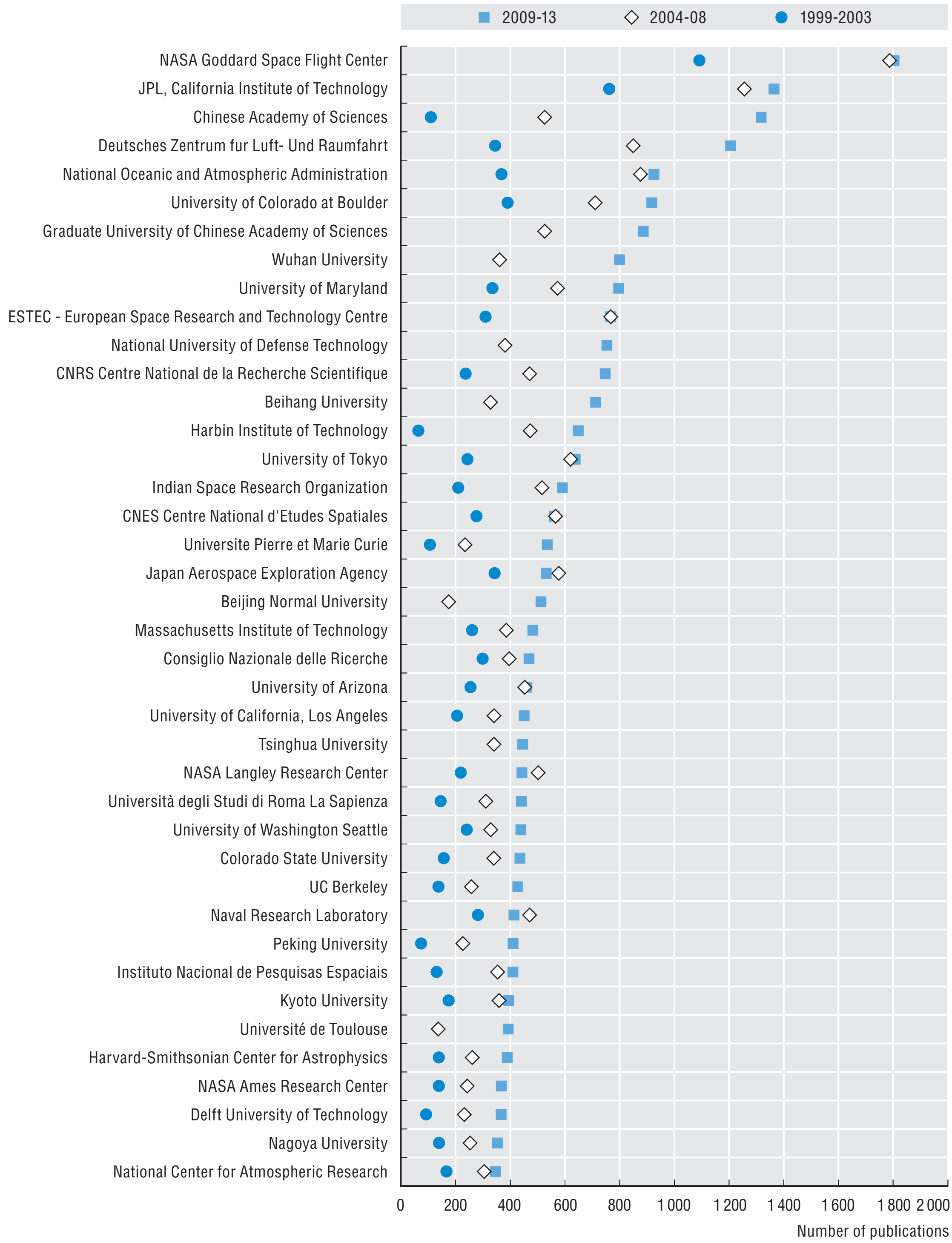
Share of publications per country, 2003 and 2013



Source: OECD calculations based on SciVerse® Scopus®, Elsevier B.V., accessed April 2014.

16.4. Scientific production in satellite technologies by top forty institutions

Peer-reviewed scientific publications over three five-year period, 1999-2002, 2003-08 and 2009-13



Source: OECD calculations based on SciVerse® Scopus®, Elsevier B.V., accessed April 2014.

17. Insurance market for space activities

Although launching satellites appears to be a routine operation to the general public, there are still major risks involved. A branch of the insurance sector specifically covers the commercial space sector's operations. The main risks covered still tend to be a failure at launch or mechanical troubles for large commercial telecommunications satellites. In addition to launch and deployment failure, space debris and solar storms pose collision and damage risks for satellites. The insured values usually cover the satellite's replacement costs and/or the resulting business interruption.

In late 2013, there were around 205 insured satellites in orbit, of which 185 were in geo-synchronous orbit (GSO). The total insured value represented about USD 24 billion (XL, 2013). Every year, there are on average 70-80 launches worldwide, of which 30-40 are insured, carrying 20-25 GSO satellites and 15-30 low-earth orbit satellites. Average insured value for a satellite in low-earth orbit is approximately USD 40 million with an operational lifespan of five years, while the more costly GSO satellites (USD100-400 million insured value) have an operational life span of about 15 years (Allianz, 2012). A dual launch may be insured for up to USD 750 million. Annual premiums average between USD 750 million and USD 1 billion (XL, 2013). The number of satellite failures in a given year has dropped in the last decades, but the average claim per loss has gone up from USD 38 million in the mid-1990s to USD 116 million in 2013, due to the increased size and complexity of telecommunications satellites. For instance, 2013 may be the first money-losing year for the insurance industry since 2007, with reported premiums of USD 775 million and possibly more than USD 800 million in claims.

Commercial suborbital flights and space tourism are not covered by any existing insurance regime. The few paying space tourists to the International Space Station have so far taken out personal accident insurance. As suborbital vehicles transporting paying customers on the edge of space (not entering into a full orbit) are to start operations in 2014-15, insurance issues will need to be addressed.

Sources

International Organization for Standardization (2014), ISO standard 16126:2014: Space systems – Assessment of survivability of unmanned spacecraft against space debris and meteoroid impacts to ensure successful post-mission disposal, ISO/TC 20/SC 14, March, *www.iso.org*.

XL Group space insurance (2014), *www.xlgroup.com*.

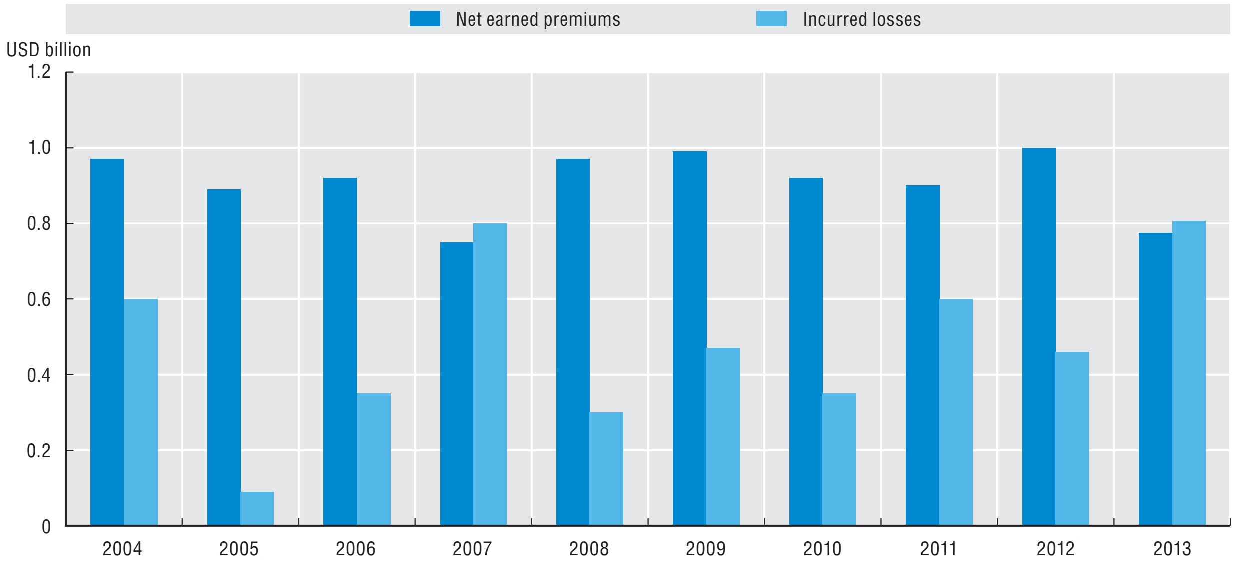
Space debris: a growing problem for the long-term sustainability of satellite operations

The number of space debris in the most used orbits around the Earth is still growing. Several commercial satellite operators and the International Space Station partners have had to repeatedly use space debris avoidance maneuvers over the past couple of years (e.g. four maneuvers for the International Space Station alone in 2012). The annual rate of new tracked debris began to decrease in the 1990s, largely because of national debris mitigation efforts, but accelerated in recent years as a result of collision due to the Chinese destruction of one of its satellites in 2007, and the 2009 impact of an active U.S. Iridium satellite and a defunct Russian Cosmos satellite.

Experts estimate that there are over 300 000 objects with a diameter larger than one centimetre and several million that are smaller. The U.S. Department of Defense's Space Surveillance Network currently tracks some 23 000 pieces of debris approximately 10 centimeter in diameter or larger, with a detailed catalog of more than 16 000 objects. The Inter-Agency Space Debris Co-ordination Committee (IADC) includes twelve major space agencies. They developed in 2007 joint "Space Debris Mitigation Guidelines", which were later endorsed by a United Nations' General Assembly resolution. This was followed in 2010 by the ISO standard 24113, which became the top-level standard in a series of standards addressing space debris mitigation. A series of lower level implementation standards provide methods and processes to industry and governmental actors to enable compliance with these requirements (ISO, 2014). A number of recent satellite failures in orbit (e.g. Envisat, Briz-M) have demonstrated the complexity of securing orbits and the need for more international co-operation to find solutions to mitigate and free up orbits of some space debris if possible, for the long-term sustainability of key orbits.

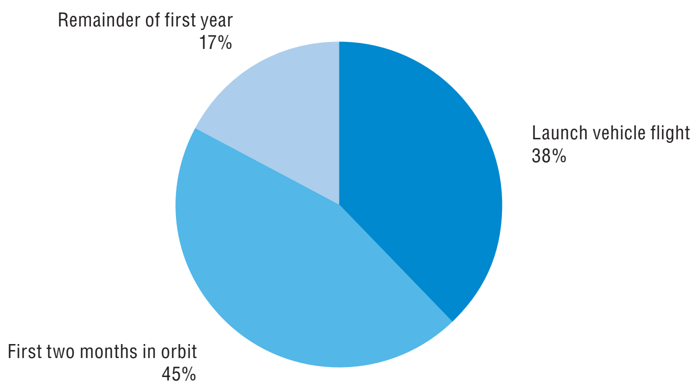
17.1. Space insurance annual premiums and claims

USD billion, 2002-13



Source: Adapted from XL Insurance, 2013.

17.2. Insured losses by phase of mission



Source: Adapted from XL Insurance, 2013.


I 78 EB/Hwy
150
yards
7.0
0:21
11:13
11:34
0
IDAHO
Boise
Salt Lake City
UTAH
N.J.
N.Y.
FORT WASH. PK.

III. IMPACTS: BRINGING SPACE DOWN TO EARTH

18. Evaluation of national space investments

19. Early warning of risks and hazards

20. Improved land and sea monitoring

21. The space industry's R&D intensity

22. The spin-offs from space investments

Part III illustrates various types of socio-economic impacts derived from the development of space activities. The main message is that many space-based services have positive impacts on society, but issues concerning economic data definitions and methodologies have to be resolved to allow the benefits to be identified and quantified more precisely.

18. Evaluation of national space investments

As institutional funding still supports the bulk of the space R&D taking place in space agencies, industry, academia and research institutes, there is a growing demand worldwide for impact assessments to evaluate any derived economic and social benefits, despite the relatively large up-front and sustained investments needed to engage durably in space activities.

While these will depend on stakeholder policy objectives (autonomous surveillance/intelligence capabilities; improving R&D and scientific capacities; new markets for a national industry, etc.), impact assessments can be conducted as part of a national administration evaluation portfolio to justify public and private spending. This is especially important in light of the fact that the internationalisation of funding mechanisms of selected space programmes and expected spill-overs in national industries tend not to be well traced. Indeed, methodological constraints and the lack of verified up-to-date data will tend to limit such assessments today.

Few countries have developed regular assessment schemes to follow up on investments in space programmes, and often only ad-hoc studies are launched to track potential returns as one-off exercises. Examining its industry every year since the 1990s, Norway has detected a positive spin-off factor derived from its space investments: for each million Norwegian kroner (NOK) of funding through the national or ESA programmes, the Norwegian space sector companies have on average attained additional turnover via new market developments worth NOK 4.7 million in 2013. Denmark found the same type of effect in its industry, with a positive 3.7 spin-off factor, whereas each million euros of Danish contributions to ESA have generated a turnover of EUR 3.7 million. Table 18.3 provides some illustrations for selected countries.

Methodological notes

Economic impact assessments need to be considered with caution, as one-off results may vary over time, scope and type of industry, and levels of institutional support. When looking at the many impacts studies conducted over the years on the use of space applications by governmental agencies, consultancies and academia, five broad lessons have been learned: 1) ad-hoc studies provide snapshots at a given date, but are often quite too limited for policy making; 2) "earlier is better" when launching a new evaluation exercise, helping to create a "history" of time series and case studies when examining specific investments; 3) an open tender process for assessments increases efficiency and potential access to other methodological angles (competition usually pays off); 4) studies are of higher quality when the technology and scientific impacts are examined in light of both economic and social impacts; 5) survey methods or peer reviews are often prerequisites to evaluations (e.g. conducting a detailed industry survey to assess the sector before trying to measure its impacts), to avoid too many assumptions from the start.

Sources

OECD (2012), *OECD Handbook on Measuring the Space Economy*, OECD Publishing. *dx.doi.org/10.1787/9789264169166-en*.

Note

18.3: The selected findings are only provided for illustration and not for direct comparison purposes, as very diverse methods have been used for each study.

18.1. Different levels of evaluation

Assessment levels	Usual types of evaluation
Mission/Project	● Peer review (scientific) ● Cost benefit analysis ● Assessment of outcomes, outputs and impacts
Selected programme	● Assessment of outcomes, outputs and impacts
Administration/Agency	● Assessment of outcomes, outputs and impacts
Entire space programme	● Assessment of outcomes, outputs and impacts

18.2. Typology of socio-economic impacts derived from institutional space investments

Possible impacts	Description
Commercial activities: new products and services	● Space industry: new line of commercial activities, new exports contracts (e.g. small satellites, equipment, components)§- Space economy: new mass market products and services using satellite capacities (e.g. actors using satellite positioning signals in car navigation products)§- Other economic sectors: new products based on transferred technologies (e.g. medical imagery)
Productivity/efficiency gains in diverse economic sectors	● Applicative sectors with documented cases: precision farming, fisheries, land transport…
Costs avoidances	● Public-good nature of many applications: e.g. costs avoided and lived saved thanks to flood forecasts

18.3. Selected national assessments of economic returns from space programmes

Country	Selected Findings*	Study Periodicity
Belgium	1 Euro : 1.4 Euros (2010)	Ad-hoc
Denmark	1 Euro : 3.7 up to 4.5 Euros (2008)	Ad-hoc
Ireland	1 Euro : 3.63 (2012)	Ad-hoc
Norway	1 Krone: 4.75 Kroner (2013)	Annual
Portugal	1 Euro : 2 Euros (2011)	Ad-hoc
United Kingdom	1 Pound : 1.91 Pound (2010)	Every two years

19. Early warning of risks and hazards

Efficiency and productivity gains derived from the use of space applications are becoming more visible across very diverse sectors of the economy, although experiences in estimating impacts vary across countries. From agriculture to energy, and routine surveillance, institutional actors and private companies are increasingly using satellite signals and imagery in geospatial tools. Satellites can also play a key role in providing communications infrastructure rapidly to areas lacking any ground infrastructure, contributing to link rural and isolated areas with urbanised centres.

Significant improvements have been achieved in weather forecasts over the past decade, due in part to a larger international fleet of improved meteorological satellites, bringing about substantial gains in the accuracy of forecasts of large-scale weather patterns in both hemispheres. This has directly benefited early warnings of major hydrometeorological hazards (such as cyclones, thunderstorms, heavy snowfall, floods and heat waves, to name but a few). Satellite data have also made it possible to better track extreme weather events, more cost-efficiently. The Emergency Events Database (EM-DAT) maintained by the World Health Organisation provides data on countries affected by cyclones that make landfall every year. On average, between 142 and 155 countries have been hit by tropical cyclones every year since 1970. When comparing events detected by satellites and the number of disasters reported annually (i.e. the reported cyclone disasters tripled between the 1970s and 2010), there is a clear trend showing that national reporting and access to information have greatly improved in a few decades, slowly catching up with the actual unbiased observations from satellites.

In the 2011 Japanese earthquake, it took only three minutes for Japan to launch a tsunami alert, which was then upgraded to a full Pacific alert. Space technology played an important role both to alert and monitor the water-covered areas, particularly as airplanes were not able to fly over some of the affected areas. It was estimated that 90% of the damages came from the tsunami, not the earthquake. The Japanese ALOS satellite took some 400 pictures of the area, and 5 000 pictures were taken from 27 satellites from 14 countries to share with Japan. For 2 months following the disaster, the only means to communicate in tsunami devastated areas was via satellite telecommunications. Two Japanese satellites and bandwidth on board other commercial satellites were used by Japanese ministries.

Methodological notes

The most common economic measurement for any technology's value is the calculation of benefits to costs. In theory, to calculate the ratio, it is necessary to divide the benefits (e.g. improved productivity, decreased cost of operations, increased revenue and better customer satisfaction rates when applicable) by the costs of deploying the system (e.g. hardware, software, maintenance, training and so forth). However space systems are by nature multifaceted and rely often on lengthy research and development. The challenge of putting a monetary value on the technologies and services they deliver remains a complex and often subjective exercise. Monetary or financial valuation methods fall into three basic types, each with its own repertoire of associated measurement issues and none of them entirely satisfactory on its own (i.e. direct and indirect market valuation, and survey-based valuation techniques). One option is to use several of these methods in parallel to test assumptions and the resulting impacts of a given space application. A forthcoming updated version of the *OECD Handbook on Measuring the Space Economy* (2012) aims to provide a source of comparative national experiences and lessons learned, when trying to apply the different methodologies to the study of impacts.

Sources

OECD (2012), *OECD Handbook on Measuring the Space Economy*, OECD Publishing. *dx.doi.org/10.1787/9789264169166-en*.

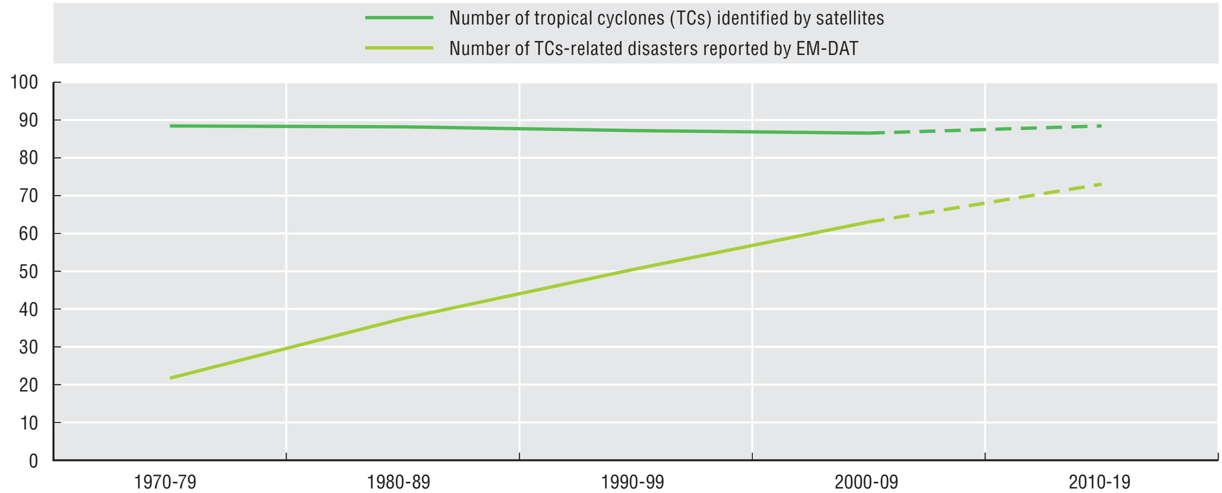
ITU (2012), Use and examples of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations, S.2151-1, *www.itu.int/pub/R-REP-S.2151-1-2012*.

World Health Organisation (2014), Emergency Events Database (EM-DAT), *www.emdat.be/*.

19.1. Selected economic impacts of space applications in different sectors

	Sectors	Documented impacts of selected satellite-related applications			Illustrations
		Weather	*Navigation*	*Telecom*	
Productivity/efficiency gains	Airlines industry	Yes	Yes	Yes	Efficiency gains in the air transport sector due to better weather forecasts
	Sea shipping transit-time	Yes	Yes	Yes	Efficiency gains, as a result of better weather forecasts, and navigation (GPS, satellite-based ice charts)
	Fishing industry	Yes	Yes	Yes	Efficiency gains and improved control of resources (illegal fishing), as a result of satellite navigation usage in ships and maritime zones surveillance with satellite observations
	Energy sector	Yes	TBD	Yes	Annual gains in the energy sector , as a result of better forecasting demand for electricity (improved weather forecasts and real-time information)
Cost Avoidances	Oil pollution detection	Yes	Yes	Yes	Cost avoidances/savings in terms of detecting and managing oil incidents
	Flood prevention and management	Yes	Yes	Yes	Cost avoidances/savings in terms of anticipating and managing flood events

19.2. Trend of tropical cyclones reported versus tropical cyclones detected by satellite



Source: Adapted from data from the World Health Organisation Emergency Events Database (EM-DAT).

20. Improved land and sea monitoring

The ubiquitous surveillance capability of satellites is currently applied to monitor food production, international borders and transportation hubs by many countries. These monitoring systems, based on imagery and real-time tracking, combined with other surveillance mechanisms, contribute to detecting and tracking the cascading effects of illegal practices or accidents (e.g. tracking illegal fishing operations; spread of piracy; sea pollution and accidents impacting populated coastal areas (fisheries, tourism and ecosystems). In terms of cost efficiencies, the value of monitoring sea routes has been studied over the years and the benefits from satellite observations and navigation are deemed important. They include improved ship detection over large geographic zones, allowed by the integration of satellite imagery with other tools (e.g., aerial patrols) has brought out efficiencies in commercial shipping thanks to faster transit times (Canada, Norway), as well as a useful deterrent factor for illegal fishing (France) (Table 22.1).

This improved monitoring also applies to land planning and agriculture. In many countries there is a growing need for governments and farmers to better map their arable land. In India, the Ministry of Rural Development is leading the National Land Records Modernization Programme, which aims at awarding conclusive titles to owners for all land holdings in the country. Already relying on data from the dozen or so Indian remote sensing satellites providing high resolution data, the objective is to improve land-use planning nationally cost-efficiently, by focussing on priority areas for ground surveys using GPS receivers for ground-truthing. Launched in 2008, the modernisation and updates of land records is ongoing with the Haryana Space Applications Centre (HARSAC) (2014). In Europe, the Common Agriculture Policy provides direct aid to eight million farmers, with amounts distributed per declared square meter of land. To improve cost-efficiencies, European Commission inspectors are using commercial precision farming products, GPS and remote sensing data, to check whether the area declared by farmers is eligible (see Figure 21.1). In 2010, the programme allowed the control of 410 000 European farmers for their area-aid applications, representing approximately 70% of the required controls for the entire European Union. Overall in the framework of the Common Agricultural Policy, around 1 000 satellite images are acquired per year, with more than 80% of these in high resolution (e.g. SPOT, IRS, Rapid Eye, etc.) the rest composed mainly of very-high resolution data (e.g. Worldview, GeoEye, Ikonos, Quickbird, etc.) (Joint Research Centre, 2012).

Methodological notes

See previous methodological notes.

Sources

Haryana Space Applications Centre (HARSAC) (2014), National Land Records Modernization Programme (NLRMP) Project, *www.harsac.org*.

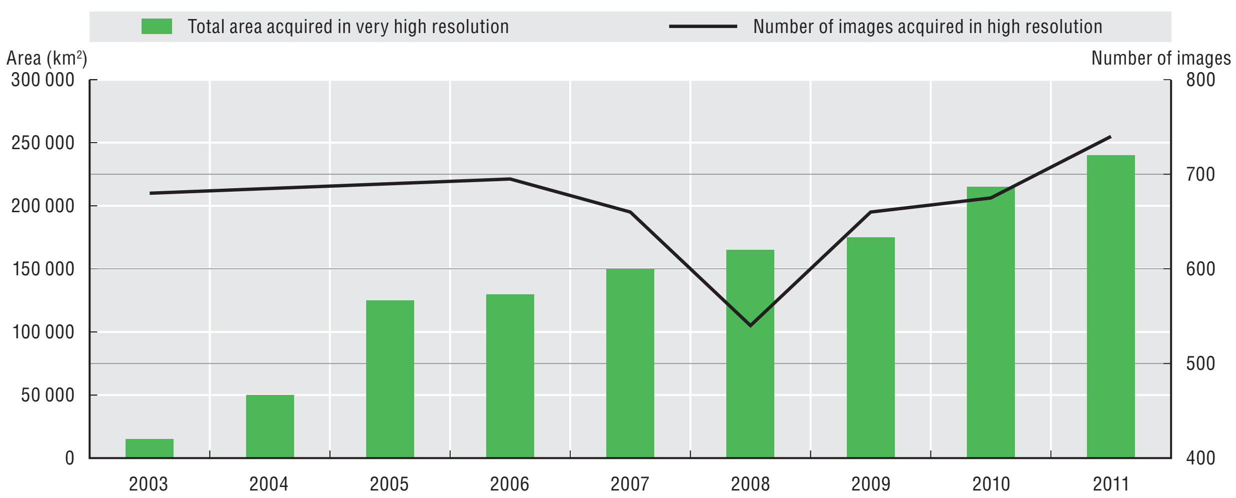
Joint Research Centre (2012), *Earth observation data supporting the CAP implementation*, European Commission, Joint Research Centre, Ispra, italy, *ies.jrc.ec.europa.eu/our-activities/support-for-eu-policies/control-with-remote-sensing.html*.

Norwegian Space Centre (2014), Norway's Satellites: AIS-Sat-1, *web.spacecentre.no/eng/Norway-in-Space/Norway-s-Satellites*.

20.1. Value of monitoring sea routes with satellites

Norway	*From quasi-blindness to full surveillance operational capacity:* Norway launched in 2010 a small satellite AISSa for a few million Krones to monitor shipping in its territorial waters, tracking vessels over 300 gross tonnes by picking up the signals from their AIS (Automatic Identification System) transponders. The data have become essential tools for the Norwegian Coastal Administration and other governmental institutions (monitoring fisheries, oil spills, and maritime traffic), with the particular case of Svalbard where authorities suddenly were able to move from no coverage to a global coverage of all islands.
France	*From limited surveillance to deterrence:* France has set up a ground receiving station on the Kerguelen (South Indian Ocean) to monitor its Exclusive Economic Zone since early 2004. All Envisat and Radarsat-1 satellite overpasses over the area were acquired, processed, correlated with the French fishing Vessel Monitoring System (i.e. authorised fishing ships in the area are required to carry a detector onboard), and followed up by ship patrol, to protect the local stocks from illegal fishing. Since then, it has been estimated that the surveillance system has cut the number of illegal fishing incursions in the vicinity of Kerguelen Island by nine-tenths and no illegal incursion was detected since 2007.
Canada	*From surveillance to commercial cost-savings:* The Canadian Ice Services (CIS) using RADARSAT-1 data: as a result of observations over a wider geographical area in much less time than with an aircraft, CIS has been able to improve its operational efficiency over five years (1995 to 2000), the net average annual savings to CIS operations have been about CAN 7.7 million per year (CAN 38.5 million over the period). The Canadian Coast Guard (CCG), the largest direct customer of CIS products, has felt these benefits most significantly, as it can provide improved routing information to commercial shipping, which allows for faster transit times. Savings in transit time through ice-infested waters are estimated to be CAN 18 million a year. Other benefits included less damage to ships and a reduction in the need for CCG escorts. The CCG has estimated dollar savings in both operating costs and transit time for those escorts to be between CAN 3.6 million and CAN 7 million a year, depending on the severity of ice conditions.

20.2. Evolution of the European Control with Remote Sensing programme through the years



Source: Adapted Joint Research Centre (2012).

21. The space industry's R&D intensity

The research and technology (R&D) intensity of higher-technology industries remains strong in developed economies, and the space sector is a good example. R&D intensity is a key indicator for the assessment of innovative activity at the firm and industry level. Although many OECD economies have seen in the past decade the number of enterprises and total employment falling in manufacturing, higher technology sub-sectors have fared relatively well so far. High technology-intensive sectors, like the space sector, tend to benefit from a stock of long-term past R&D investments, not easily and rapidly delocalised. The challenge for these sectors is to constantly prepare the future with new R&D investments.

The space sector has been a leading-edge high technology industry for decades, diffusing innovative applications in different economic sectors (e.g. location-based technologies in cars and smartphones), despite not being a major source of patenting as compared to other sectors. The space industry also increasingly benefits from the effect of spin-in from other domains, as different types of innovation find their way to the space sector (i.e. computing advances and electronics miniaturisation infusing new ideas in space manufacturing).

In this context, the space sector remains a R&D intensive leading-edge sector and a source of innovation, as demonstrated by two recent case studies conducted independently in Canada and Italy, using survey results for the space industry data. In Canada, space manufacturing is close to six times more R&D intensive than total manufacturing in 2012. It also outperforms key sectors such as pharmaceuticals and motor vehicles and parts (space is also included in the aerospace category). In Italy, the same type of case study was conducted on R&D intensity. In 2012 the space sector was found to be more R&D-intensive than the broader aerospace segment, and eight times more than total manufacturing in Italy.

Methodological notes

The *Frascati Manual* provides statistical guidelines used by OECD economies and many partner economies to measure and report R&D efforts. R&D intensity for an industry is defined as the R&D expenditure as a percentage of gross domestic product (GDP). By examining the relative importance of their R&D intensity, industries and firms in the same industry can be compared nationally. The two case studies presented here use data based on international industry classifications and micro-data collected via space industry surveys. For the patents, the data refer to counts of patent applications filed under the Patent Cooperation Treaty (PCT), by priority date. Patents in biotechnologies and nanotechnologies are based on a selection of International Patent Classification (IPC) classes, for space-related patents, specific keywords were used in addition. Patents in environment-related technologies are defined using combinations of IPC classes and codes Y02 of the European Classification (ECLA).

Sources

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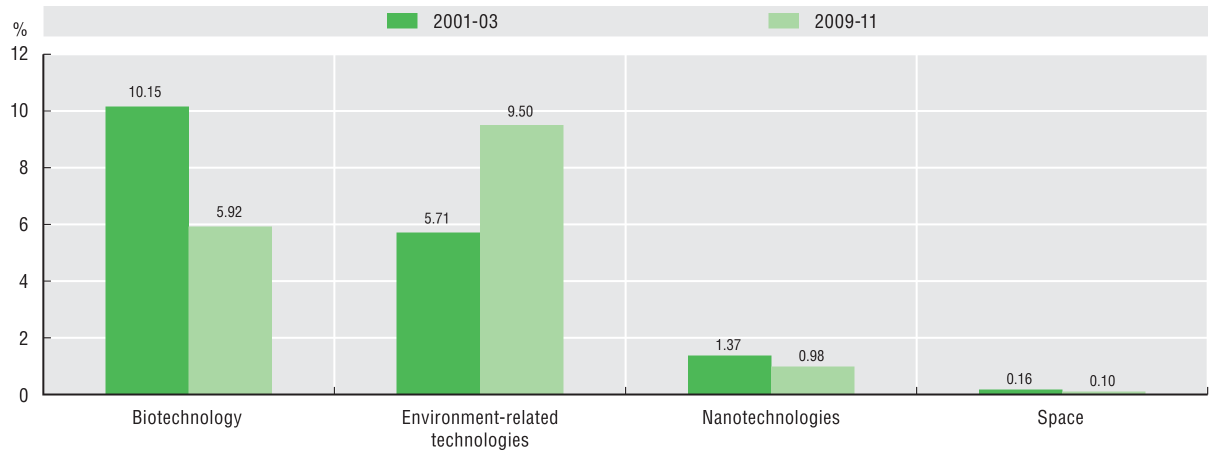
University of Bergamo and Italian Space Agency (2014), Measuring the Importance of the technological spillovers from high tech sector, with particular attention to the Italian space industry, Work presented at the OECD Space Forum Workshop on impacts of national space investments, OECD, Paris, June.

Note

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

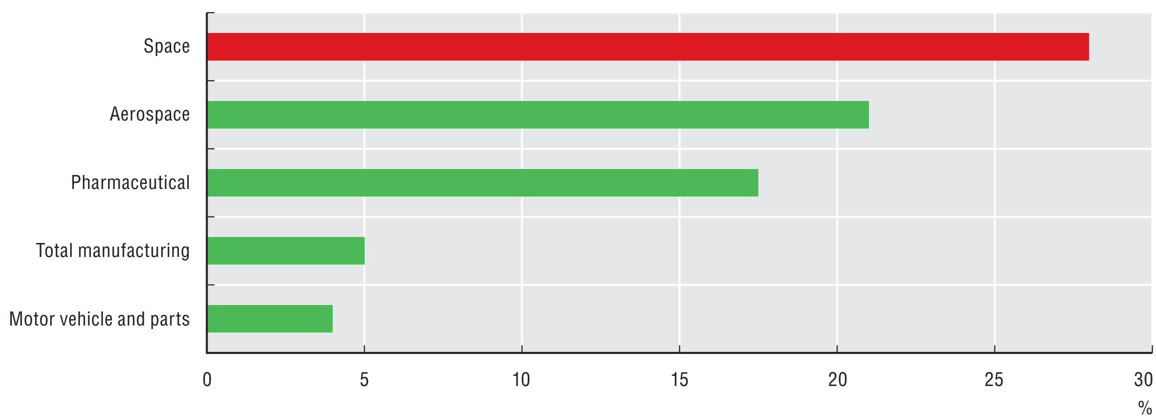
21.1. Patents by technology fields

Share of total patents (%), 2001-03 and 2009-11



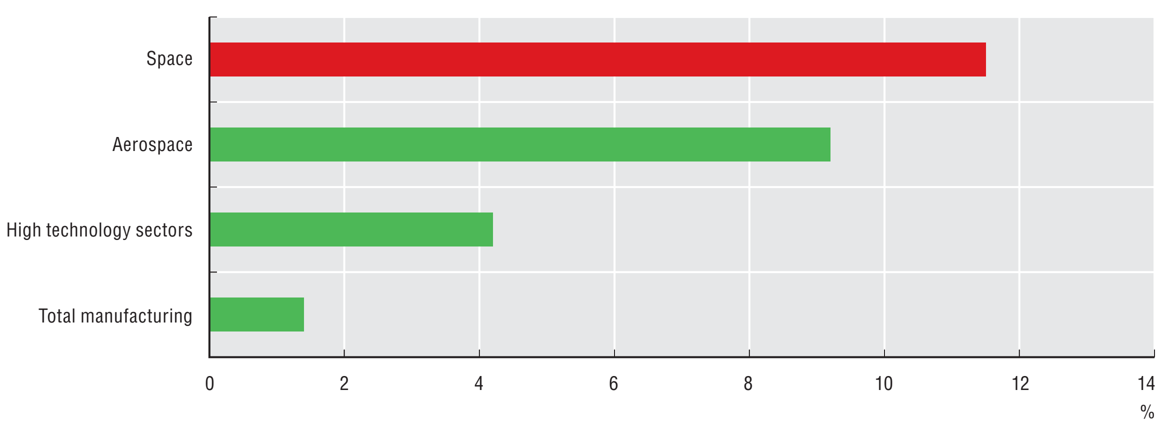
Source: OECD, *Patent Database*, June 2014.

21.2. Canadian space manufacturing R&D intensity, 2012



Source: Industry Canada, 2014.

21.3. Italian space manufacturing R&D intensity, 2012



Source: University of Bergamo and Italian Space Agency, 2014.

22. The spin-offs from space investments

Technologies are usually developed to respond to specific needs, but once they are created, they may have multiple uses. Over the years, space agencies have been facilitating the exploitation of space technologies to non-space applications.

As of 2012, based on its database, NASA has documented nearly 1 800 spin-off technologies to sectors as varied as health and medicine, transportation, manufacturing practices and materials, or computer technologies (NASA, 2014). In Europe, documented applications of space technology transfers to these sectors include for instance air purification systems in hospital intensive care wards, radar surveying of tunnel rock to improve the safety of miners, and enhanced materials for a wide variety of sporting products from racing yachts to running shoes (ESA, 2014). In France, ultrasound probes were tested by universities during the first French human spaceflights in the early 1980s. Based on these, innovative echocardiography probes were developed and commercialised by a still very active spin-off firm, with cumulated sales representing around EUR 200 million since 1984 (CNES, 2014). In the United States, a cardiac imaging system was developed commercially by the medical industry in 1990, derived from camera technologies onboard NASA earth resources survey satellites. The benefit was at the time a significantly improved real-time medical imaging, with the ability to employ image enhancement techniques to bring out added details while using a cordless control unit (NASA spin-off reference JPL-SO-68). It remains that for some technologies, the target market is so specialised or the product is so advanced that it takes a long time to be commercialised (NASA, 2014). For example, rotating cellular bioreactors have taken nearly twenty years to reach commercial maturity, as their application in cellular-level biological research is more advanced than current state-of-the-art technology. Some medical technologies also require regulatory certification or clearance nationally and in different countries before they are used publicly, thus taking even longer to reach market. At the other end of the spectrum, some technologies have been rapidly commercialized. One US company, for example, licensed in a few months an electrolyte-based rehydration beverage developed at the NASA Ames Research Center (NASA, 2014).

Methodological notes

Definitions differ when examining "spin-offs" and technology transfers of space technologies. For NASA, a spin-off is a technology, originally developed to meet NASA mission needs that has been transferred to other uses and now provides benefits as a commercial product or service. These spin-offs are transferred to the public through various NASA partnerships including licensing, funding agreements, assistance from NASA experts, the use of NASA facilities, and other collaborations between the Agency, private industry, other government agencies, and academia. Rather than using the word spin-off, ESA and other national agencies in Europe (e.g. CNES, DLR) use the expression "technology transfer" to share the benefits of European research and development, making space sector technologies available to the larger industry. In ESA, the Agency's Technology Transfer Programme Office identifies industrial needs then maps them to suitable space technologies, as a way of enabling new applications and business opportunities.

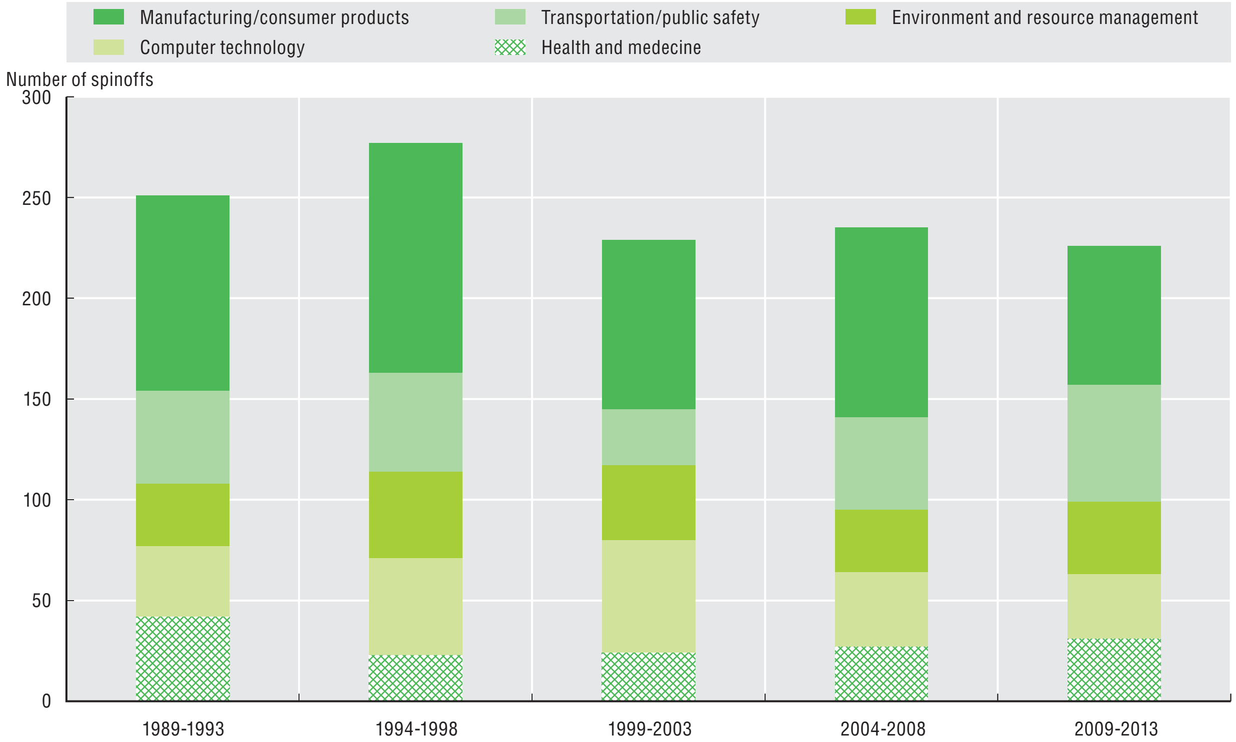
Sources

CNES (2013),"Transfert technologique de l'innovation technologique au marché", *CNES Mag,* December. *www.cnes.fr*.

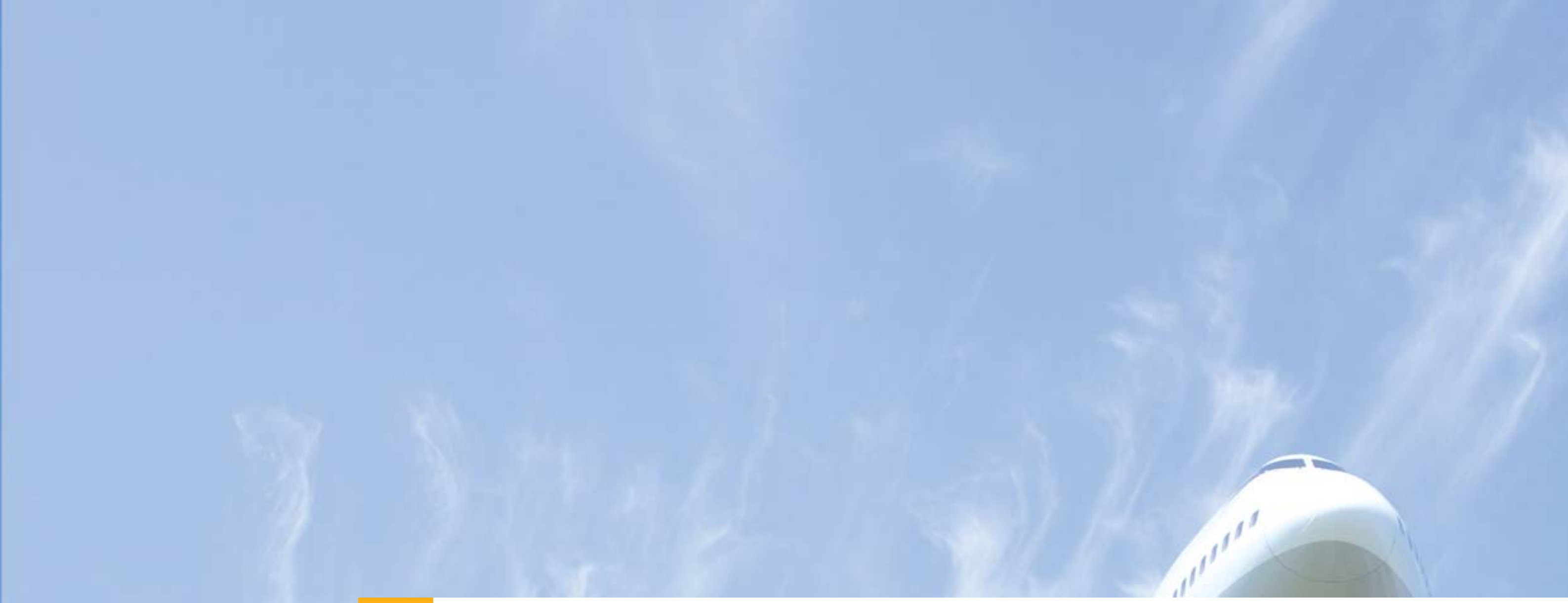
ESA (2014), ESA Technology Transfer Programme, *www.esa.int/Our_Activities/Technology/TTP2*.

NASA (2014), Office of the Chief Technologist, NASA Spinoffs, *www.spinoff.nasa.gov*.

22.1. NASA spin-offs in different economic sectors



Source: OECD calculations based on NASA spin-offs database (2014).



IV. THE GLOBAL AEROSPACE SECTOR IN PERSPECTIVE

23. The civil aerospace markets

24. Business enterprise R&D (BERD) in aerospace

25. Aerospace trade

Part IV provides an overview of the global aerospace sector, an important sector for an increasing number of OECD and non-OECD economies. The space sector evolved to a large extent from the aerospace and the defence sectors, and it still shares many aspects, components and technologies (e.g. space launchers are modified guided-missiles), although it often represents only a small segment of the activities of large aerospace and defence groups.

23. The civil aerospace markets

The aerospace sector is an important source of manufacturing employment in the OECD area. It is historically linked to defence programmes; and civil and military aerospace products and services are often provided by the same major industrial groups. The sector is expected to grow significantly in the next decade, as mobility in general and air traffic in particular is expected to increase, especially in emerging economies. There are several aerospace markets, which are often quite distinct from each other, although they all share the same basic need for sustained research and development. The space sector represents a rather small segment of the industry, as indicated by large aerospace industry associations. The data usually take into account space manufacturing activities, and overlook other space-related activities that are taking place outside the aerospace industry (e.g. commercial satellite telecommunications operators).

Zooming in the civil aeronautical market, the assembly of airplanes takes place all over the world. Many countries take part in the global aerospace value chain, hosting primes as well manufacturers of major components and equipment (e.g. propulsion, aerodynamics, mechanical structures, etc.). In addition, the maintenance, repair and overhaul activities (MRO) of airlines follow the air traffic, and concentrate in major hubs, increasingly located in Asia. Companies specialising in MRO are facing more competition from manufacturers who develop this service in their sales contracts. Airbus and Boeing compete on the market of civil aircraft over 100 seats, with a booming air traffic market, particularly driven by demand from companies in Asia and the Middle East and the renewal of major fleets around the world. In 2013, both manufacturers have achieved historical sales performance with a record 1 503 net orders for Airbus and 1 355 net orders for Boeing, with also record deliveries for the two (648 for Boeing; 626 for Airbus). Their order books are full, each with over 5 000 aircraft for delivery, ensuring almost eight years of production. Concerning the construction of regional aircraft (less than 100 seats) and business airplanes orders have also progressed worldwide. Selected key manufacturers include Bombardier (CAN), Gulfstream (USA), Dassault (FRA), Cessna (USA) and Embraer (BRA). In that segment, commercial airplane shipments increased by 4.3% to 2 256 airplane deliveries, with billings reaching USD 23.4 billion across all airplane types, the second-highest industry billing number ever recorded (GAMA, 2014). The business jets worldwide fleet has grown more than 60% since 2000, reaching 33 861 aircraft in 2013 with some 678 airplanes delivered in 2013, with North America representing 50% of the market. In terms of helicopters, the worldwide fleet counts around 28 877 aircraft (both turbine and piston). Finally, unmanned aircraft systems represent an emerging industry segment, transitioning from military applications into civilian and commercial uses although there are still some privacy and safety concerns.

Methodological notes

The aerospace and defence leading companies total sales include sales and profits. For airlines, only publically traded companies were included, and the Emirates Group's data were collected separately (annual reports).

Sources

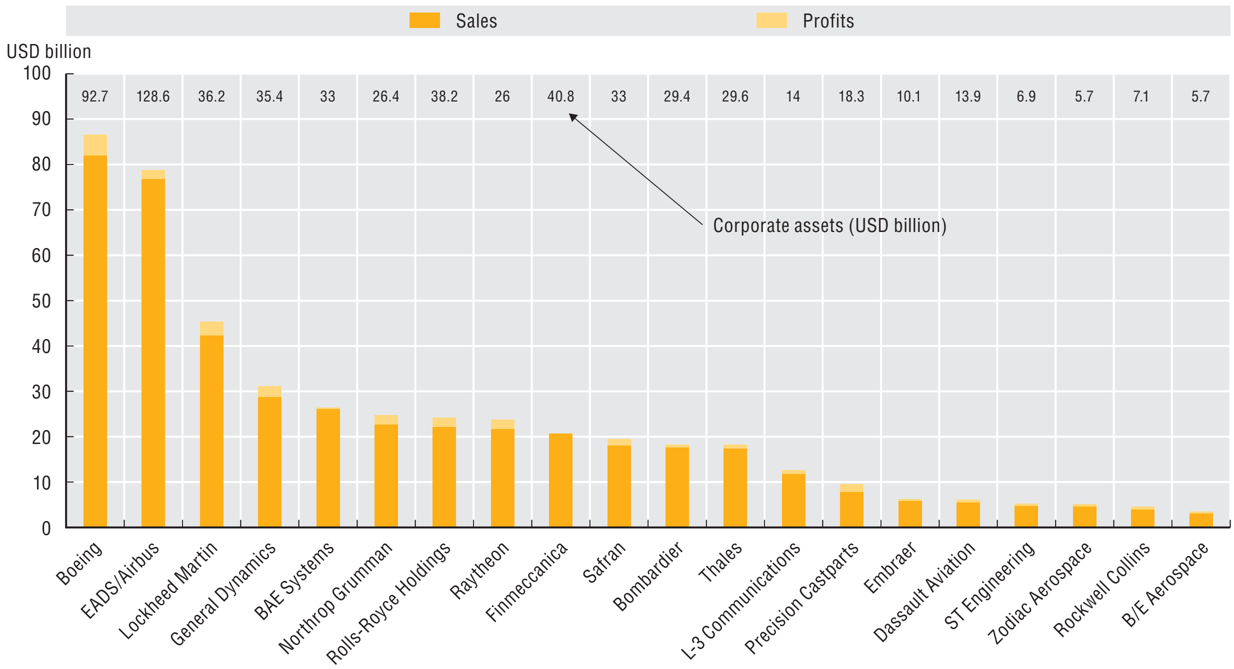
Schofield, Adrian (2014), "Rise of the Giants", *Aviation Week and Space Technology*, May, *www.aviationweek.com*.

Forbes, *Top Companies 2000 2014*, accessed 20 June, *www.forbes.com/global2000/list*.

General Aviation Manufacturers Association (GAMA) (2014), *2013 General Aviation Statistical Databook and 2014 Industry Outlook*, accessed 15 June, *www.gama.aero*.

23.1. Aerospace and defence leading companies

Ranked by sales in USD Billion, 2013



Source: Adapted from Forbes, 2014.

23.2. Leading airlines by revenues

In billion USD, 2013

Company	Revenue in USD billion
Deutsche Lufthansa	39.9
United Continental Holdings	38.3
Delta Air Lines	37.8
Air France-KLM	33.9
American Airlines Group	26.7
International Airlines Group	24.7
The Emirates Group*	21.0
Southwest Airlines	17.7
China Southern Airlines	16.5
Air China	16.2
All Nippon Airways	15.8
China Eastern Airlines	15.2
Quantas Airways	14.7
Japan Airlines	13.0
Cathay Pacific Airways	13.0
Latam Airlines Group	12.9
Singapore Airlines	12.2
Air Canada	11.9
Korean Air Lines	11.2
Aeroflot Russian Airlines	9.1

Source: Schofield, 2014.

24. Business enterprise R&D (BERD) in aerospace

BERD is an indicator covering R&D activities carried out in the business sector by firms and institutes. Although R&D is often carried out in government agencies and academic institutions, it is the business-driven research that is mostly associated with the creation of new products and business practices and innovation.

When analysing available OECD data for the aerospace sector, businesses located in the United States account for more than 70% of recorded aerospace BERD expenditure for 2012, more than three times higher than the European industry combined. Aerospace BERD is also much lower than BERD in other sectors, like the pharmaceutical and in the computer, electronics, optical industry. When looking at total BERD carried out in a given economy, the share which is performed in the aerospace industry ranges from 8% to 10% in the United States, France, Italy, Canada and Spain to less than 1% in Australia or Slovenia in 2012.

During the last decade, certain countries such as Korea and the Russian Federation saw a significant decrease in aerospace BERD, first in 2001, followed by a second decrease in 2007-08. Although recovering, their BERD are not yet back at 2000 levels. BERD in European countries saw a slow but steady growth until 2007/08 before evening out. In North America, Canadian BERD grew quicker than in European countries, but was more strongly affected in 2007/08 and is now more or less back at 2000 levels. US BERD evolved differently than in other OECD countries and more than doubled between 2007 and 2008. Despite steadily falling since 2009, US aerospace BERD in 2011 was still triple that of 2000.

Methodological notes

Business enterprise expenditure on R&D (BERD) covers R&D activities carried out in the business sector by performing firms and institutes, regardless of the origin of funding and is arguably most closely linked to the creation of new products and production techniques. The OECD Analytical Business Enterprise Research and Development (ANBERD) database use for the data provides internationally comparable time-series on industrial R&D expenditures. The data on R&D expenditures by the aerospace industry are based on official statistics provided to the OECD by its member countries. The comparability of BERD data over time may be affected by a number of factors, including changes in survey methods, notably the sectoral extension of survey coverage and the reclassification of units to/from the business sector.

Sources

OECD, Main Science and Technology Indicators database, data extracted 16 May, *www.oecd.org/sti/msti*.

Note

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

24.1. BERD performed in the aerospace industry for selected economies

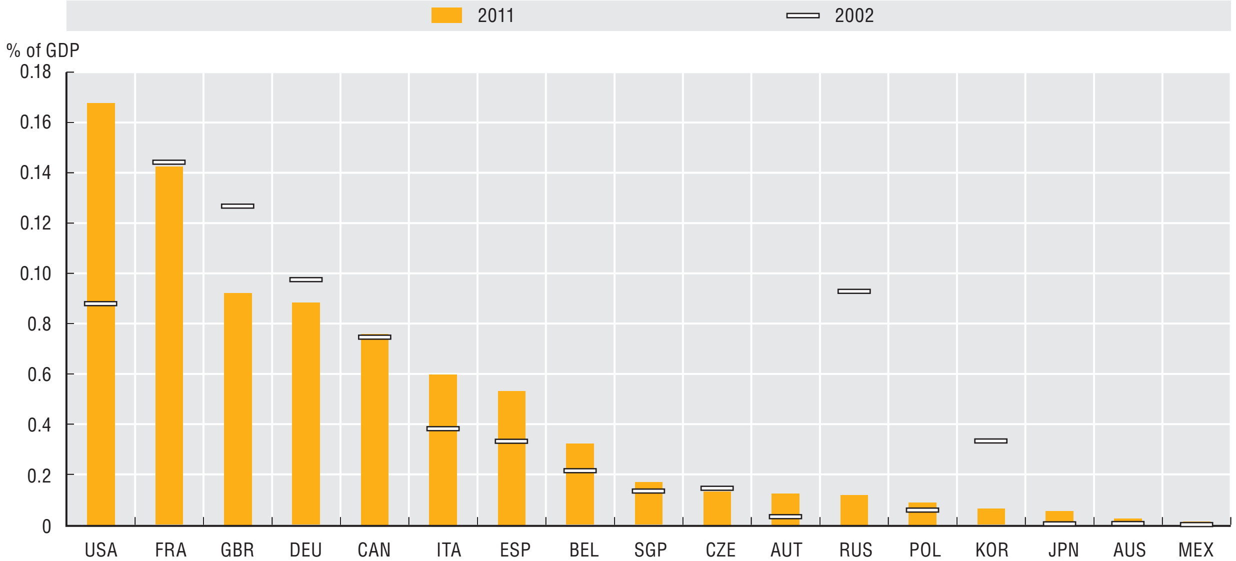
USD PPP million (current), 2012 or latest year

Country	Aerospace BERD	% of total BERD performed in aerospace industry
USA	26 054.00	8.86
FRA	3 374.49	9.91
DEU	3 061.59	4.42
GBR	2 029.93	8.14
ITA	1 227.06	8.71
CAN	1 071.08	8.26
ESP	789.40	7.53
RUS	394.00	1.99
JPN	238.02	0.21
KOR	187.19	0.37
BEL	141.67	2.12
POL	74.46	2.53
SGP	52.44	1.22
CZE	45.74	1.57
AUT	44.76	0.65
NDL	37.69	0.46
AUS	23.56	0.19
MEX	20.28	0.65
ROU	5.87	0.85
NOR	2.71	0.11
SLN	1.04	0.09

Source: OECD, 2014.

24.2. Aerospace BERD as a share of GDP

2011 and 2002, or latest year



Source: OECD, 2014.

StatLink http://dx.doi.org/10.1787/888933141988

25. Aerospace trade

The aerospace sector accounts for about 35% of total OECD exports in goods, with OECD economies still representing 90% of the global aerospace export market shares. The OECD countries exported aerospace goods for a total value of about USD 309 billion in 2012, and imported goods for USD 194 billion. The main OECD exporting countries were the United States, France, Germany and the United Kingdom, which are homes to 16 of the 20 top global aerospace and defence manufacturers. The United States, France and Germany were also the top importers of aerospace goods, followed by the United Kingdom, China and the United Arab Emirates. Asia and the Middle East are particularly homes to rapidly growing airlines, with air traffic inside China projected to grow annually by almost 8%, (Boeing, 2013). Few countries export more aerospace final goods (e.g. entire aircraft and satellites) than intermediate goods (e.g. aircraft and satellite components, propulsion equipment), and those that do tend to be among the top exporters. The importance of intermediate goods and services in trade is growing. In 2012, the biggest exporters of intermediate products were the United Kingdom, France, Germany and Singapore, while the biggest importers of intermediate products where the United States, France, Germany and the United Kingdom. Some 18 countries showed a positive aerospace trade balance in 2012, with the United States, France and Germany having an aerospace trade surplus of more than USD 20 billion. Ireland and Japan are the OECD countries with the highest negative trade balances. The negative aerospace trade balance of China amounted in 2012 to USD 18 billion. Some details in trade for selected countries can be found in Chapter 6 (country profiles).

Methodological notes

Trade data are extracted from the Bilateral Trade in goods Database by Industry and End-Use (BTDIxE) is derived from the OECD's International Trade by Commodities Statistics (ITCS2) and the UNSD's Comtrade3, where annual values and quantities of imports and exports are compiled by partner country and according to product classifications. Trade commodity statistics are broken down into intermediate goods and final goods, with intermediate goods meaning products that are used as inputs in the production of other goods. The volume of trade in intermediate goods depends on the availability and variety of producer countries, as well as the volume of intercompany trade. Mirror flows may not match between two countries, the export values from country A to country B (reported by country A) may well not agree with the import values to country B from country A (reported by country B). Although asymmetries exist for almost all trade flows, the differences observed may be relatively small.

Sources

OECD (2014), STAN Bilateral Trade in Goods by Industry and End-use (BTDIxE), ISIC Rev.4, Paris, data extracted 27 May, *www.oecd.org/sti/btd*.

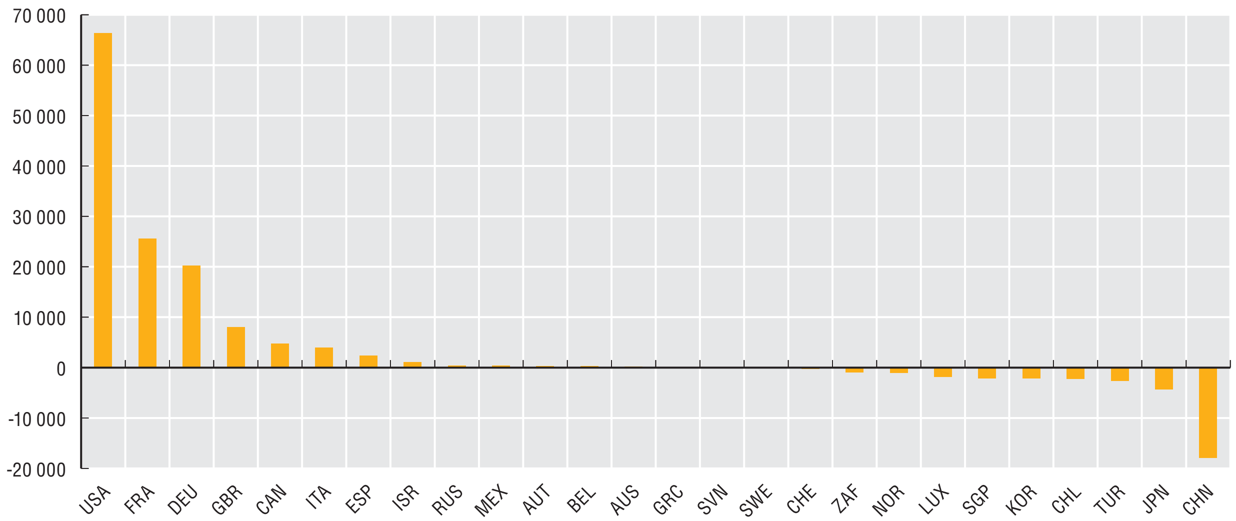
OECD (2014), *Main Science and Technology Indicators database, www.oecd.org/sti/msti*.

Note

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

25.1. Aerospace trade balance for selected OECD and non-OECD economies

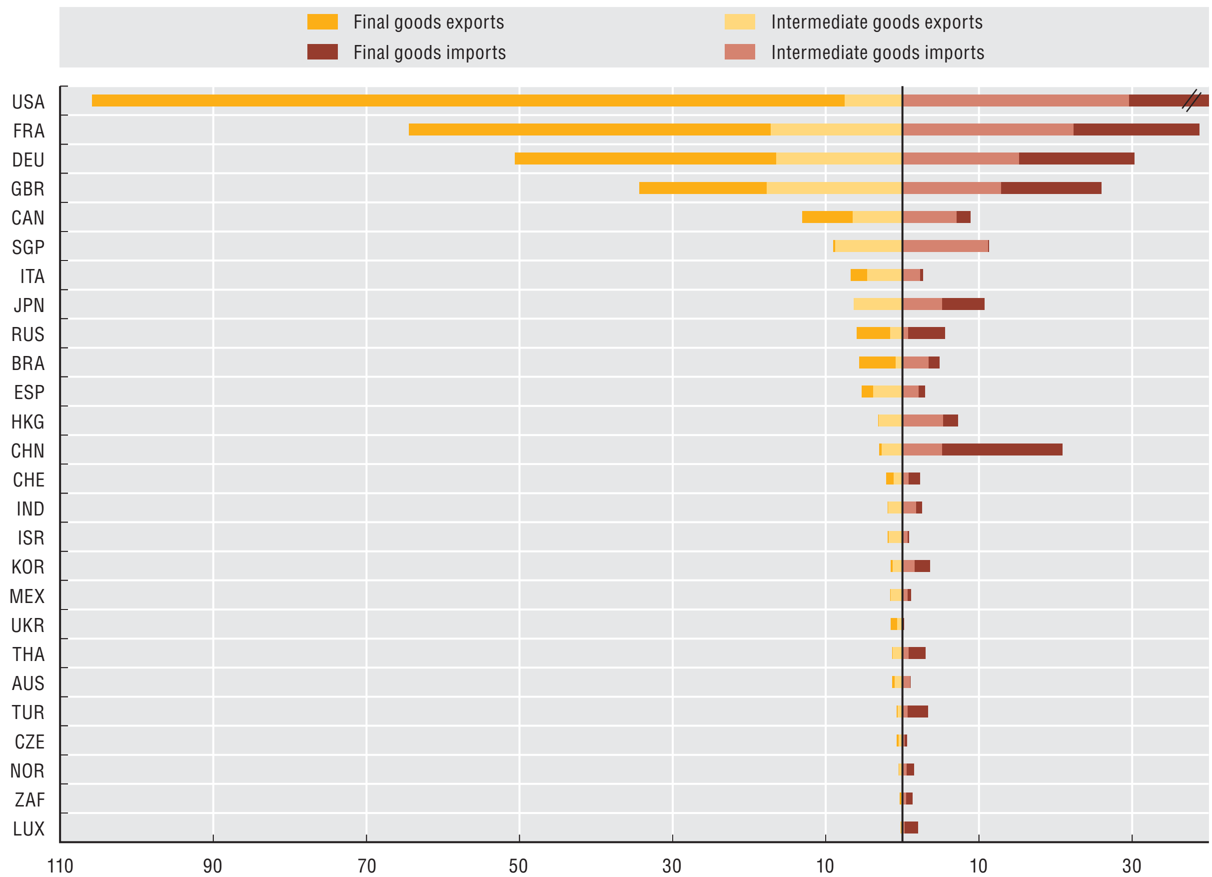
In million USD (current), 2012 or latest year



StatLink http://dx.doi.org/10.1787/888933142007

25.2. Aerospace exports and imports for selected OECD and non-OECD economies

In billion USD (current), 2012



Source: OECD STAN Database.

StatLink http://dx.doi.org/10.1787/888933142026

V. COUNTRY PROFILES: ACTORS IN THE SPACE ECONOMY

26. Guide to the profiles

27. Canada

28. France

29. Germany

30. India

31. Italy

32. Korea

33. Norway

34. Switzerland

35. United Kingdom

36. United States

Part V presents selected country profiles, focussing on members of the OECD Space Forum and selected emerging economies with space programmes. The countries covered are (in alphabetical order): Canada, France, Germany, India, Italy, Korea, Norway, Switzerland, the United Kingdom, and the United States.

26. Guide to the profiles

Using a common framework to present information, country profiles provide facts and indicators for a selected number of countries with space programmes (i.e. members of the OECD Space Forum and selected emerging economies). Country profiles provide general information on the state of the country's space sector, supported by indicators: a brief review of the institutional framework for space activities; a section on industry; and a section on the national aerospace sector.

The section on **institutional framework** provides an indication of the entity in charge of space affairs in the country, as well as the institutional budget for space programmes with a review of trends in investments. There are often differences between budget estimates and actual spending for a given year. Budget estimates have been used, in order to improve timeliness and ensure coherency across countries. Where there are particularly large discrepancies between estimates and actual spending, actual spending is used, with a dedicated note. Budget trends are also provided in both constant national currencies and in constant US dollars when applicable, to give an indication of the currencies' fluctuations, as many space contracts are often affected by the exchange rates. For calculations, this report makes use of the consumer price index (all items) as a deflator, from the *OECD Main Economic Indicators (MEI)* (database).

The section on **space industry and employment** provides an overview of the national space industry: where available, the number and main geographic location of enterprises, employment levels in space manufacturing between 2007 and 2012, and the total turnover in national currency and USD in 2013 (or latest year) are provided. Data for the section come from a combination of national space agencies, Eurospace and national industry associations. The Eurospace data only include space manufacturing jobs in industry, as defined by the association in its annual survey, thus providing useful comparability between European countries, but excluding de facto a number of space-related activities and jobs (i.e. total space-related employment is actually higher in some countries, where public agencies, universities and space services providers have significant roles in space activities).

The section on **aerospace** provides an overview of the national aerospace industry, including data for the space industry. Current international statistical classifications bundle aeronautics and space manufacturing. Where available, the information includes number and main geographic location of enterprises, latest available employment levels, total turnover in national currency and USD in 2013 or latest year, and bilateral trade data for 2012. Data from the *OECD Bilateral Trade Database by Industry and End-use category (BTDIxE)* were used to compile the aerospace trade data. The BTDIxE is derived from the OECD's International Trade by Commodities Statistics (ITCS2) and the UNSD's Comtrade, where annual values and quantities of imports and exports are compiled by partner countries and according to industrial product classifications (ISIC rev. 3 and ISIC rev. 4). The trade data include intermediate trade. The country under review is the "reporting country", and the different "partner countries" are ranked by export markets. Users should bear in mind that in BTDIxE, mirror flows often do not match between two countries, i.e. the export values from country A to country B (reported by country A) may not agree exactly with the import values to country B from country A (reported by country B). The discrepancies are usually relatively small for most countries, although some particular reporting-partner pairs may show slightly more divergence.

Several of the indicators below can be found in different chapters of the publication with more comparable country data.

The country's institutional space budget (in current USD) is first presented as a share of Gross Domestic Product (GDP) in 2013, based on OECD data and calculations (OECD, 2014a). Indicators with more comparable countries' budgetary data can be found in Chapter 1 and 3.

The per capita budget in 2013 is also provided for each country. It provides an estimated amount in USD purchase power parities (PPP) per inhabitant. The use of PPP was chosen to provide comparability across different economies. The demographic data and PPP estimates come from OECD databases (See Table 1.1).

The number of regional clusters of space activities is also provided. Governments increasingly focus on regional clusters of innovation, as industrial structure, research capabilities and other territorial characteristics affect the capacity of actors to generate and absorb knowledge.

The share of space-related patent applications filed under the Patent Co-operation Treaty (PCT) is indicated. The data are based on priority date and applicant's location, using fractional counts, for the period 2009-11 (see Chapter 15).

Share of scientific production in satellite technologies in 2013: this is a bibliometrics indicator, giving the country's share in total scientific publications (i.e. papers at space-related conferences and in scientific journals) (see Chapter 16).

The number of subscribers of Direct-to-home (DTH) satellite services (i.e. services using a satellite dish capable of receiving satellite television broadcasts). The penetration of digital television by country, as a share of television households is also provided, except for India. The 2011 data are based on ITU data, except for India (data are coming from the Telecom Regulatory Authority of India) (see Chapter 8).

The number of satellites in orbit: this is an estimate of the known number of satellites, as recorded by the Union of Concerned Scientists, as of January 31st, 2014, including governmental and commercial satellites, as well as dual-use satellites. Satellites owned by universities have been excluded.

Students' performance in science: Over the past decade, the OECD Programme for International Student Assessment, PISA, has become a key instrument for evaluating the quality, equity and efficiency of school systems. It tracks the evolution of student performance over time and across subjects. As space programmes use highly-qualified human resources, a focus on students' performance in science is provided here. The relative standing of countries is analysed through countries' mean performance, both relative to each other and to the OECD mean (OECD, 2014b). For PISA 2012, the mean in science for OECD countries increased to 501 points. This establishes the benchmark against which each country's and economy's science performance in PISA 2012 is compared (see summary Table 5.1).

Sources

OECD (2014a), Main Economic Indicators (MEI) Database, *www.oecd.org/std/mei*.

OECD (2014b), International Trade by Commodity database (ITCS), *www.oecd.org/std/its/itcsinternationaltradebycommoditystatistics.htm*.

OECD (2014c), STAN Bilateral Trade Database by Industry and End-use (BTDIxE,), *www.oecd.org/sti/btd*.

OECD (2014d), PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014), PISA, OECD Publishing. *dx.doi.org/10.1787/9789264201118-en*.

27. Canada

Institutional framework

Canada's history in space goes back to the 1960s when it was the third country to send an artificial satellite into space (Alouette 1). Canada has over the years developed a dynamic space programme, positioning its space industry in several niche areas, including robotics, satellite communications and satellite radar imagery. Canadian space policy has been the subject of review during the last couple of years, with the publication of *the Aerospace Review* at the end of 2012, and the launch of the new space policy framework in February 2014. The new policy puts a strong emphasis on space applications to support national interests and also envisages increased private sector participation in space and an increased commercialisation of Canadian space activities. There will also be a continued emphasis on international collaboration and R&D.

Under the authority of the Ministry of Industry, the Canadian Space Agency (CSA) is responsible for the implementation of space policies in Canada. It had a budget of some CAD 462.4 million (USD 442.3 million) for the 2014-15 fiscal year. The Department of National Defence also supports dedicated military space activities, with Sapphire, Canada's first military satellite launched in February 2013. Canadian military space activities are co-ordinated by Director General Space, on behalf of the Minister of National Defence, within the Chief of Force Development organization. Current projects include satellite communications systems (Mercury Global, Protected MILSATCOM); Search and Rescue Satellite Aided Tracking System (SARSAT); Surveillance of Space; Polar Epsilon; Joint Space Support Project (JSSP); and Navigation Warfare (NAVWAR). Despite some years of decline, the Canadian space budget saw a 20% increase in funding over six years, when adjusting for inflation between 2007 and 2013. The earth observation and satellite communications programme funding (now the space data, information and services) almost doubled during the period, mainly due to Radarsat constellation investment needs. The science programme (space exploration), on the other hand, saw a budget cut of almost 40%.

The main programme of the Canadian Space Agency in 2013 was the earth observation and satellite communications programme (space data, information and services) which received CAD 288 million (USD 281 million) in funding. The main priorities of the programme are the Radarsat constellation mission, scheduled to be launched in 2018, and the development of microsatellites. Some CAD 95 million (USD 93 million) were allocated to the science programme (space exploration), which is responsible for the International Space Station (ISS) and other manned space operations as well as other science missions. The future Canadian space capacity activity aims to ensure future availability of skilled manpower in the space sector and industrial questions. ESA participation falls under this programme, and approximately CAD 30 million was allocated to ESA, mainly to earth observation.

Canadian space industry

Canada has a well-developed space industry, including about 200 private companies, in addition to research institutions and universities, some of which have some commercial activities. The ten biggest companies accounted for almost 88% of revenues and 64% of employment (Canadian Space Agency, 2013). Space manufacturing is mainly located in Ontario (more than half of the workforce) and in Quebec (19% of workforce). Some 7 993 people were employed in the space sector in 2012, an increase compared to 2011, with more than half defined as "highly" qualified' (engineers, scientists and technicians). Total Canadian space sector revenues amounted in 2012 to CAD 3.3 billion (USD 3.3 billion), a 4.5% decrease as compared to 2011 (Canadian Space Agency, 2013). Satellite communications applications and services generated the largest revenue share, followed by the earth observation sector. The applications and services segment generated two thirds of total revenues.

Key facts for Canada

Space budget as a share of GDP (2013): 0.026%.

Space budget per capita (2013): USD 11.7 (PPP).

Number of regional clusters including space industry: 2 (Ontario, Quebec).

Share in scientific production in satellite technologies (2013): 4.18%.

Share of space-related patent applications filed under PCT (2009-11): 2.43%.

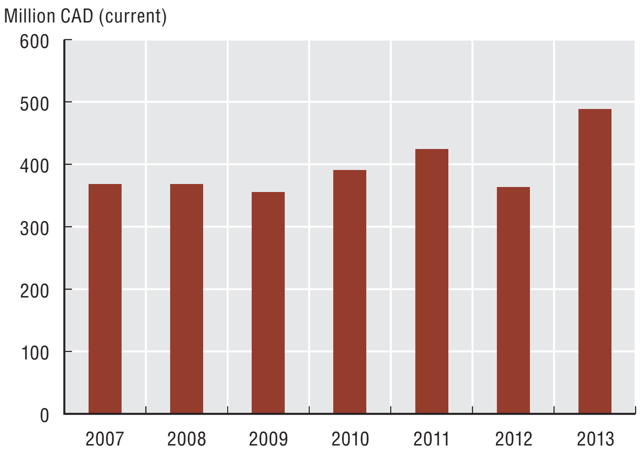
Subscribers of Direct-to-home (DTH) satellite services (2011): 2.9 million (21.60% of television households).

Number of operational satellites: 20.

Student performance in science (PISA 2012 mean score): 525 (above the OECD average).

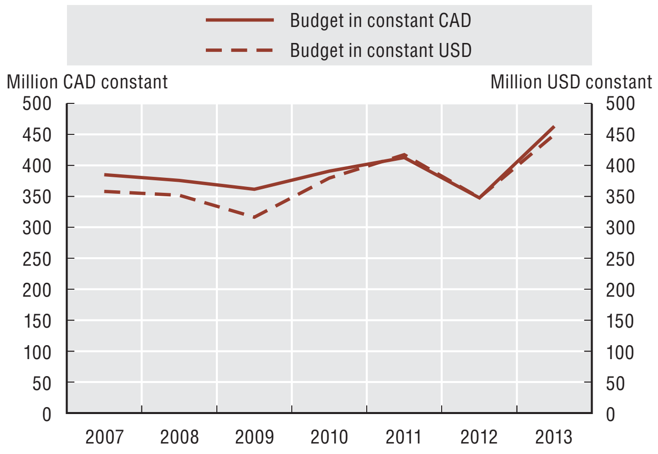
27.1. Canada's space budget

In CAD million (current), 2007-13



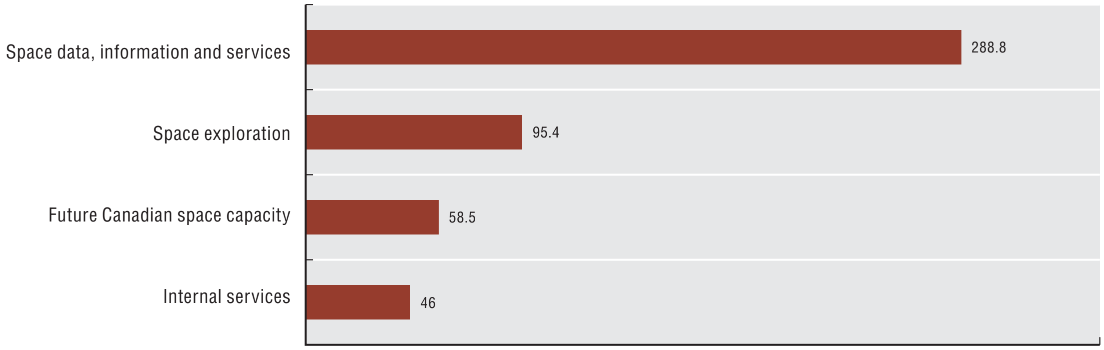
27.2. Canada's inflation-adjusted space budget

In constant CAD and USD million, 2007-13



27.3. Canadian Space Agency's budget by main programmes

In CAD million (current), 2013



Sources: OECD calculations based on Canada Treasury Board Secretariat, 2014a and 2014b.

Canadian aerospace industry

The Canadian aerospace industry comprised in 2012 more than 700 firms located in every region of the country according to the biggest industry association in the sector (Aerospace Industries Association of Canada, 2013). Collectively, these aerospace companies (manufacturing and MRO) employ 73 000 employees. If indirect (Canadian suppliers to firms where aerospace is their main activity) and "induced" (offset economic impact of direct and indirect) employment are included, an estimated 170 000 employees work in the extended aerospace sector in Canada (Aerospace Industries Association of Canada, 2013). Canadian aerospace industry revenues reached CAD 22.8 billion (USD 22.8 billion) in 2012, with nearly 80% in exports. Taking into account indirect and induced revenues, the total amount was CAD 42 billion (USD 42 billion). In terms of aerospace trade, Canadian aerospace industry exports amounted to USD 13.7 billion, with total imports amounting to USD 8.9 billion. Main trading partners were the United States, France, United Kingdom, Germany and China. Exports to the United States accounted for more than half of total exports (OECD, 2014).

Methodological notes

The Treasury Board Secretariat of Canada provides an official annual government expense plan which gives an overview of main estimates for the forthcoming year. Industry Canada and the Canadian Space Agency put together an annual report on plans and priorities, indicating planned spending for the different programmes. These are the data that are used in OECD calculations. The Canadian Space Agency conducts annual industry surveys sent to some 200 organisations (including private entities, research organizations and universities) with strategic interests in the space industry, while the Aerospace Industries Association of Canada reports and aggregates data from the different provincial industry associations. Differing industry surveying methods may account for differences in data. For the trade statistics the classification code HS88 (Harmonised System, 2007) for Aircraft, spacecraft and parts thereof has been used, with Canada as reporting country.

Sources

Aerospace Industries Association of Canada (AIAC), *www.aiac.ca*.

Canada Treasury Board of Canada (2014a), 2014–15 Estimates, Parts I and II: The Government Expenditure Plan and Main Estimates,Ottawa.

Canada Treasury Board of Canada (2014b), Reports on Plans and Priorities (RPP): The Canadian Space Agency 2010-11, Ottawa.

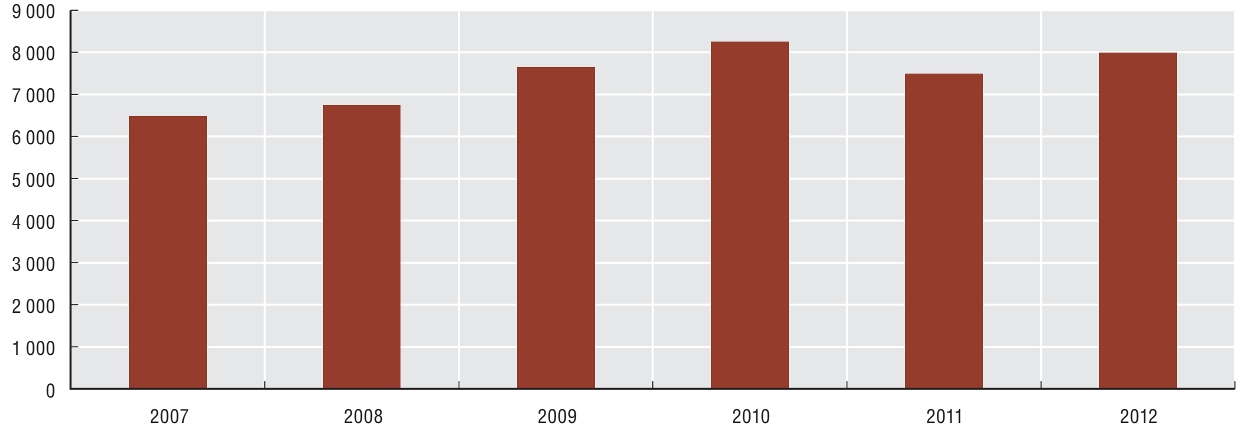
Canadian Space Agency,*www.asc-csa.gc.ca*.

OECD *STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd*.

OECD, *Main Science and Technology Indicators database*, *www.oecd.org/sti/msti*.

27.4. Canadian space sector employment

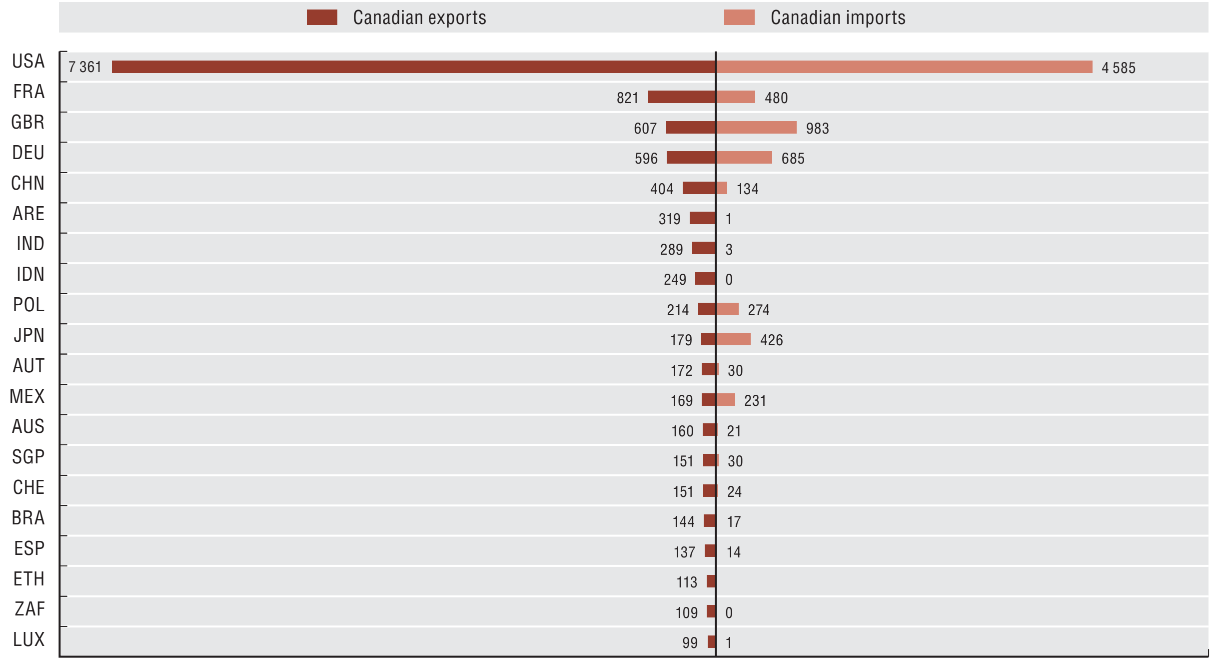
Number of employees, 2007-12



Source: Canadian Space Agency, 2013.

27.5. Canada's main aerospace trade partners

In USD million (current), 2012



Source: OECD STAN Database, 2014,*www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142045

28. France

Institutional framework

France became the third country to place a satellite in orbit independently in 1965 (Asterix). Ever since, it has been a driving force behind autonomous European access to space, with the development of the Ariane launchers and continuing support for the European spaceport in French Guyana. In 2013, France had the largest national space budget in Europe and was the second biggest contributor to the European Space Agency, with major aerospace production sites located throughout the country.

The French space agency (*Centre national d'études spatiales* – CNES), established in 1961, is placed under the joint supervision of the Ministry of Higher Education and Research and the Ministry of Defence. It is responsible for formulating and executing space policies and representing French interests in the European Space Agency (ESA). It is responsible for several national and international programmes covering both upstream (launchers and hardware) and downstream activities (applications), in addition to industry development and science. France allocated about EUR 2.2 billion (USD 2.9 billion) to space in 2013, with an estimated EUR 1.1 billion (USD 1.5 billion) going to CNES for national and bilateral programmes. This figure included government subsidies from the Future Investment Plan (PIA) to sustain economic development, and an estimated EUR 400 million (USD 532 million) in revenues from external contracts. The Future Investment Plan granted CNES some EUR 500 million (USD 662 million) in 2010 in French public bonds over a period of several years to stimulate research and future economic growth, via investments in the next generation of European launcher and innovative satellites. Each year, almost half of the total French space budget (EUR 700-800 million) is allocated to ESA. In addition to investments relative to specific military programmes carried out by the General Delegation for Armaments (DGA) in the Ministry of Defence, such as Syracuse III and MUSIS, some EUR 799 million (USD 1.1 billion) were earmarked in 2013 for the European Space Agency and EUR 31 million (USD 40 million) were allocated to EUMETSAT, the European organisation for weather satellites. In constant euros, the French budget decreased by 1.2% between 2007 and 2013. In constant US dollars the fluctuations seem greater, due to the weakening of the US dollar to the Euro during the period.

When looking at France's allocations to ESA and CNES, the biggest programme in 2013 was "Access to Space", the launcher programme, at a total estimated cost of EUR 744 million (USD 990 million). It was followed by Science (EUR 387 million/USD 515 million) and the Defence and earth observation programmes (EUR 292 million/USD 388 million and EUR 253 milllion/USD 336 million respectively). This reflects the main priorities of the French government concerning European independent access to space as a key element (ESA Members States are in 2014 examining the future of the heavy-lift launcher Ariane 5), with strong emphasis on science, and with civil and commercial satellite applications growing in importance.

Notes

28.1 and 28.2: For 2013, a provisional EUR 400 million has been added to the budget. This covers external contracts to CNES in the area of Access to Space' and Security and Defence.

28.3: The main categories have been adapted by OECD. The category "administration and other joint programmes": the national segment covers taxes and payroll, pooled resources in CNES as well as central directorates budget lines; the ESA segment covers the European agency's operations and debt management. The category "mass market" includes investments in telecommunications. Note: includes an estimated EUR 400 million in external contracts to CNES.

Key facts for France

Space budget as a share of GDP (2013): 0.1%.

Space budget per capita (2013): USD 37.4 (PPP).

Number of regional clusters encompassing space industry: 3 (Aerospace Valley in Toulouse; AsTech cluster in Paris; Pégase cluster in Provence).

Share in scientific production in satellite technologies (2013): 7.36%.

Share of space-related patent applications filed under PCT (2009-11): 17.66%.

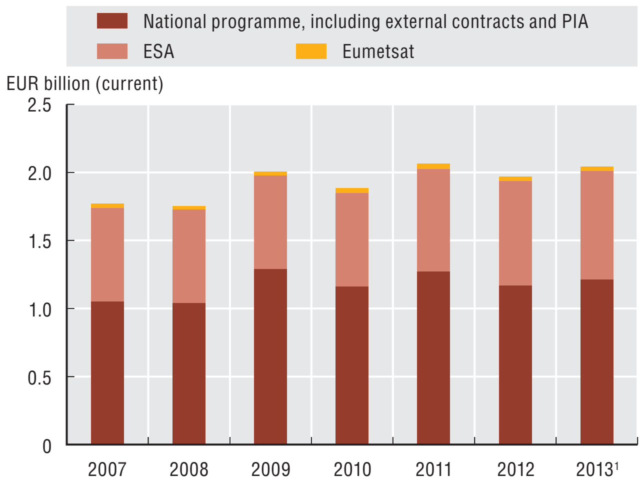
Subscribers of Direct-to-home (DTH) satellite services (2011): 6.6 million (32.33% of television households).

Number of operational satellites: 54.

Student performance in science's mean score (PISA 2012): 499 (OECD average of 501).

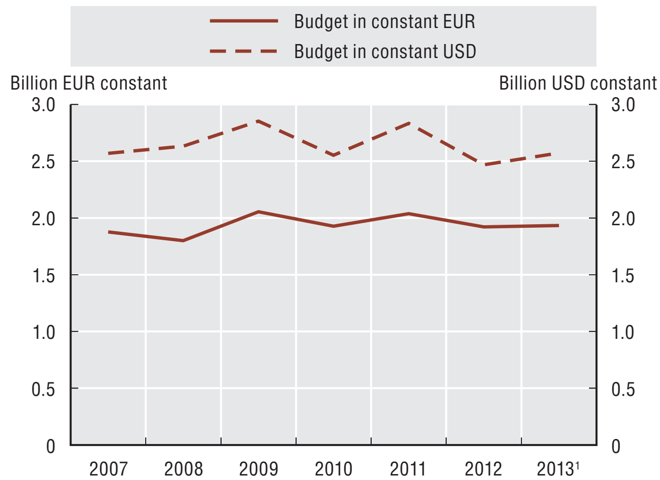
28.1. France's space budget

In billion EUR (current), 2007-13



28.2. France's inflation-adjusted space budget

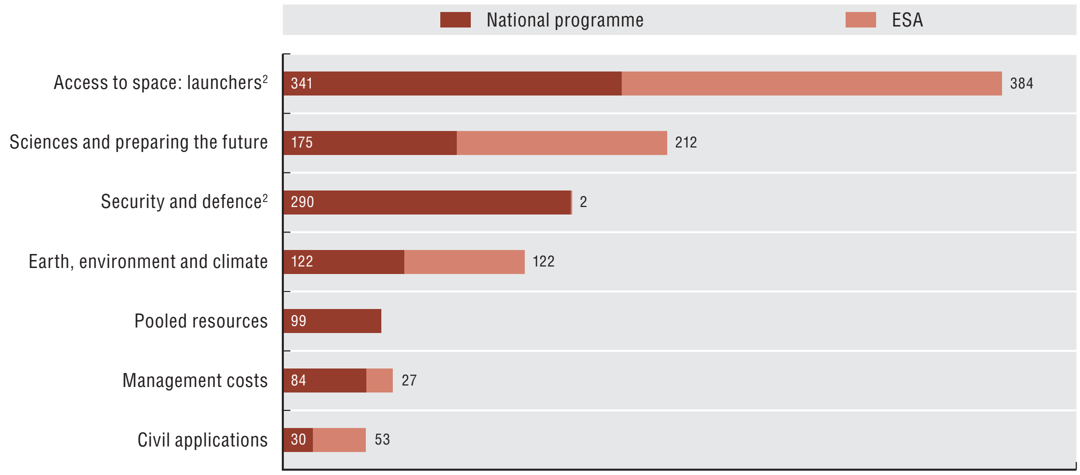
In billion EUR and USD (constant), 2007-13



Source: OECD calculations based on French government sources.

28.3. CNES budget by main programmes

In million EUR (current), 2013



Source: OECD estimates, adapted from CNES, 2014.

French space industry

Space manufacturing remains a niche industry accounting for about 14% of revenues and 8% of total full-time employment in 2012 in the French aerospace sector, based on data from GIFAS, the French aerospace trade organization. Unconsolidated revenues reached EUR 6 billion (USD 7.7 billion) in 2012, a 40% increase compared to 2011 (GIFAS, 2013). Some 13 205 persons were employed in the space manufacturing industry in France in 2012 (Eurospace, 2014). Overall, it is estimated that some 16 000 persons work in the French space sector in metropolitan France and the European spaceport in French Guyana employs about 1 700 people (CNES, 2014). This estimate does not take into account the many French universities, research institutions and defence-related administrations also involved in space research, development and in some cases spacecraft operations.

French aerospace industry

The aerospace sector represents an important source of economic growth for the French economy, remaining robust during the economic crisis. The sector generated EUR 43 billion (USD 55 billion) in unconsolidated revenues in 2012 and employed 170 000 people (GIFAS, 2013). There are aerospace companies located throughout the country, however France is home to three major regional aerospace clusters: the *Aerospace Valley* in the Aquitaine and Midi-Pyrenees regions, with Toulouse representing the first aerospace pole in Europe, with more than 210 French and international companies; the *ASTech* cluster in Paris and its region, representing half of the French R&D aerospace employment; and finally the*Pégase* cluster in Provence-Alpes-Côte-d'Azur, with more than a hundred companies. In these clusters, large companies' revenues are in many cases derived from aeronautics and space activities, space currently representing for example 16% of companies' revenues in the Great South-West region of Aquitaine and Midi-Pyrenees (INSEE, 2012). Based on OECD data, France exported aerospace goods for a total value of USD 64 billion and imported goods for USD 38.8 billion in 2012. Main trading partners were Germany, the United States and China. Trade with Germany accounted for a third of exports and more than half of total imports, reflecting particularly the intra-European Airbus aircraft production value chains (OECD, 2014).

Methodological notes

Eurospace, in co-operation with GIFAS, conducts annual surveys on the European space manufacturing industry. The national statistical office INSEE conducts regional surveys in Midi-Pyrenees (annual since 1982), Aquitaine (annual since 2000) and French Guyana (regular, not annual) specifically on manufacturers, subcontractors, and service providers in the aeronautical and space sectors. These surveys provide snapshots of the French aerospace industry, an important sector for the economies of those three French regions in terms of revenue and employment.

Sources

Centre national d'études spatiales (CNES), *www.cnes.fr*.

Eurospace, *www.eurospace.org*.

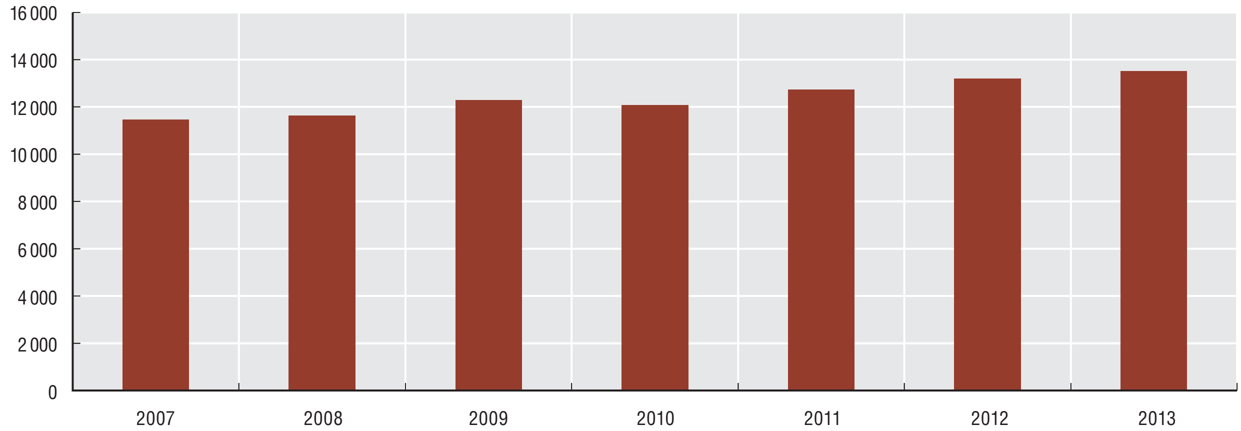
Groupement des industries Françaises Aéronautiques et Spatiales (GIFAS), *www.gifas.asso.fr*.

OECD *STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd*.

OECD Main Science and Technology Indicators database, *www.oecd.org/sti/msti*.

28.4. French space manufacturing industry employment

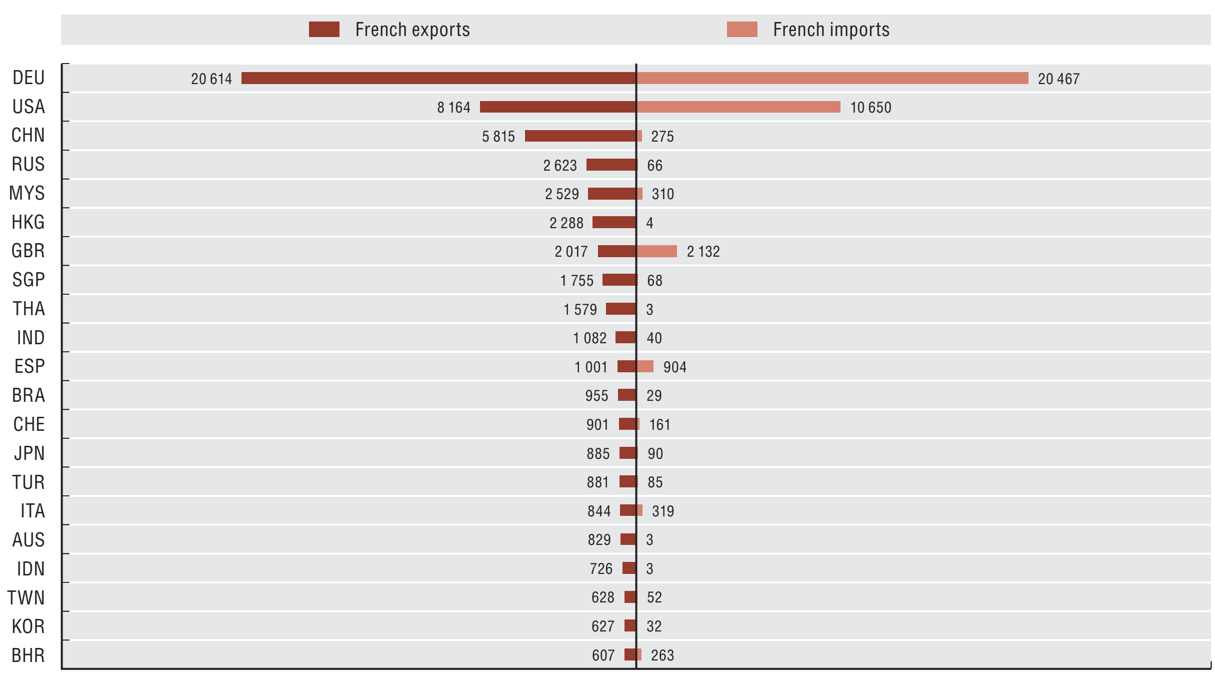
In full-time equivalents, 2007-13



Source: Eurospace, 2014.

28.5. France's main aerospace trade partners

In USD million (current), 2012



Source: OECD STAN Database, 2014,*www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142064

29. Germany

Institutional framework

Germany is a major actor in the European space sector, as the largest funder to the European Space Agency (ESA) in 2013, as well as an important location for space manufacturing. Germany's space policy focuses on the sustainable use of space for the benefit and needs of the population (Federal Ministry of Economics and Technology, 2010). The latest government space strategy was published in 2010 and identified ten priorities: expanding strategic space expertise; sustainably reinforcing Germany's position in space research; tapping new markets and establishing a unified legal framework; using space for purposes of whole-of-government security preparedness; shaping the distribution of roles in the European space sector; defining German and European roles in exploration; securing technological independence; retaining human spaceflight; maintaining the Moon as a target for exploration; and ensuring the sustainability of space activities (Federal Ministry of Economics and Technology, 2010).

Space policies are carried out by the German Aerospace Centre (*Deutsches Zentrum für Luft- und Raumfahrt* – DLR), under the main responsibility of the Federal Ministry of Economics and Technology. Germany's institutional space budget amounted to roughly EUR 1.3 billion in 2013 (USD 1.8 billion), about half of which (EUR 766 million/ USD 1 billion) was allocated to ESA and other European space programmes (figure 1), while the rest was dedicated to the national research programme, as well as to the EUMETSAT and METimage programmes. The budget is funded by three ministries – Ministry of Economics and Technology (BMWi) and the Ministry of Transport and Digital Infrastructure (BMVI) (Galileo). The Ministry of Defence funds military research conducted in DLR. In both constant EUR and USD, the German budget as a whole increased by more than 20% compared to 2007, with the national programme growing by 30%.

In 2013, combining funds allocated both at the national and European level, Germany allocated the highest amount of funds to earth observation, EUR 311 million (USD 414). This fed into the ESA earth observation programmes (Copernicus and "the Living Planet", covering among others the Sentinel and MetOp missions). In its national earth observation programme, Germany operates 15 satellites (8 of which are in civil use), for environmental mapping and remote sensing. Germany allocated a total of EUR 205 million to launcher development (USD 274 million) and EUR 168 million (USD 224 million) to Space Sciences.

German space industry

The German space industry is characterised by the production of high-technology components and systems, with a particular emphasis on satellite manufacturing. The largest space companies, estimated at about 80 in number, are located all over the country. The bulk however is concentrated in the two southern-most federal states of the country, Bavaria and Baden-Wuerttemberg, where the University of Stuttgart and other research organisations are also found. There are also companies represented in the north-western part of the country (Bremen). German industry is active in many segments of space activities, but looking only at space manufacturing, 6 837 full-time equivalents were employed in 2013 (Eurospace, 2014). The space sector's sales amounted to about EUR 2.4 billion (USD 3.1 billion).

Note

29.3: This category includes Robotics, Technology support, Space Situational Awareness.

Key facts for Germany

Space budget as a share of GDP (2013): 0.046%.

Space budget per capita (2013): USD 19.5 (PPP).

Number of regional clusters including space industry: 3 (Bremen, Bavaria, Baden Württemberg).

Share in scientific production in satellite technologies (2013): 8.16%.

Share of space-related patent applications filed under PCT (2009-11): 10.4%.

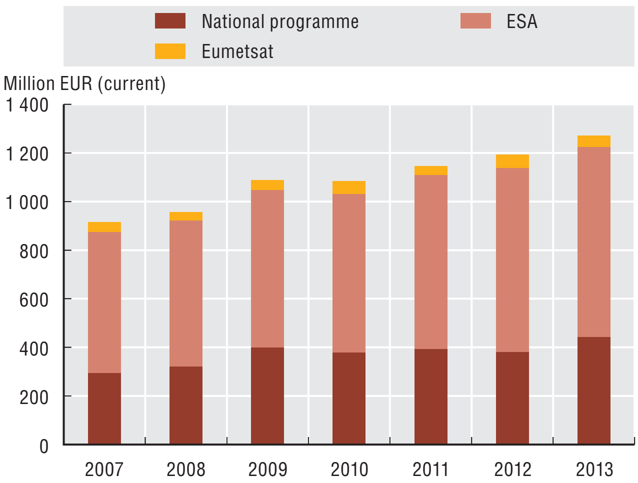
Subscribers of Direct-to-home (DTH) satellite services (2011): 13.5 million (38.80% of television households).

Number of operational satellites (2013): 15 (+3).

Student performance in science (PISA 2012 mean score): 524 (above the OECD average).

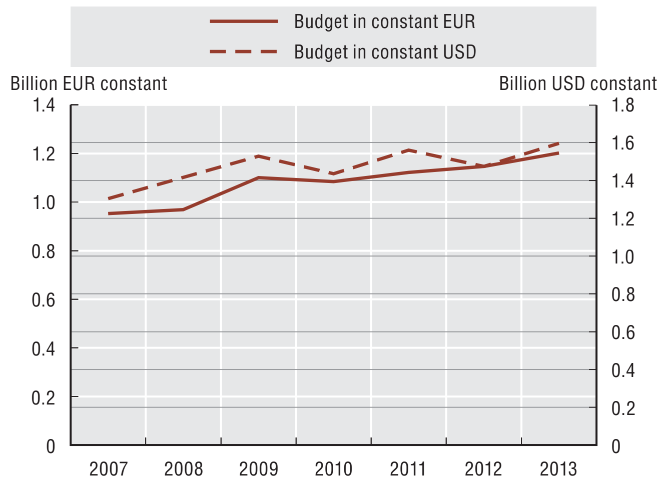
29.1. Germany's space budget

In million EUR (current), 2007-13



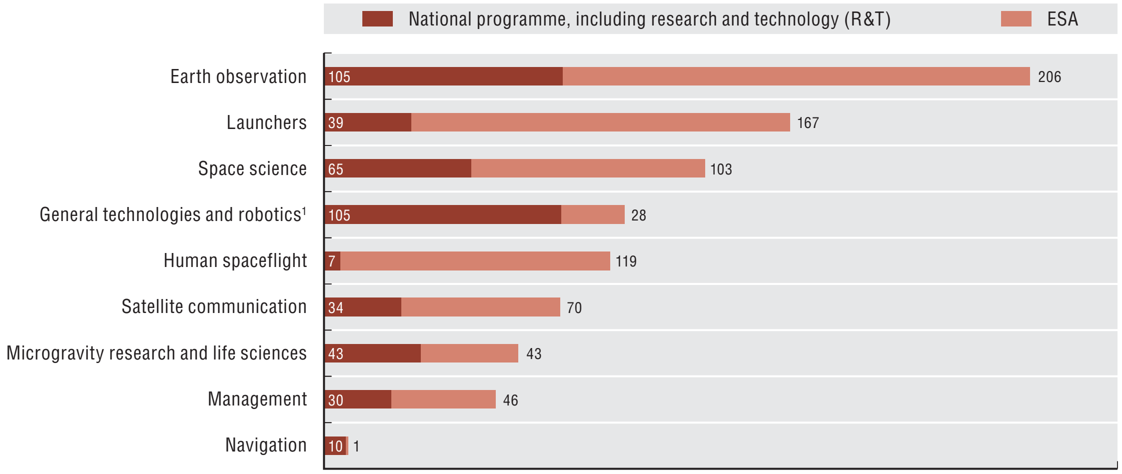
29.2. Germany's inflation-adjusted space budget

In billion EUR and USD (constant), 2007-13



29.3. DLR's space budget by main programmes

In million EUR (current), 2013



Source: OECD calculations based on DLR, 2014 and previous years.

German aerospace industry

The aerospace sector is an important source of innovation, employment and economic growth in Germany, with several clusters of activity located in different parts of the country. Hamburg (main German Airbus location) and Bavaria have the highest numbers of employees in aerospace, followed by Niedersachsen, Hessen and Baden-Wuerttemberg (Biermann et al, 2013) The manufacture of aerospace systems accounts for about 50% of employment and 60% of sales (BDLI, 2013). Aerospace manufacturing companies employed 100 700 people in 2012, according to the German trade organization BDLI, with sales amounting to EUR 28 billion. According to the German Statistical Office, there were 95 major aerospace firms in Germany in 2012 (German Federal Statistical Office, 2012). BDLI, with its larger circle of actors in defence and electronics, reports membership of about 150 manufacturing companies (of their 200 members, about 50 are “supporting” members). According to OECD data, Germany exported aerospace goods for about USD 50 billion in 2012 primarily to France, a key partner for Airbus industrial manufacturing, China, the United Arab Emirates and the United States. The country imported aerospace goods for USD 30 billion, with more than a third coming from France, followed by the United Kingdom and the United States (OECD, 2014).

Methodological notes

The Federal Statistical Office collects aerospace manufacturing data monthly and yearly. The monthly survey covers companies with more than 50 employees; the yearly survey covers companies with more than 20 employees. Reporting is mandatory. The statistical code for manufacture of air and spacecraft is NACE Rev. 2/WZ 2008 3030 (Luft- und Raumfahrzeugbau). The Federal Statistical Office publications cover the employment and turnover of manufacturers, including mining. The German aerospace industry association BDLI issues an annual factsheet with the major space industry statistics (employment and turnover). Eurospace conducts yearly surveys that also cover German companies.

Sources

Bundesverband der Deutschen Luft- und Raumfahrtindustrie e.V. (BDLI), German aerospace industry association, *www.bdli.de*.

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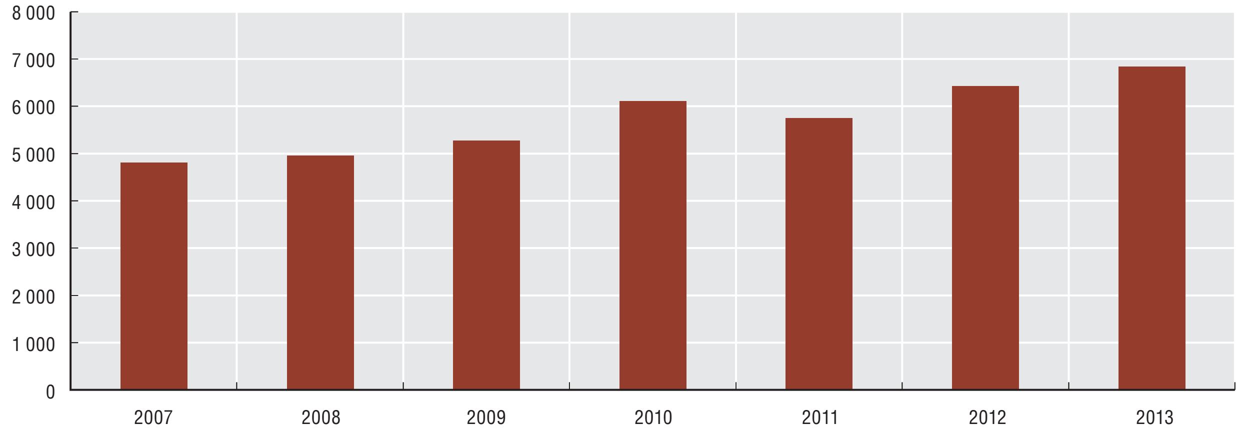
OECD, *Main Science and Technology Indicators database*, *www.oecd.org/sti/msti*.

29.4. German space manufacturing industry employment

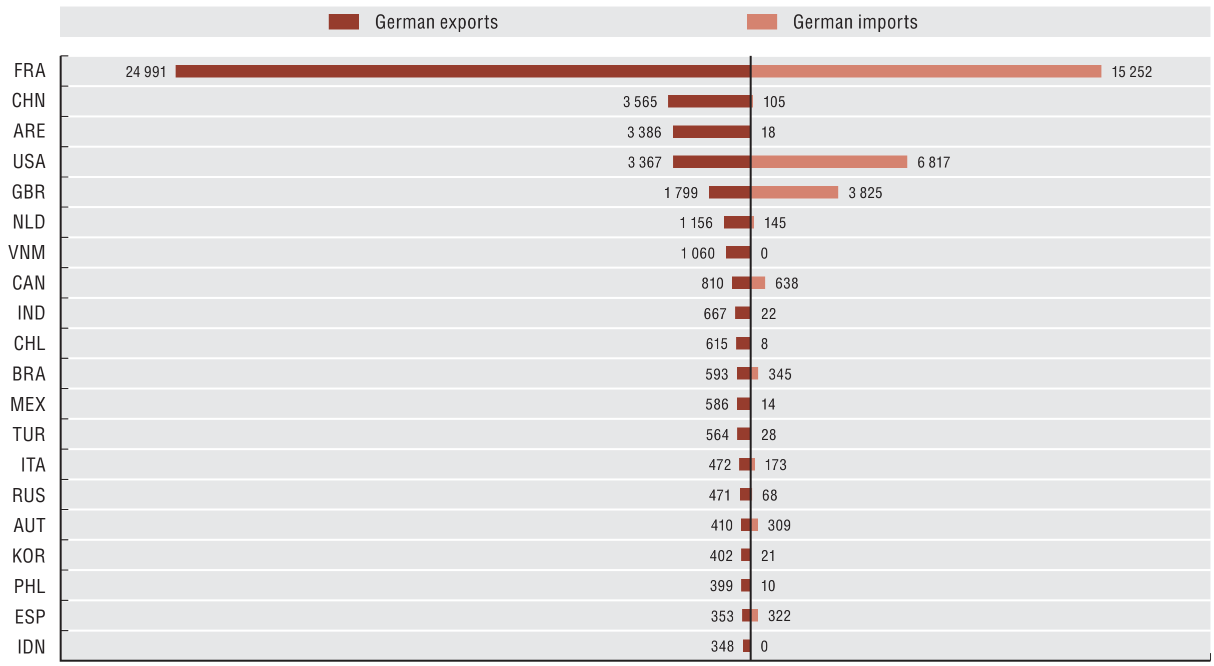
Number of full time equivalents, 2013



Source: Eurospace, 2014.

29.5. Germany's main aerospace trade partners

In USD million (current), 2012



Source: *OECD STAN Database*, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142083

30. India

Institutional framework

India has an ambitious and wide-ranging space programme, aiming to develop independent capabilities and indigenous high technologies. The Indian Space Programme has been active for more than half-a-century, since its first experiments with sounding rockets in the early 1960s. The Department of Space, which is responsible for managing the Indian Space Research Organisation (ISRO), is directly under the authority of the Indian Prime Minister. The budget and policies of the Department of Space and ISROs are determined in 5-year planning cycles by the Indian Planning Commission; the latest plan was launched in 2012 and ends in 2017. This *Twelfth Five Year Plan*assigned INR 397.5 billion (Indian Rupees) to the Department of Space (around USD 7.4 billion). In 2013, ISRO's budget estimate amounted to INR 68 billion (USD 1.2 billion). The main objectives until 2025 include the strengthening/expanding of operational services in communications and navigation; developing enhanced imaging capabilities for natural resource management, weather and climate change studies; space science missions for better understanding of the solar system and the universe; planetary exploratory missions; development of heavy lift launcher and reusable launch vehicles; and a human space flight programme (Indian Planning Commission, 2013). Even after adjustment for inflation, the Indian space budget saw significant increases in 2010 and 2011, followed by decreases more pronounced in constant USD due to exchange rates impacts.

In recent years, the biggest budget line in the space programme has been devoted to access to space technologies, i.e. developing the Polar Satellite Launch Vehicle (PSLV) and the Geostationary Launch Vehicle (GSLV). The Indian Space Research Organisation is currently working on a larger geostationary launch vehicle, the GSLV-MkIII, which could launch commercial telecommunications satellites, making the country fully autonomous for all types of satellite launches and giving it access to the commercial geostationary launch market. The satellite programme has received significantly more allocations in recent years, funding the implementation of the regional satellite navigation programme IRNSS (Indian Regional Navigational Satellite System), with the first satellite of seven launched in July 2013. The country currently has 26 satellite missions with another 7 missions planned to launch by 2017. The 11 INSAT telecommunications satellites provide telephone services to remote areas and send direct-to-home television to 85% of the Indian population. There is extensive use of telemedicine and tele-education in rural areas. India has one spaceport with two independent launch pads, from which it launched its first Mars orbiter, Mangalyaan, in November 2013, scheduled to reach Mars orbit in September 2014.

Indian space industry

Unlike many other space agencies, the Indian Space Research Organisation is also the main space manufacturer in India. It assembles satellites and launch vehicles from parts provided by ISRO's eleven centres spread around the country, with production mainly carried out in the southern part of India, in Thiruvananthapuram (launchers), Bangalore (satellites) and Sriharikota. Important centres are also the Space Applications Centre in Ahmedabad and National Remote Sensing Centre in Hyderabad. ISRO had 14 716 employees in 2012, distributed between the different centres, and its commercial branch, Antrix, located in Bangalore. It sells remote sensing data imagery, ground station services, satellite launches and exports of satellite components and other products. Antrix is also responsible for selling transponder leases on Indian telecommunications satellites, a market that has seen considerable growth in the last years (turnover in 2011 amounted to about USD 200 million). Private space manufacturers are expected to become more important as the demand for PSLV launch vehicles currently surpasses ISRO's production capacity. About 80% of the parts of the PSLV are now produced by industry. The *Twelfth Five Year Plan*clearly states the need to increase the capabilities of private industry to take over some production and assembly tasks (Indian Planning Commission, 2013).

Note

30.1 and 30.2: The data include only budgets for the civil space programme. India's fiscal year runs from 1 April to 31 March.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

Key facts for India

Space budget as share of GDP (2013): 0.063%.

Space budget per capita (2013): USD 2.4 (PPP).

Number of regional clusters including space industry: 3 (Bangalore, Thiruvananthatapuram, Sriharikota).

Share in scientific production in satellite technologies (2013): 5.1%.

Share of space-related patent applications filed under PCT (2009-11): 0.62%.

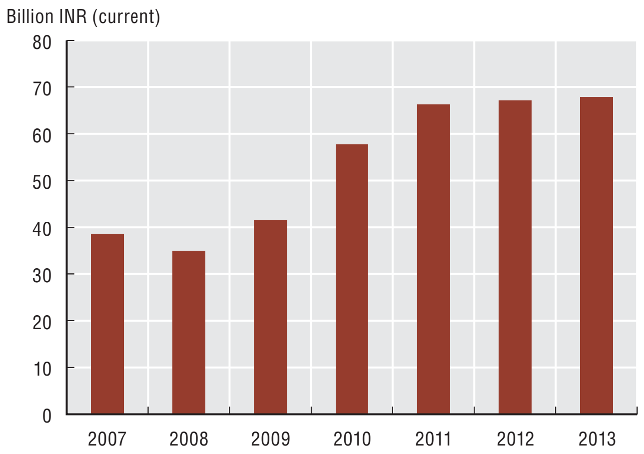
Subscribers of Direct-to-home (DTH) satellite services (2013): 56.5 million.

Number of operational satellites: 30.

Student performance in science (PISA 2012 mean score): n/a.

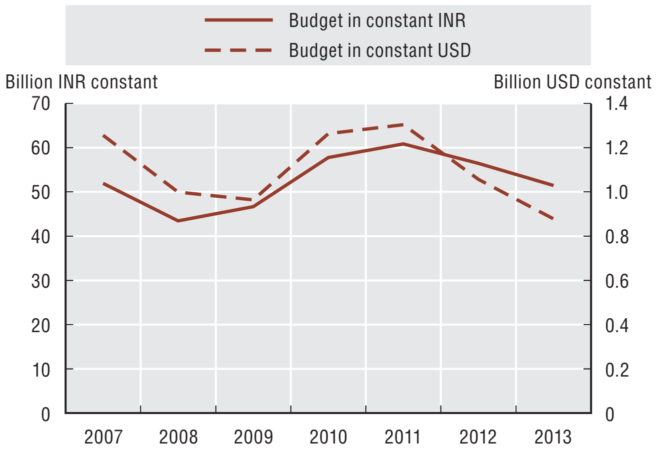
30.1. Indian space budget

In INR billion (current), 2007-13



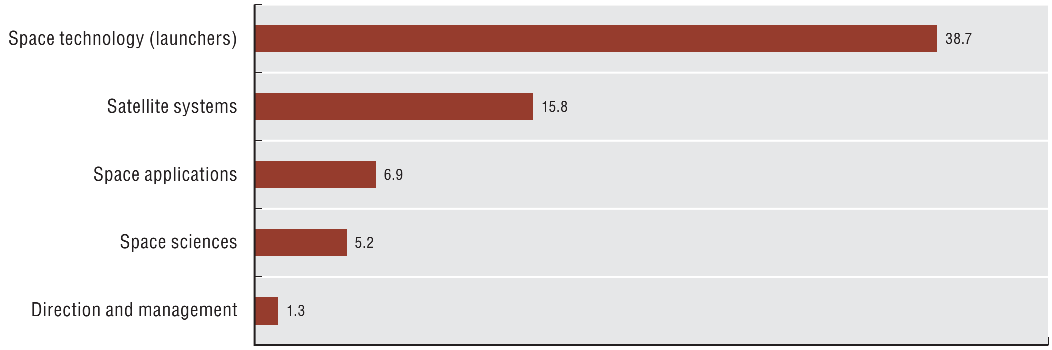
30.2. Indian inflation-adjusted space budget

Constant INR and USD billion, 2007-13



30.3. ISRO budget by main programmes

In INR billion (current), 2013



Source: ISRO, 2013 and OECD calculations.

Indian aerospace industry

The rising technological and manufacturing capabilities of the Indian aerospace industry, which now cover all segments in the industry (e.g. civil and military aviation, missiles) contribute to a larger share of commercial activities in the Indian space sector. Aerospace companies can be found throughout India, with main clusters located in Bangalore, Hyderabad, Thiruvananthapuram and Sriharikota. The major actors are organised in the Society of Indian Aerospace Technologies and Industries (SIATI), which has membership of around 300 industries from both the public and private sector, including Hindustan Aeronautics Ltd. (HAL), Indian Space Research Organisation (ISRO), DRDO Labs, the Aeronautical Development Agency (ADA) and the National Aerospace Laboratories (NAL). The aerospace sector in India expects a considerable increase in domestic demand in the coming years for both civilian and defence programmes. India is among the top world spenders on defence, and two of the key objectives under the *Twelfth Five Year Plan* is to increase the share of domestic procurement from 30 to 75% in the next 10 years, and are to create one million new direct and indirect jobs in defence manufacturing (Indian Planning Commission, 2013). The civil aviation sector in India is also expecting significant growth, with some market studies suggesting a requirement for 1 000 new aircraft by 2020 (Indian Planning Commission, 2013).

According to OECD data, India exported aerospace goods in 2012 for a total of USD 2 billion, while importing for USD 2.6 billion. Main OECD trading partners in the aerospace sector were the United States, United Kingdom and France, with imports of US and French aerospace products amounting to 60% of total imports.

Methodological notes

The budget figures use the Indian rupee (INR) as currency and US Dollars, USD, if not stated otherwise. In official Indian documents, the Rupee amounts are often given in Crores, a unit which corresponds to 10 million rupees.

Sources

Indian Planning Commission (2013), Twelfth Five Year Plan (2012–2017): Volume 1, Delhi.

Indian Space Research Organisation, *www.isro.org*.

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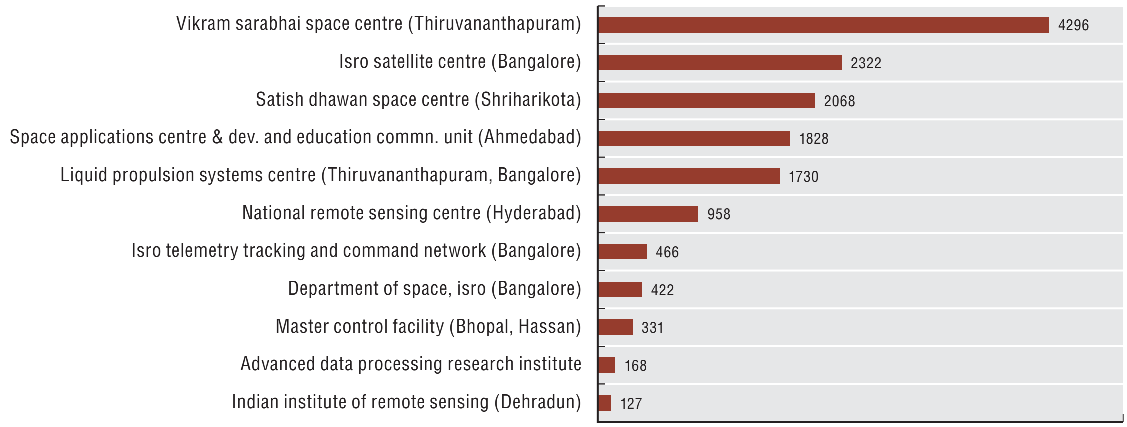
OECD, *Main Science and Technology Indicators database*, *www.oecd.org/sti/msti*.

30.4. Employment at ISRO space centres

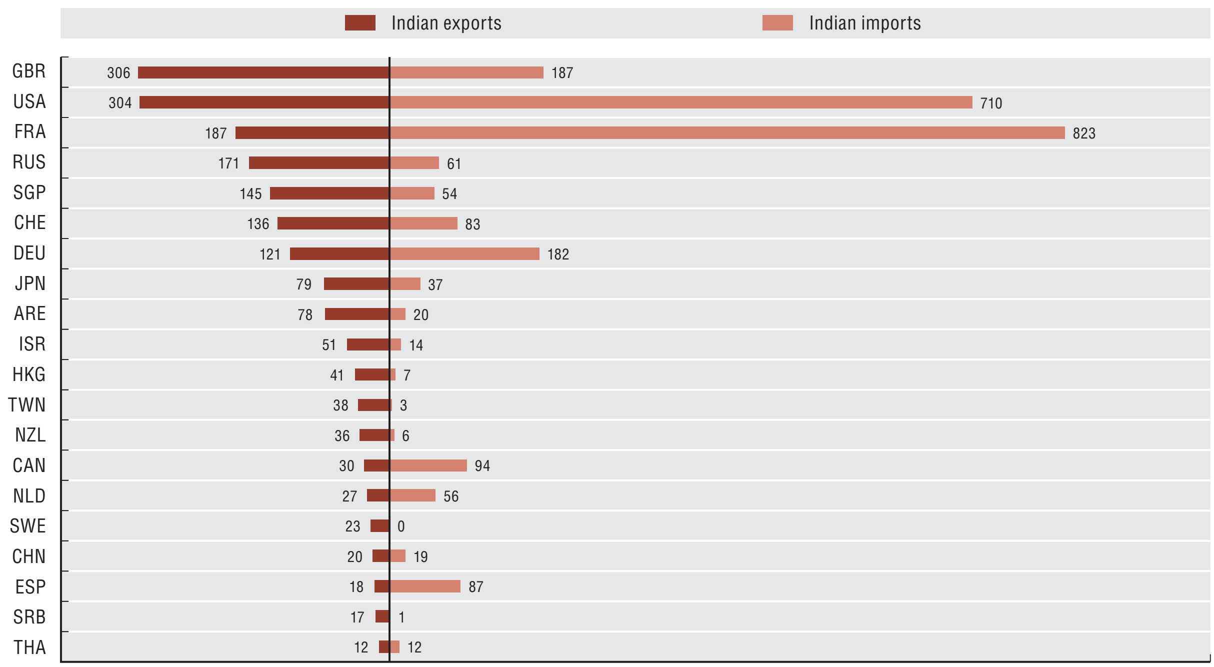
Number of employees, 2012



Source: ISRO, 2013.

30.5. India's main aerospace trade partners

Million USD (current), 2012



Source: OECD STAN Database, 2014,*www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142102

31. Italy

Institutional framework

Italy has a long history of space exploration and was the third country in the world to launch and operate a satellite in orbit in 1964 (San Marco 1). It was also a founding member of the European Space Agency, to which it is today third biggest contributor, after Germany and France. Italy is actively involved in all domains of space applications and exploration, both at the national and international level, and has an important space manufacturing industrial base as well as a mature "downstream" sector providing services.

The Italian Space Agency, *Agenzia Spaziale Italiana* (ASI), is headquartered in Rome with three additional centres in Matera (Space Geodesy Centre); in Malindi, Kenya (Luigi Broglio Space Centre); and Rome (ASI Science Data Centre). ASI defines, coordinates and manages national space programmess and the Italian participation to European and international space projects, under the supervision of the Ministry of Education, University and Research. In 2013 the total Italian budget dedicated to space amounted to EUR 921.5 million (USD 1.2 billion) with EUR 767 million (USD 1 billion) managed by ASI, of which contributions to ESA activities and programmes accounted for EUR 521.5 million (USD 694 million), more than half of the total Italian budget. The budget in 2013 saw a one-off increase due to administrative compensatory measures. In constant EUR the ASI space budget decreased by 5% in total over the period 2007-2013. Whereas budget allocated to national programmes by ASI decreased by 37% over the last seven years, contributions to ESA registered a 24% increase over the same period. The main programmes of the Italian space budget in 2013 were earth observation, with an allocation of EUR 231.5 million (USD 308.1 million), followed by the Launchers programme, which consisted mostly of ESA-led activities (EUR 167.8 million/ USD 223.3 million) and Space Science, Space Situational Awareness (SSA) (EUR 129.0 million/USD 171.7 million).

Italian space industry

The Italian space industry is composed of a few large system integrators and a much wider number of SMEs (small and medium-sized enterprises), connected through a complex network of vertical relationships. About two-thirds of the Italian space companies (large and small) operate in manufacturing, contributing to the increase or maintenance of space infrastructure, while the remaining one-third provides space-based services and applications for end-users (downstream). The Italian space industry is primarily located in the centre of the country (Lazio, Toscana, Abruzzo), where the firms account for about half of total turnover. The Lazio Region holds by far the lion's share. The second most important area is the north-west (Piemonte and Lombardia), while the south and the Islands are behind but recently increasing their share (Campania, Puglia).

The Italian space industry consisted of approximately 250 firms in 2012 (of which only 150 had space activities as core business) reporting a turnover of EUR 1.6 billion (USD 2.2 billion) (ASI, 2014). A small number of bigger groups dominate the sector, both in terms of employment and sales. About 6 000 people work in the Italian space sector, with four major companies (Avio, Selex ES, Telespazio and Thales Alenia Space Italia) employing 78% of the total space-related workforce. These data include also the downstream sector (ground service systems, user segment and applications, etc.). Purely manufacturing jobs accounted for about 4 700 full-time equivalents in 2013 (Eurospace, 2014). Exports of the space sector represented 70% of turnover, with more than half exported to other EU countries (with a prominent share of ESA orders and collaboration with Germany and France). An increasing share of orders came from countries outside the European Union.

Note

31.1 and 31.2: The 2013 budget includes one-off administrative provisions. The data cover allocations to ASI and Eumetsat. Space activities of other Italian Ministries, regional clusters and research organisations are not included.

Key facts for Italy

Space budget as share of GDP (2013): 0.059%.

Space budget per capita (2013): USD 20.7 (PPP).

Number of regional clusters including space industry: 6 (Piemonte, Lombardia, Toscana, Lazio, Campania, Puglia) and 1 national (National Aerospace Technological Cluster).

Share in scientific production in satellite technologies (2013): 5.74%.

Share of space-related patent applications filed under PCT (2009-11): 1.78%.

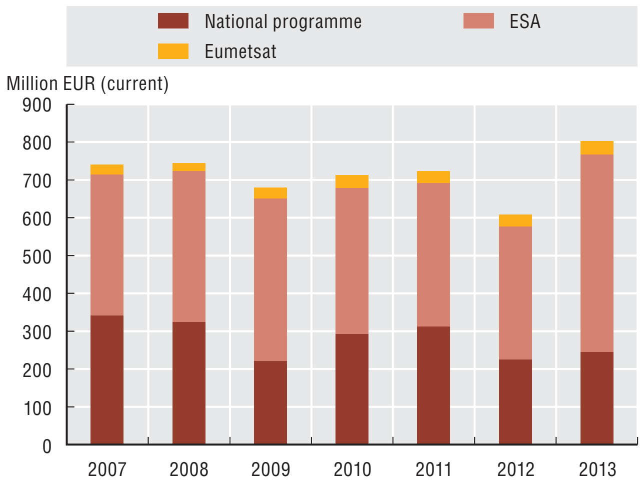
Subscribers of Direct-to-home (DTH) satellite services (2011): 6.9 million (27.96% of television households).

Number of operational satellites: 11.

Student performance in science (PISA 2012 mean score): 494 (OECD average of 501).

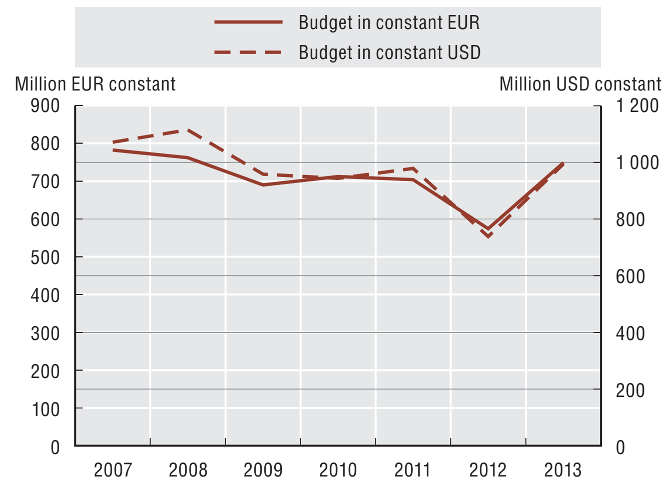
31.1. Italy's space budget

In million EUR (current), 2007-13



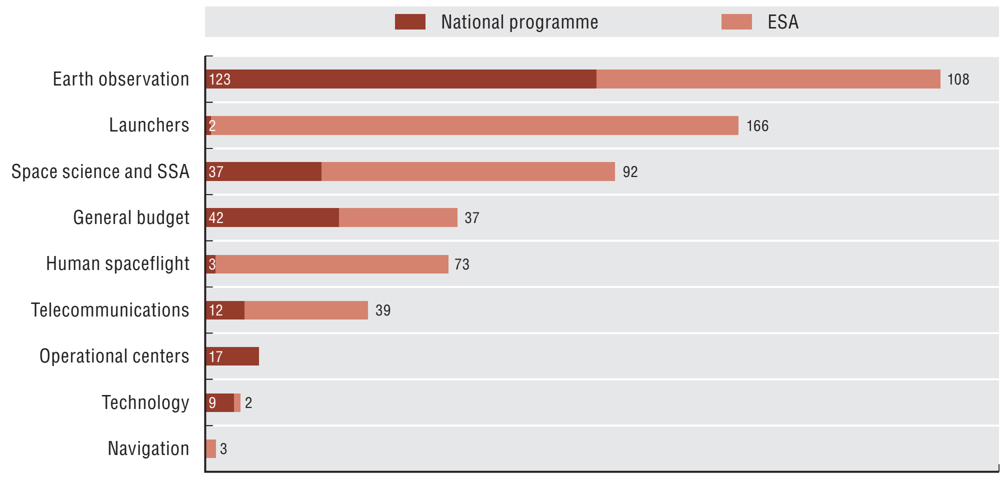
31.2. Italy's space budget, adjusted for inflation

In constant EUR and USD million, 2007-13



31.3. Italian space agency's budget by main programmes

In million EUR (current), 2013



Source: OECD calculations based on ASI, 2014.

Italian aerospace industry

The Italian aerospace sector is the fourth biggest in Europe, home to several hundred companies and numerous regional clusters (Basilicata, Campania, Lazio, Lombardia, Piemonte, Puglia, Sardegna, Toscana, and Umbria) and employing about 50 000 people (AIAD, 2013). The sector specialises in aerospace systems, structures and components, as well as helicopters and training aircraft. The main bulk of companies are located in the northwest (Piemonte and Lombardia) and the centre (Lazio region). According to the Italian industry association for aerospace, defence and security industries (AIAD), their 130 members generated some EUR 14.5 billion (USD 18.6 billion) in revenues in 2012. Civil aerospace accounted for roughly 60% of total revenues. According to OECD data, Italy exported aerospace products for a total value of USD 6.7 billion in 2012, and imported products for USD 2.7 billion. The main trading partners for exports were the United States, France, United Kingdom and Germany (OECD, 2013).

Sources

Agenzia Spaziale Italiana (ASI), *www.asi.it/*.

Eurospace, *www.eurospace.org/*.

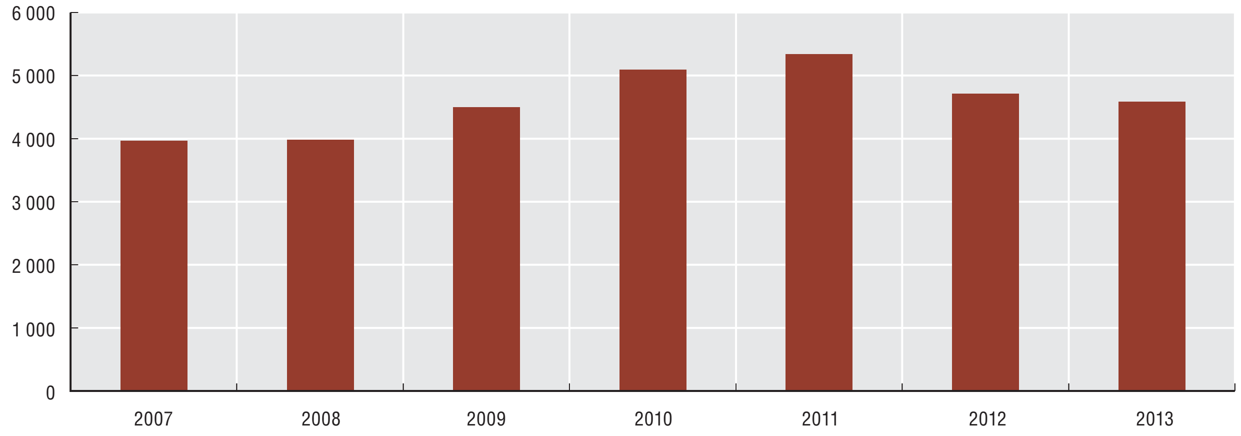
Italian Aerospace, Defence and Security Industries (AIAD), *www.bciaerospace.com*.

OECD STAN *Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd*.

OECD, *Main Science and Technology Indicators database*, *www.oecd.org/sti/msti*.

31.4. Space manufacturing industry employment in Italy

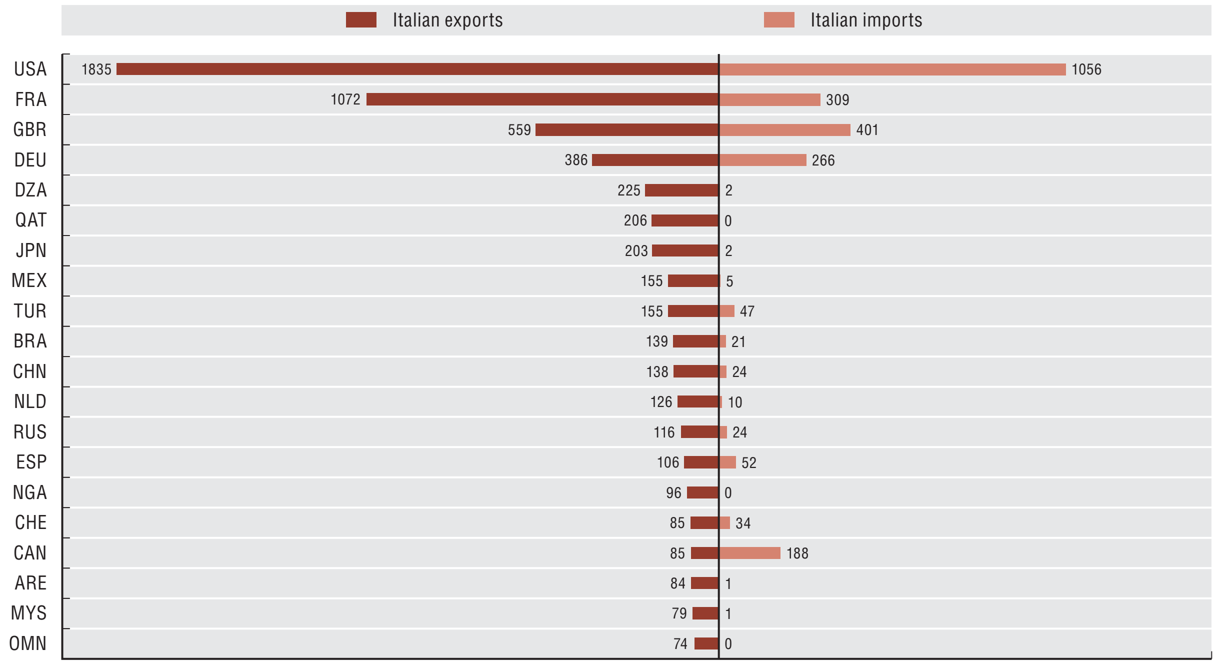
Number of full time equivalent, 2007-13



Source: Eurospace, 2014.

31.5. Italy's main aerospace trading partners

In USD million (current), 2012



Source: OECD STAN Database, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142121

32. Korea

Institutional framework

Korea's space activities started in the early 1990s with the construction and overseas launching of satellites and sounding rockets. In 2007, in accordance with the Space Development Promotion Act, Korea established its first Space Development Basic Plan, which covered space development matters, including policy, organisational structure, financial and human resources, infrastructure expansion and international co-operation. The Basic Plan was consolidated by Ministry of Education, Science and Technology, Ministry of Strategy and Finance, Ministry of Foreign Affairs, Ministry of National Defence, Ministry of Security and Public Administration, Ministry of Knowledge Economy, Ministry of Land, Transport and Maritime Affairs and the National Intelligence Service.

The Korean Aerospace Research Institute (KARI) manages the Korean space programme, under the responsibility of the Ministry of Science, ICT and Future Planning. It is primarily a research agency. The construction of the Naro space centre was started in 2005, from which the NARO-1 (with an indigenously-built second stage engine) was successfully launched in 2013 with the experimental satellite STSAT-2C on board. The Korean government plans to develop a rocket built entirely with Korean technology by 2018-20 (KARI, 2013). The First Space Development Basic Plan allocated some KRW 1 546.9 billion (Korean Won) for the period 2007 to 2011. In 2012, the Second Basic Plan for 2012-16 was launched, with an estimated total allocation of KRW 2 133.1 billion for the five-year period. It was revised in November 2013 with a budget increase towards an earlier development of Korea's Space Launch Vehicle 2. From 2007 to 2012, the Korean space budget actually fell, but saw a substantial increase from 2012 to 2013. When adjusted for inflation, the budget decreased by 20% between 2007 and 2013 in local currency. In 2013, Korea's space budget amounted to KRW 348.2 billion (around USD 318 million), with the allocation to launcher development and the Naro space centre accounting for 40% of the total budget. Satellite operation and development was the second-biggest budget item, with KRW 105 billion (USD 96 million), more than 30% of the total budget.

Korean space industry

Space industrial activities and research in Korea are mainly government-funded, with KARI acting as the contracting agency. The number of space-related companies is estimated at about 100, with the aerospace conglomerate Korean Aerospace Industries (KAI) playing an important part. Space activities are concentrated in two main locations – research institutions in Daejeon in conjunction with KARI, and companies in the Seoul metropolitan area. In the annual industry survey conducted by the Korean Ministry of Science, Information and Communications Technology and Future Planning, there were 146 active organisations in the Korean space industry in 2013, including 91 companies, 22 research agencies and 33 universities (Ministry of Science, ICT and Future Planning, 2014). The space sector generated KRW 1 441 billion (USD 1.3 billion) in sales in 2012, and employed 3 600 people, including both the industry and research personnel in research institutions and universities, and both upstream and downstream sectors. Space manufacturing employed some 1 838 people in 2012, with research institutions and universities accounting for about half of the manufacturing em-ployment (Korean Ministry of Science, ICT and Future Planning, 2013).

Key facts for Korea

Space budget as a share of GDP (2013): 0.023%.

Space budget per capita (2013): USD 8.2 (PPP).

Number of regional clusters including space industry: 2 (Daejeon, Goheung).

Share in scientific production in satellite technologies (2013): 2.51%.

Share of space-related patent applications filed under PCT (2009-11): 4.11%.

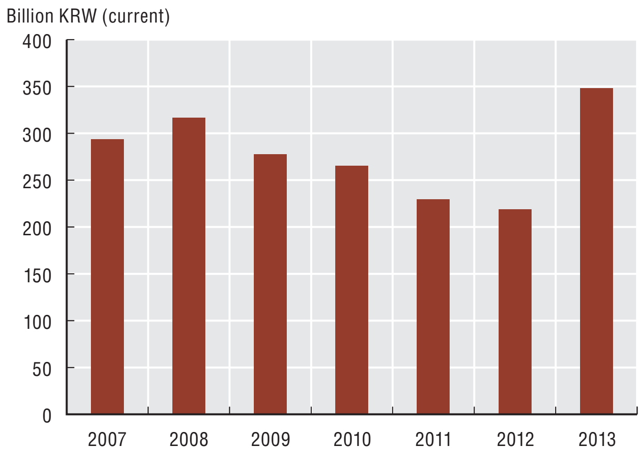
Subscribers of Direct-to-home (DTH) satellite services (2011): 3.3 million (17.57% of television households).

Number of operational satellites: 7.

Student performance in science (PISA 2012 mean score): 538 (above the OECD average).

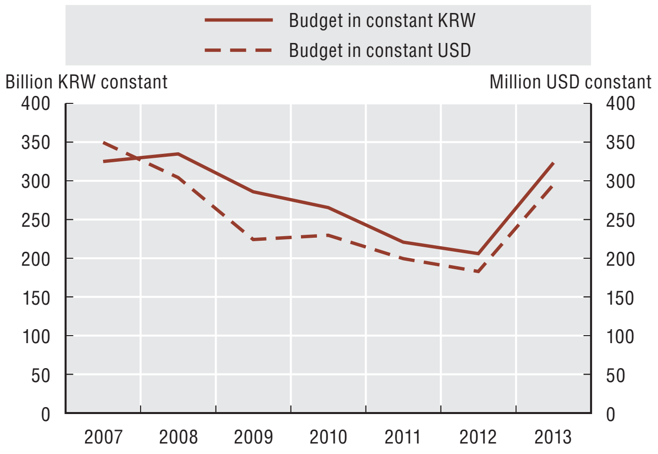
32.1. Korea's space budget

In billion KRW, 2007-13



32.2. Korea's inflation-adjusted space budget

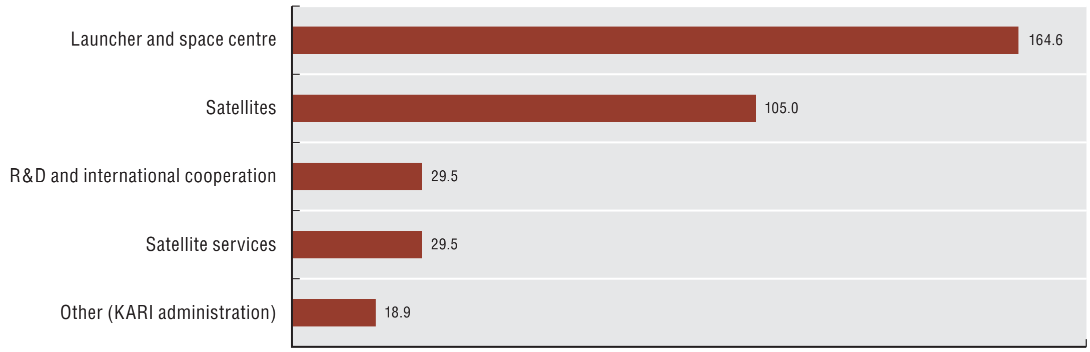
In constant billion KRW and million USD, 2007-13



Source: Korean Ministry of Education, Science and Technology, 2014.

32.3. KARI's space budget by main programmes

In billion KRW (current), 2013



Source: Korean Ministry of Science, ICT and Future Planning, 2014.

Korean aerospace industry

In 2010, the Ministry of Trade, Industry and Energy published an ambitious 10-year Basic Plan for the Development of the Aerospace Industries to significantly increase aerospace production by 2020. The Korean aerospace sector currently focuses mainly on military aircraft and parts, employing some 10 000 people (Invest Korea, 2014). The sector is dominated by the conglomerate Korean Aerospace Industries (KAI). Production is mainly carried out in the southern Gyeongnam region (Sacheon, Changwon and Busan). According to OECD data, South Korea exported aerospace products for a total value of USD 1.5 billion and imported aerospace products for USD 3.7 billion in 2012 (OECD, 2013). Main trade partners were the United States, accounting for 80% of imports and 53% of exports, followed by France, Japan and the United Kingdom.

Sources

Korean Ministry of Science, ICT and Future Planning (former Korean Ministry of Education, Science and Technology) (2013),*Status of the Korean Space Sector 2012*, Seoul.

Korean Ministry of Science, ICT and Future Planning (2014), *Status of the Korean Space Sector 2013,* Seoul.

OECD *STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd.*

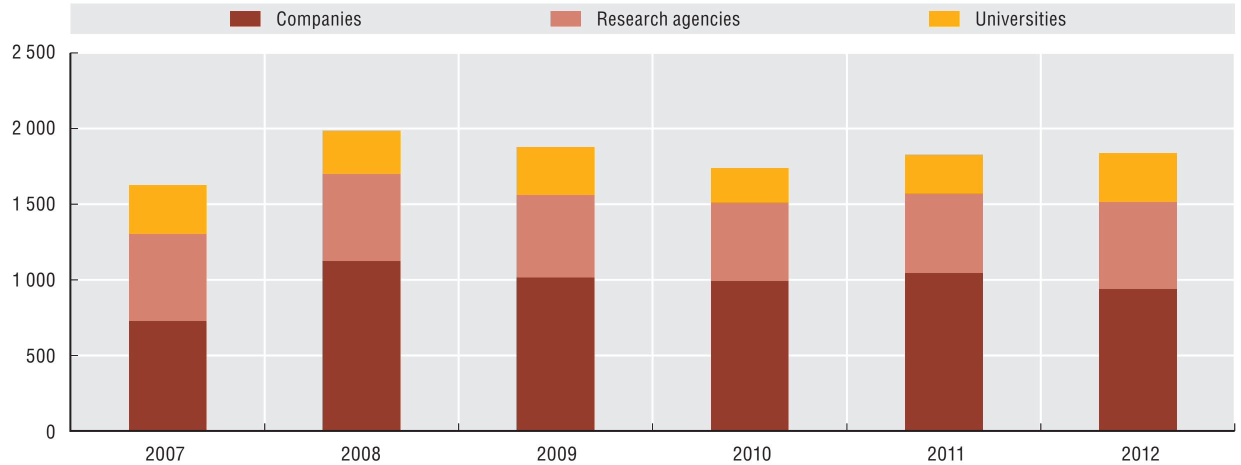
OECD, *Main Science and Technology Indicators database, www.oecd.org/sti/msti.*

Note

32.4: Space manufacturing is defined in the Korean survey as the "production of space equipment".

32.4. Space manufacturing employment in Korea

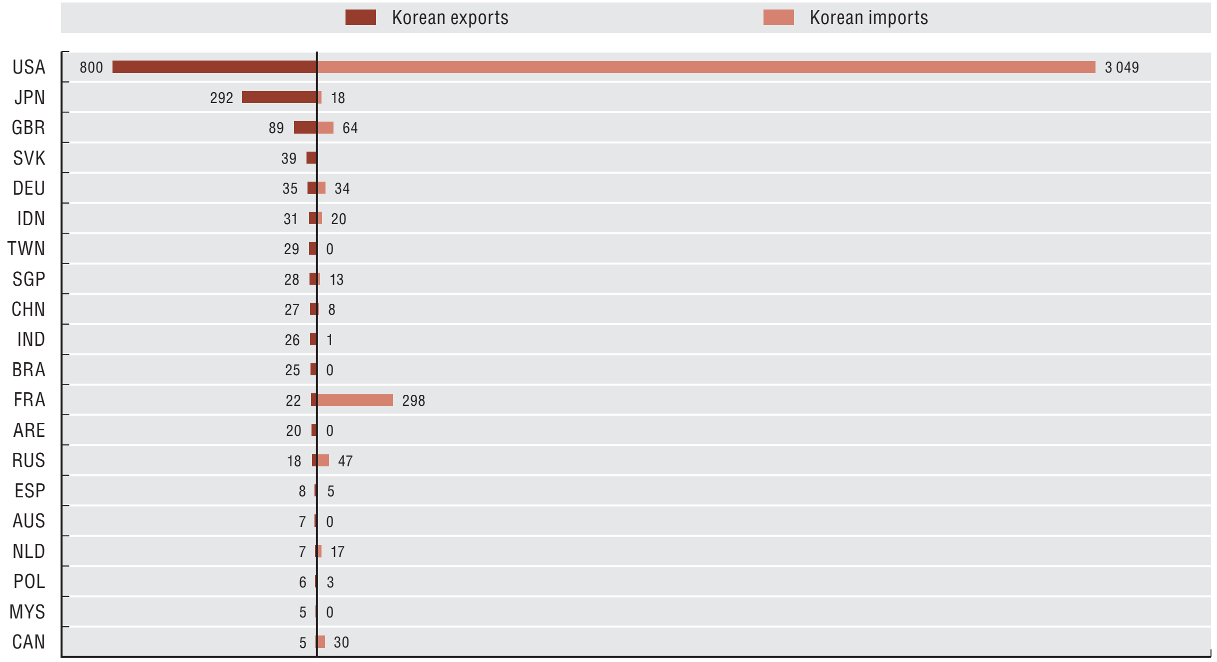
Number of employees, 2007-12



Source: Adapted from Korean Ministry of Science, ICT and Future Planning, 2013 and 2014.

32.5. Korea's main aerospace trade partners

In million USD (current), 2012



Source: OECD STAN Database, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142140

33. Norway

Institutional framework

Norway has been active in space for the last 50 years, driven in the beginning by solar research and sounding rocket activities on the launch facility of Andøya, an island in northern Norway. In the last decades, the country's geographic situation combined with low population density and strong maritime interests have made space applications particularly relevant. The proximity to the North Pole also makes it an important location for ground stations for polar-orbiting satellites. In 2013, the Norwegian government expressed a series of priorities and goals in a White Paper reviewing the national space policy for the first time in almost 30 years (Norwegian Ministry of Trade, Industry and Fisheries, 2013). The importance of space for economic growth and meeting societal needs was underlined.

The Norwegian Space Centre (NSC) is a government agency under the Ministry of Trade, Industry and Fisheries. The Agency carries out Norwegian space policy, co-ordinates all space-related activities and represents the country in the European Space Agency. In 2013, the total space-related institutional budget was NOK 788.9 million (USD 134 million). This included NOK 428 million (USD 73 million) in allocations to the European Space Agency and NOK 196 million (USD 33 million) to the European Union for their Galileo and Copernicus satellite programmes. It should be noted that Galileo and Copernicus are operated by the European Space Agency through its earth observation and navigation programmes. Norway also participates in several bilateral programmes with Canada, Switzerland, Germany, France and Sweden. In addition, the yearly contingent in Eumetsat (i.e. the European Organisation for the Exploitation of Meteorological Satellites) amounted to USD 6.4 million. All in all, of the Norwegian space budget was spent on international activities, with 13% devoted to the Norwegian Space Centre and support to national industry and infrastructure. In the period between 2007 and 2013, the Norwegian space-related budget increased by 38%, adjusted for inflation, reflecting mainly the increase in European allocations due to investment and operation costs of the Galileo (satellite navigation) and Copernicus (earth observation) programmes. In 2013, Norway made allocations to all of the voluntary programmes of the European Space Agency, with a main emphasis on earth observation, technology development and telecommunications.

Norwegian space industry

The Norwegian space industry has strong links to the defence industry, as well as the off-shore and maritime industries. An important space-related sector in Norway is satellite telecommunications and there are also a significant number of ground stations for polar-orbiting satellites on Norwegian territory (including Svalbard and Antarctica Troll station). The industry produces high-technology equipment to ground stations and there are Norwegian-built electronics on the Galileo-satellites (e.g. frequency generation units and Search and Rescue transponders). In 2012, annual space-related turnover amounted to approximately NOK 6 billion (USD 1 billion), 70% of which was generated by the telecommunications sector. In 2012, there were about 40 companies with a level of space activity. The manufacturing sector was dominated by one company (Kongsberg), both in terms of employment and turnover. Space manufacturing employment in industry amounted to at least 364 full-time-equivalents in 2013 (Eurospace, 2014). The number of people employed in the other Norwegian space-related services companies, as well as in universities and research institutions involved in space activities, is probably much higher.

Notes

33.1 and 33.2: EUMETSAT estimates for 2007 and 2008.

33.3: Several types of multi-annual adjustments and other mechanisms of the ESA financial system have an effect on yearly comparisons. ESA budgets and national allocations to ESA will not necessarily add up.

Key facts for Norway

Space budget as a share of GDP (2013): 0.025%.

Space budget per capita (2013): USD 18.1 (PPP).

Number of regional clusters including space industry: 1 (Norwegian Aerospace Cluster).

Share in scientific production in satellite technologies (2013): 1.08%.

Share of space-related patent applications filed under PCT (2009-11): 0.9%.

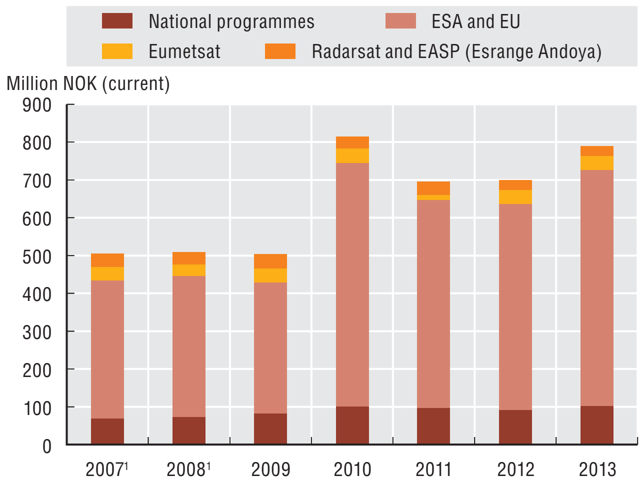
Subscribers of Direct-to-home (DTH) satellite services (2011): 655 000 (30.55% of television households).

Number of operational satellites: 4.

Student performance in science (PISA 2012 mean score): 495 (OECD average of 501).

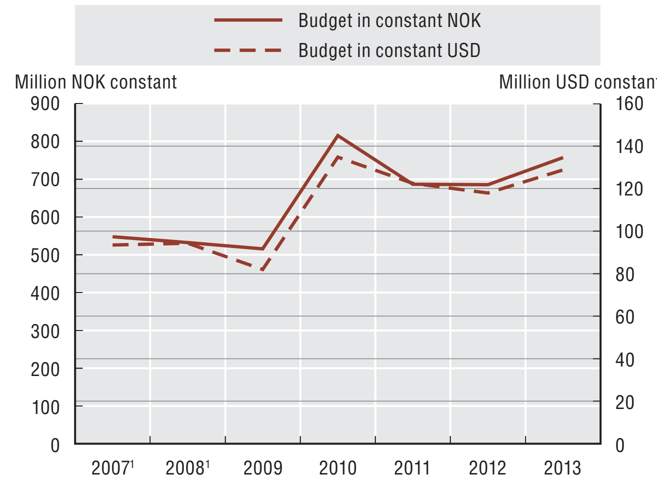
33.1. Norway's space budget

In million NOK (current), 2007-13



33.2. Norway's inflation-adjusted space budget

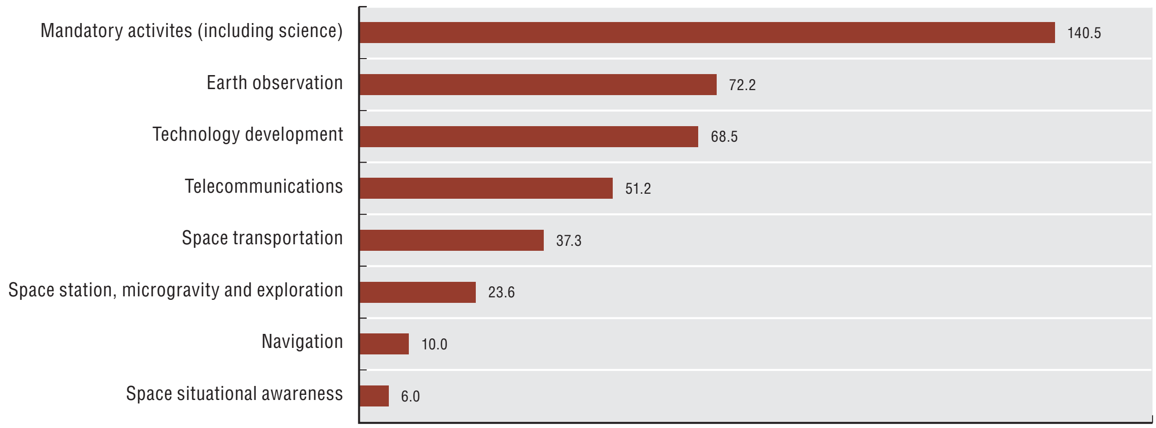
In constant NOK and USD million, 2007-13



Source: OECD calculations and data from the Norwegian Ministry of Industry and Trade and Fisheries, 2013b and previous years, and Norwegian Meteorological Institute, 2013 and previous years.

33.3. Norway's ESA allocations by main programmes

In million NOK (current), 2013



Source: Norwegian Ministry of Trade and Industry and Fisheries, 2013.

Norwegian aerospace industry

The aerospace industry is relatively small in Norway compared to other OECD countries. Norwegian aerospace companies are organised in the Norwegian Aerospace Industry Cluster, which counted 12 members in early 2013 (FSI, 2014). They specialise mainly in maintenance, repair and overhaul (MRO) for civil and military aircraft as well as the production of composites and structures for defence aircraft. According to OECD data, Norway exported aerospace goods for a total value of USD 517 million in 2012, while the value of imported goods amounted to USD 1.5 billion (OECD, 2014). Main export trading partners in 2012 were the United States, France and the United Kingdom. Imports from the United States accounted for 75% of total imports in 2012.

Sources

Eurospace, *www.eurospace.org/*.

Norwegian Ministry of Trade and Industry and Fisheries (2013a), Meld. St. 32 (2012–2013) Report to the Storting (White Paper): Between heaven and earth: Norwegian space policy for business and public benefit, Oslo, 26 April.

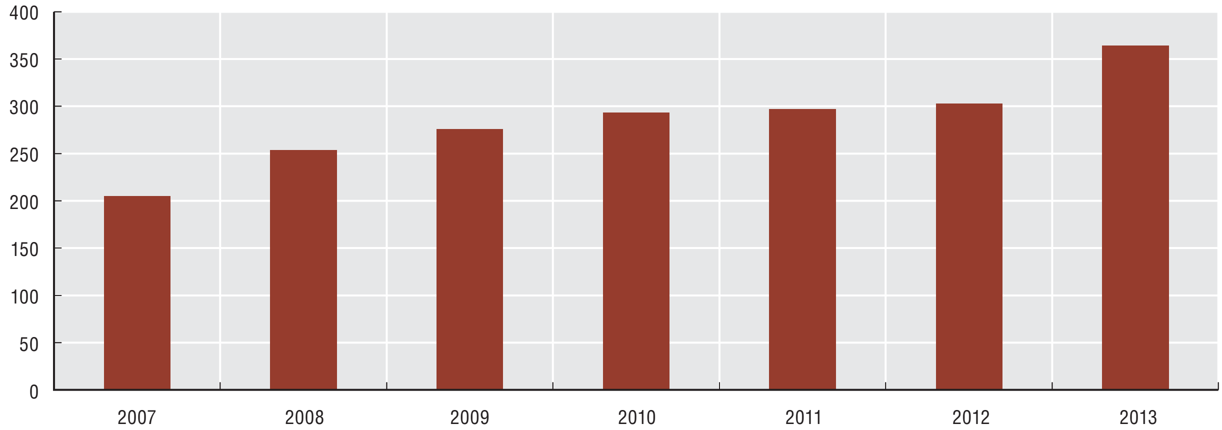
Norwegian Ministry of Trade and Industry and Fisheries (2013b), *Prop. 1 S (2013–2014): Proposisjon til Stortinget (forslag til stortingsvedtak)*, September, Oslo.

OECD *STAN Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd*.

OECD, *Main Science and Technology Indicators database, www.oecd.org/sti/msti*.

33.4. Space manufacturing industry employment in Norway

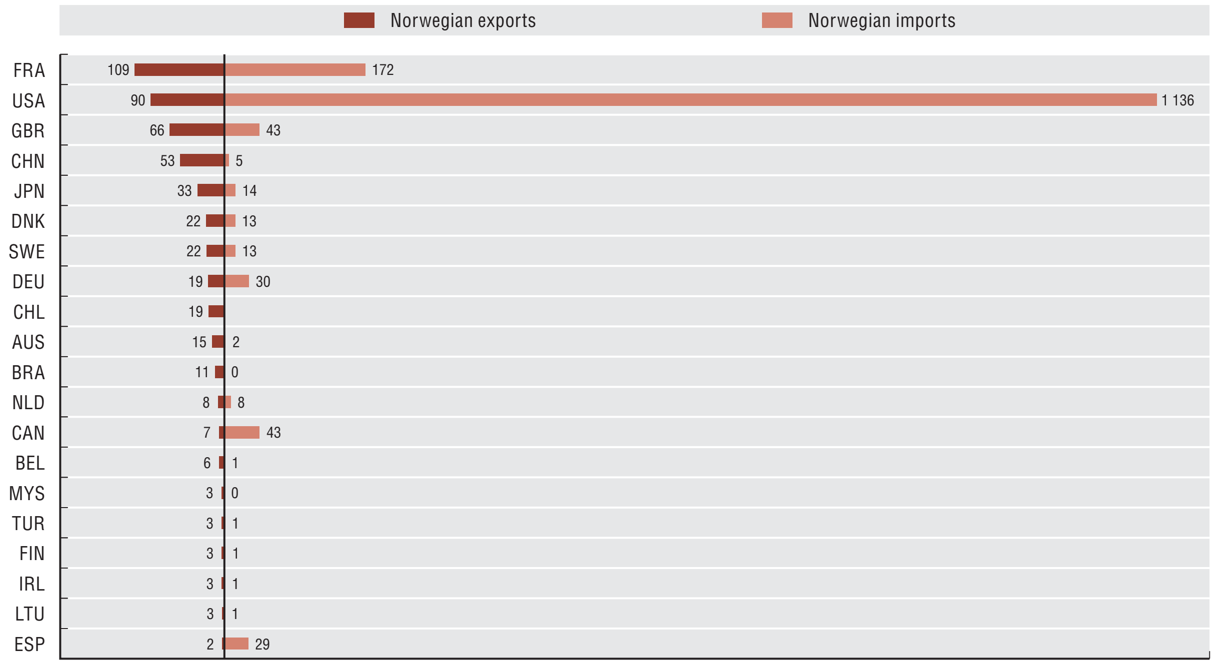
Number of full time equivalent, 2007-13



Source: Eurospace, 2014.

33.5. Norway's main aerospace trading partners

In million USD (current), 2012



Source: *OECD STAN Database*, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142159

34. Switzerland

Institutional framework

Switzerland has been active in European space activities since the early 1960s. It was a founding member of the European Space Agency (ESA) and co-chairs the ESA Council at ministerial level since 2012. The country takes a wide-ranging interest in space, while specialising in specific segments. Having longstanding capacities in space science, it has been a supporter of European launcher programmes from the beginning and has developed industry capabilities in this sector. Over time Switzerland has built up capacities in exploration and exploitation of space infrastructure, where applications and services are becoming increasingly important. Switzerland is also one of 10 countries supporting the European Southern Observatory (ESO) which operates two major observatories in Chile. The Swiss Space Office (SSO) is the administrative unit responsible for planning and implementing Swiss space policy, as defined by the Federal Council. It is under the direct authority of the Federal Department of Economic Affairs, Education and Research.

The Swiss Space Implementation Plan (SSIP) within the Education, Research and Innovation Framework 2014-2023 focuses on the consolidation of current fields of excellence; promotion of merging themes and additional measures including business incubation, internationalisation and export, application push and public-private-partnerships. Each year, approximately 90% of all R&D budgeted space-related funding is allocated to ESA, which makes the latter the *de facto* space agency of Switzerland, as is the case for many of the ESA member states. The Swiss institutional R&D space budget amounted in 2013 to CHF 158 million (USD 171 million), with 95% of the budget allocated to the European Space Agency (CHF 150 million/USD 162 million). Switzerland contributed to almost all of ESA's optional programmes, with a main emphasis on launchers, earth observation, technology and telecom (which accounted respectively 20.9%, 18.5% and 15.8%). The remaining CHF 8 million (USD 8.6 million) were budgeted for national complementary activities to support national pilot projects and research and technology activities (i.e. promoting the transfer of knowledge from academia to industry, stimulating co-operation between Swiss actors). In addition to this institutional R&D space budget (CHF 158 million), Switzerland contributed CHF 8 million (USD 8.5 million) to Eumetsat in 2013, and CHF 97 million to the European Union Global Navigation Satellite System Programmes (Galileo and Egnos), for the period 2008-2013 (about CHF 16 million per year).

Swiss space industry

Around 100 Swiss companies and academic institutes are engaged in space activities. The Swiss space sector has been supplying highly specialised and high-technology subsystems and components for the last 40 years, providing for example external fairings to all European-built launch vehicles (Ariane and Vega) since 1974 and to the American Atlas V launch vehicle. Other products include mechanisms for solar arrays, structures, electronics subsystems, mechanical and electrical ground system equipment, atomic clocks used in satellites and components for Mars planetary rovers and scientific instruments. The Swiss space-related companies and institutes are spread across the country, with a concentration near Zürich and in the French-speaking cantons. According to a Eurospace survey, about 800 persons were employed in space manufacturing industry in 2013 (the survey does not include all Swiss actors, in particular SMEs and institutes developing scientific instruments). More people are actually engaged in Swiss space activities in both the private sector and in research institutions. Preliminary estimates lead to several thousand employees. Net sales of the biggest space company in Switzerland (RUAG Space Division) amounted to approximately CHF 299 million (USD 322 million) in 2013, with 1 151 employees in three countries. Many Swiss institutions are conducting space-related research: the federal institutes of technology of Lausanne and Zürich, large universities (Bern, Geneva) and universities of applied science (UAS) (Lucerne), as well as various institutes, such as the World Radiation Center/Physikalisch-Meteorologisches Observatorium, the International Space Science Institute, or the Centre Suisse d'Electronique et Microtechnique.

Note

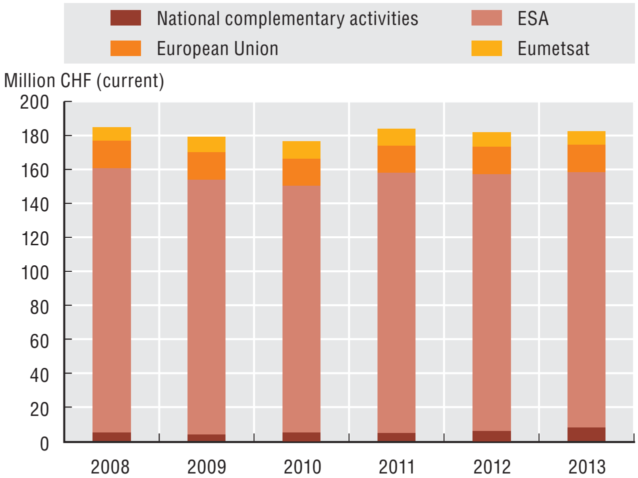
34.3: The Swiss institutional R&D space budget comprises ESA and the national complementary activities. The contribution to the European Union's Global Navigation Satellite System Programme has been equally distributed over the period 2008-13. Several multi-annual adjustments and other mechanisms of the ESA financial system have an effect on yearly comparisons. ESA budgets and national allocations to ESA will not necessarily add up.

Key facts for Switzerland

Space budget as a share of GDP in 2013: 0.03%.
Space budget per capita in 2013: USD 16.6 (PPP).
Number of regional clusters including space industry: n/a.
Share in scientific production in satellite technologies (2013): 1.67%.
Share of space-related patent applications filed under PCT (2009-11): 0.19%.
Subscribers of Direct-to-home (DTH) satellite services (2011): 253 000 (7.92% of television households).
Number of operational satellites: n/a.
Student performance in science (PISA 2012 mean score): 515 (above the OECD average).

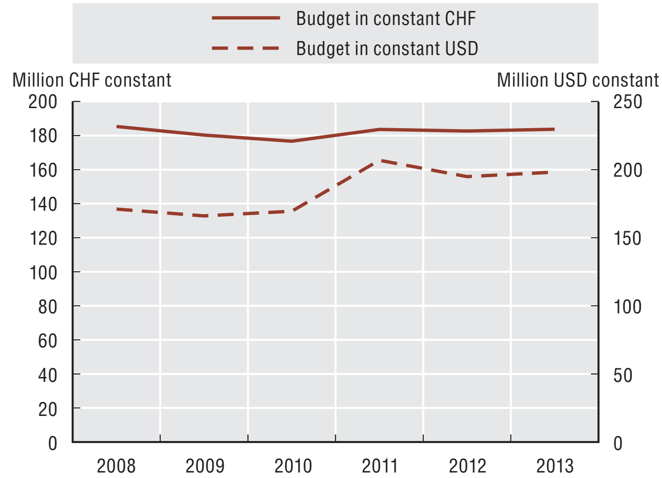
34.1. Switzerland's space budget

In million CHF (current), 2008-13



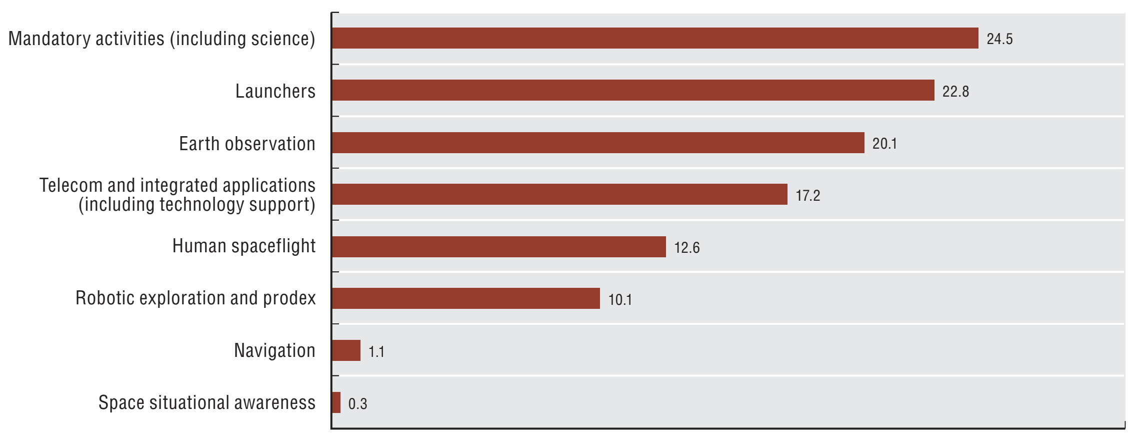
34.2. Switzerland's inflation-adjusted space budget

In million constant CHF and USD, 2008-13



34.3. Switzerland's ESA allocations by main programmes

In million EUR (current), 2013



Source: Adapted from the Swiss Federal Finance Administration (FFA), 2014 and ESA, 2013.

Swiss aerospace industry

Switzerland has a small but dynamic aerospace sector, focussing on aircraft manufacturing and Maintenance, Repair and Overhaul (MRO) activities. These two industries employed, according to the Swiss Statistical Office, about 3 000 full-time-equivalents in 2011 in manufacturing and 5 500 full-time equivalents in MRO, mainly in the cantons of Basel, Zurich and Nidwalden. Activities include manufacturing structural components, aircraft and helicopter systems integration. Aerospace exports accounted for 1% of total Swiss exports in 2012, at USD 2.2 billion (OECD, 2013). Main export markets were the United States, the United Arab Emirates, France and the United Kingdom. The country imported aerospace products for a total value of USD 2.4 billion, mainly from France (accounting for a third of all imports), the United Kingdom and the United States.

Sources

Eurospace, *www.eurospace.org*.

OECD STAN *Bilateral Trade Database by Industry and End-use (BTDIxE)*, data extracted April 2014, *www.oecd.org/sti/btd*.

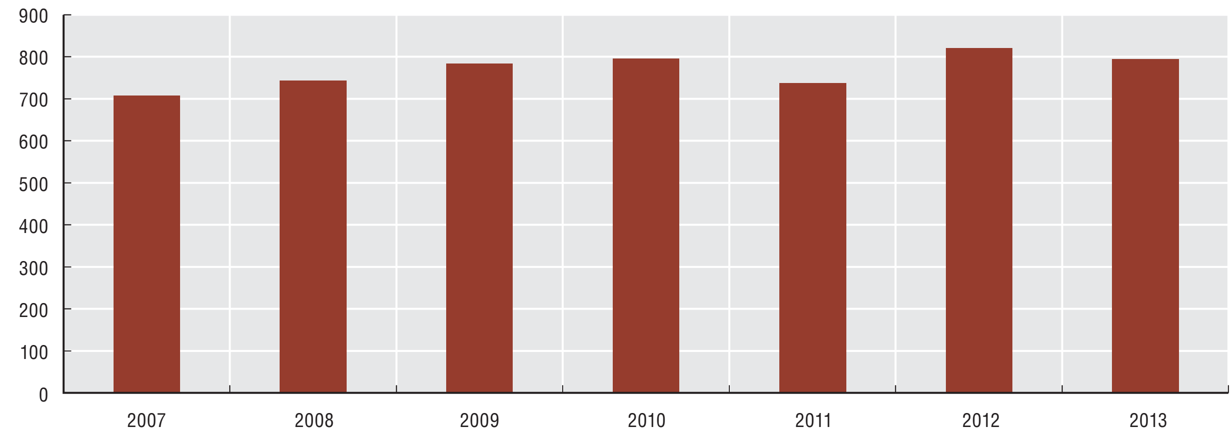
OECD, *Main Science and Technology Indicators database*, *www.oecd.org/sti/msti*.

Swiss Federal Finance Administration (FFA) (2014), budgets & suppléments, 2008-2013, Bern.

Swiss Statistical Office (2011), Arbeitsstätten und Beschäftigte bei Jahr, Wirtschaftsart (NOGA 2008), updated 31.12.2011, Bern.

34.4. Space manufacturing industry employment in Switzerland

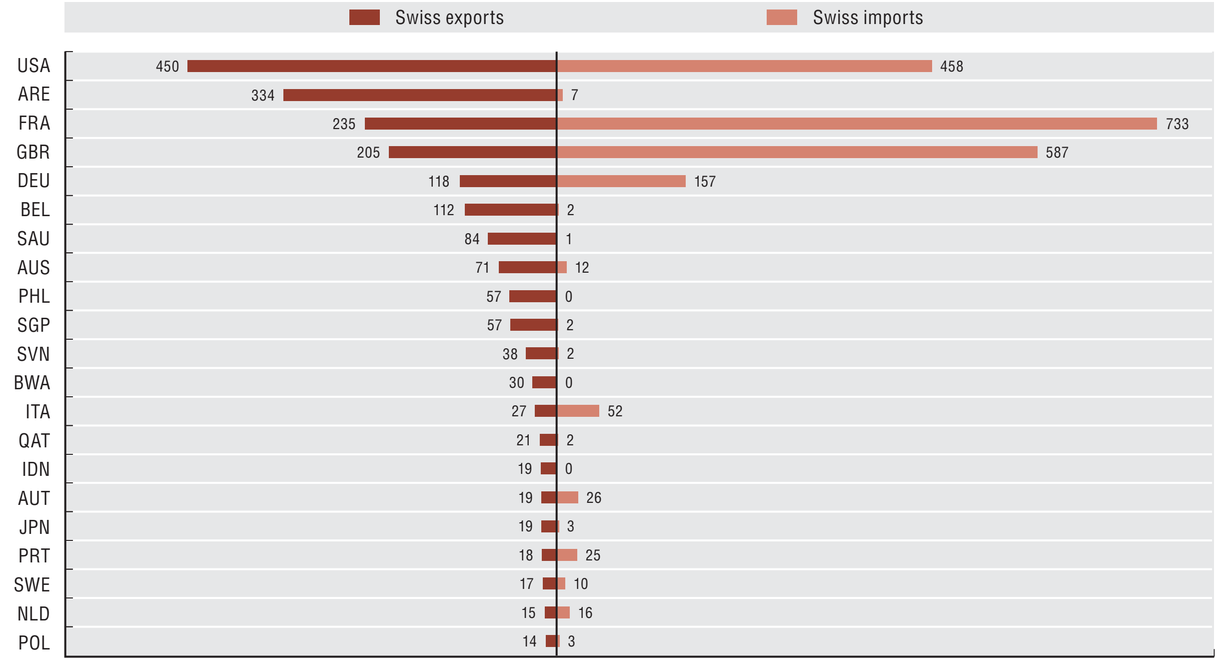
Number of full time equivalents, 2007-13



Source: Eurospace, 2014.

34.5. Switzerland's main aerospace trading partners

In USD million (current), 2012



Source: *OECD STAN Database*, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142178

35. United Kingdom

Institutional framework

The United Kingdom is the fourth-biggest contributor to the European Space Agency (ESA), after Germany, France and Italy. The country has a strong space-related scientific and industrial base, particularly in satellite manufacturing and downstream applications. The development of the space sector is today considered an important part of UK industrial policy, with the expressed objectives to reinforce private sector research, support foreign trade and strengthen national and international public space organisations. This could be accompanied by an increase in government allocations from 2014 onwards (UK Space Agency, 2014).

The UK Space Agency is an executive agency of the Department for Business, Innovation and Skills (BIS) and the main government body responsible for civil space policy in the United Kingdom. The Agency represents the United Kingdom at ESA and co-ordinates and funds national research projects. The 2013 budget (fiscal year 2013-14) of the UK Space Agency amounted to GBP 308 million (USD 481 million), with GBP 53 million (USD 83 million) devoted to national programmes, and GBP 251 million (USD 392 million) allocated to the European Space Agency. In addition, the United Kingdom allocated about GBP 30 million (USD 50 million) to the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). ESA allocations constituted 81% of the total space-related budget in 2013. The national programmes focus on research and industry support to public and private institutions and companies. When adjusted for inflation, the UK space-related budget increased by 17% between 2007 and 2013, with the allocations to ESA and to national support programmes increasing by 16% and 13% respectively.

UK space industry

There were about 230 organisations active in the UK space sector in 2013, located mostly in the south-eastern part of the country and London. In addition, the European Centre for Space Applications and Telecommunications (ECSAT) is a newly established European Space Agency facility in Harwell, near Oxford, which is aiming to become an important hub for space activities and business. Aside from a strong scientific community involved for decades in many major international space science projects, the UK research institutions and companies have developed early expertise in satellite and instruments manufacturing (e.g. small satellites). This is still an important sector in the industry, although downstream services provide the bulk of commercial activities. Eurospace's annual business survey, limited in scope to industry space manufacturing activities, counted for instance some 3 612 employees in 2013, although this does not into account many other actors involved in UK space activities. Like for other countries, UK universities and research institutions provide key competencies. The 2011 business survey of the UK Space Agency uses a wider definition of the space economy (upstream and downstream activities) and found that 29 000 people were employed in space-related activities (UK Space Agency, 2012). In terms of turnover, the telecommunications sector dwarfs the other industry segments, with major UK operators providing mobile satellites services (e.g. Inmarsat) , and large media groups providing satellite television broadcasting services to customers (e.g. BskyB).

Notes

35.1 and 35.2: United Kingdom's fiscal year runs from 1 April to 31 March, and EUMETSAT estimate for 2013.

35.3: Several kinds of multi-annual adjustments and other mechanisms of the ESA financial system affect yearly comparisons. ESA budgets and national allocations to ESA will not necessarily add up.

Key facts for the United Kingdom

Space budget as a share of GDP (2013): 0.0146%.

Space budget per capita (2013): USD 5.3 (PPP).

Number of regional clusters including space industry: 1 (Harwell).

Share in scientific production in satellite technologies (2013): 7.22%.

Share of space-related patent applications filed under PCT (2009-11): 2.62%.

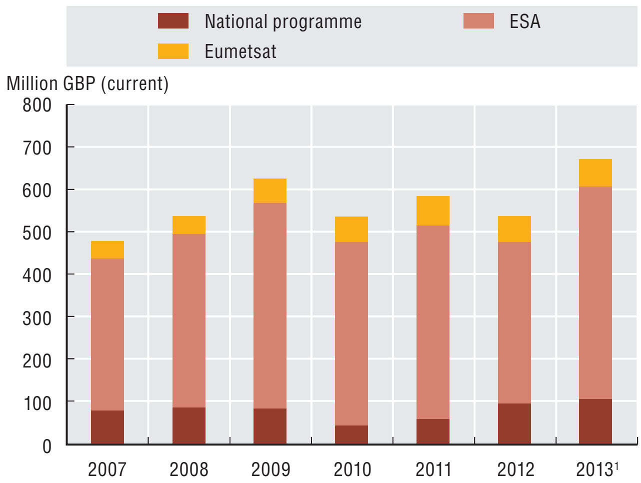
Subscribers of Direct-to-home (DTH) satellite services (2011): 11.2 million (42.64% of television households).

Number of operational satellites: 25.

Student performance in science (PISA 2012 mean score): 514 (above the OECD average).

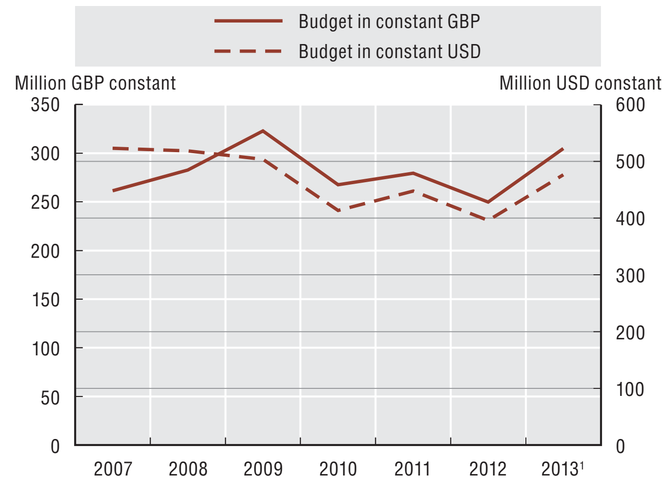
35.1. United Kingdom's space budget

In million GBP (current), 2007-13



35.2. United Kingdom's inflation-adjusted space budget

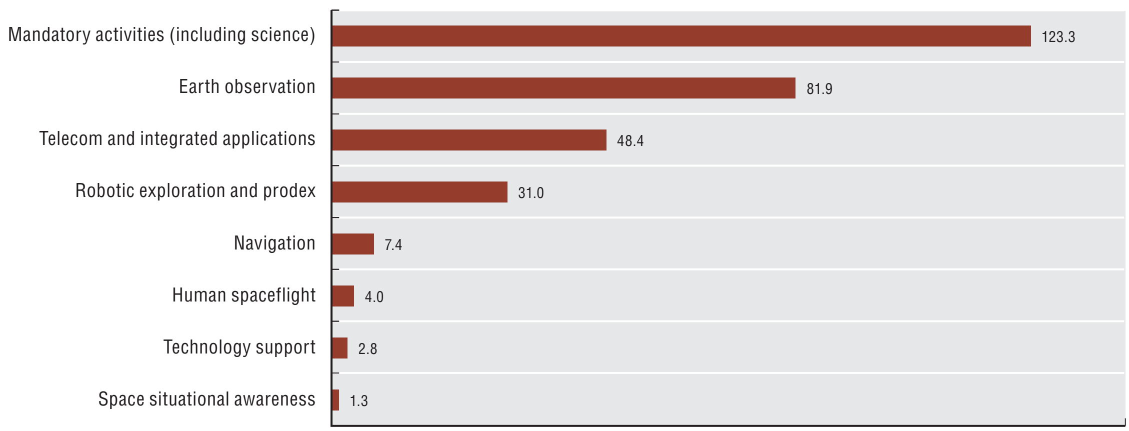
In constant GBP and USD million, 2007-13



Source: OECD calculations based on UK Space Agency, 2014 and previous years.

35.3. United Kingdom's ESA allocations by main programmes

In million EUR (current), 2013



Source: ESA, 2013.

UK aerospace industry

The UK aerospace sector may consist of more than 3 000 firms, according to the UK aerospace industry association with civil aerospace generating GBP 22.1 billion (USD 35 billion) in revenues in 2011, employing more than 100 000 people (ADS, 2012). Manufacturing sites are spread across the country, with companies located in the North-west, East Midlands, Wales, the Southwest and the South-east. Key competence areas of the UK aerospace industry include wing design and assembly, propulsion and avionics. In 2012, the UK exported aerospace goods for a total value of USD 34 billion, and imported goods for USD 26 billion. Main trading partners were the United States, Germany, France and Canada.

Sources

ADS (2012), UK Aerospace Survey 2012, London.

Eurospace, *www.eurospace.org*.

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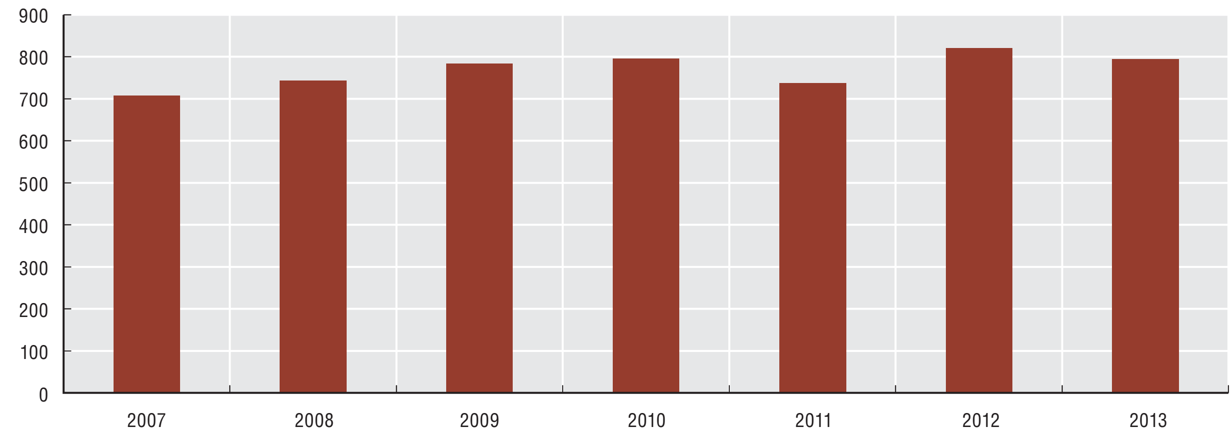
UK Space Agency (2012), The Size and Health of the UK Space Industry, October.

UK Space Agency (2014), Government Response to the UK Space Innovation and Growth Strategy 2014-2030: Space Growth Action Plan, April, Swindon.

35.4. Space manufacturing industry employment in the United Kingdom

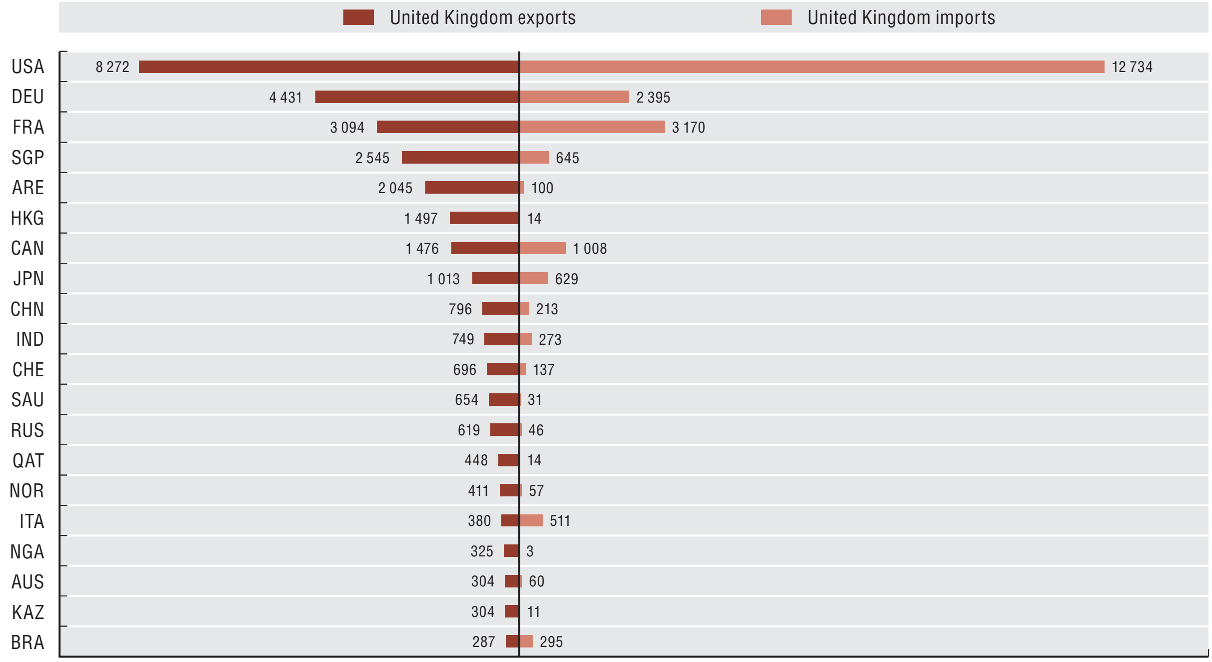
Number of full time equivalents, 2007-13



Source: Eurospace, 2014.

35.5. United Kingdom's main aerospace trade partners

In million USD (current), 2012



Source: *OECD STAN Database*, 2014, *www.oecd.org/sti/btd*.

StatLink http://dx.doi.org/10.1787/888933142189

36. United States

Institutional framework

The United States has the largest space programme in the world, involving several civilian and defence-related organisations. Major organisations with space missions include the National Aeronautics and Space Administration (NASA), the Department of Defense, the Department of Energy, the Department of Transportation (Office of Commercial Space Transportation), the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and the Department of the Interior's Geological Survey (USGS).

The main priorities of the US space programme are set in the 2010 National Space Policy, which covers commercial, civil, and national security space activities. It is completed by other sector-specific policies, such as as the November 2013 National Space Transportation Policy. The institutional budget covering both public civilian and military space activities amounted to about USD 39 billion (current) in 2013. It did not include classified military programmes on space, which has been historically an important source of contracts for the US industry. NASA has 18 centres and facilities in 13 states. The Agency had a budget request totalling USD 17.7 billion in 2013, down from USD 18.7 billion requested in 2012 (actual spending amounted to USD 17.8 billion), and employs some 17 480 civil servants. NASA's budget is divided in different key segments. The biggest budget lines comprised in 2013 the science programme (particularly the earth and Planetary Science programmes), space operations (mainly the International Space Station), and exploration, which included commercial spaceflight. In terms of major procurement for US agencies, launching governmental satellites is a key item. The US government is expected to spend around USD 44 billion in launch costs over the next 5 years (GAO, 2013). Procurement for launch related activities is trending upward with annual funding increasing nearly 19% from 2014 to 2018, although some savings were achieved through multi-year block buy acquisition strategy. Procurement of commercial launch services is expected to represent about USD 28 billion (65% of total) for all agencies (e.g. this includes NOAA funds to procure launch vehicles for weather satellites), while Research, Development, Test, and Evaluation funding represents about USD 11 billion (26% of total) with NASA investing in the Space Launch System (SLS). Other costs include civil service and military personnel, operations and facilities construction and maintenance.

US space industry

Industry-wise, the US space sector is part of a much larger aerospace and defence manufacturing base. In terms of geographical distribution, the space industry is located throughout the United States, with a particularly large presence in California, Texas, Florida, New Mexico, Colorado and Alabama. As for other countries, disentangling statistics specifically on the space industry remains challenging. In the wake of the end of the space shuttle era, the Department of Commerce (DoC) with NASA and other agencies conducted in 2011-13 a large US Space Industry "Deep Dive" Assessment. Surveying a large sample of organisations, the DoC found that some 348 00 full time employees were dependent in 2012 on US government space programmes. This includes personnel in US governmental agencies, commercial companies (including subcontrators to the space manufacturing industry, providing electronics, engineering and other services, etc.), universities and non-profit organisations. This is usefully complemented by data from the US Bureau of Labor Statistics/Aerospace Industry Association (AIA) which encompass the "core" or "pure-play" space manufacturing sector, representing some 73 000 full time equivalent employees (see graph and note below).

Key facts for the United States

Space budget as a share of GDP in 2013: 0.23%.

Space budget per capita in 2013: USD 123.2 (PPP).

Number of regional clusters including space industry: ~+15 states with space industry presence.

Share in scientific production in satellite technologies (2013): 28.2%.

Share of space-related patent applications filed under PCT (2009-11): 33.58%.

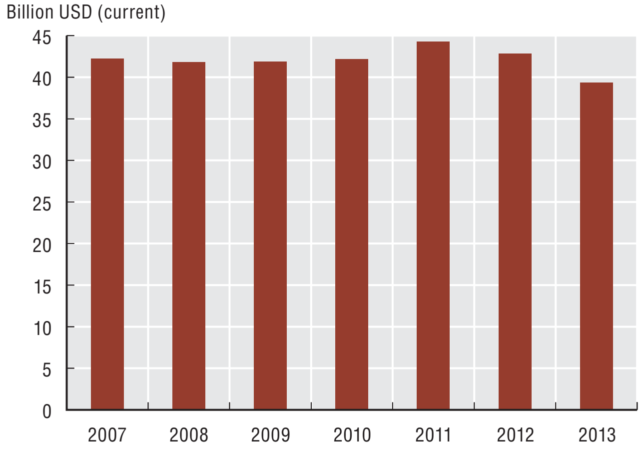
Subscribers of Direct-to-home (DTH) satellite services (2011): 34 million (29.56% of television households).

Number of operational satellites: 415.

Student performance in science: 497 (OECD average - mean score 501).

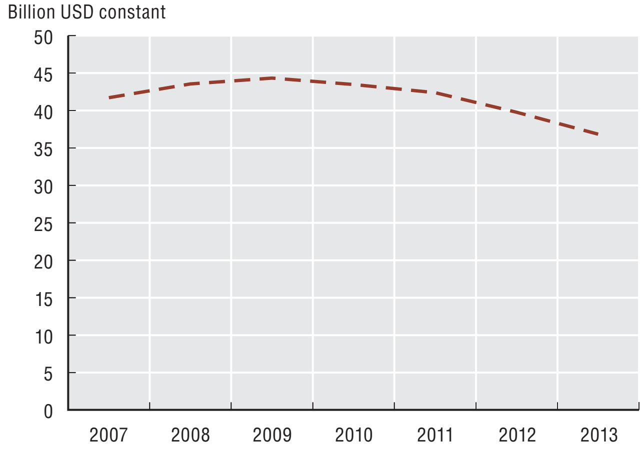
36.1. US space budget estimates

In billion USD (current), 2007-13



36.2. US inflation-adjusted space budget

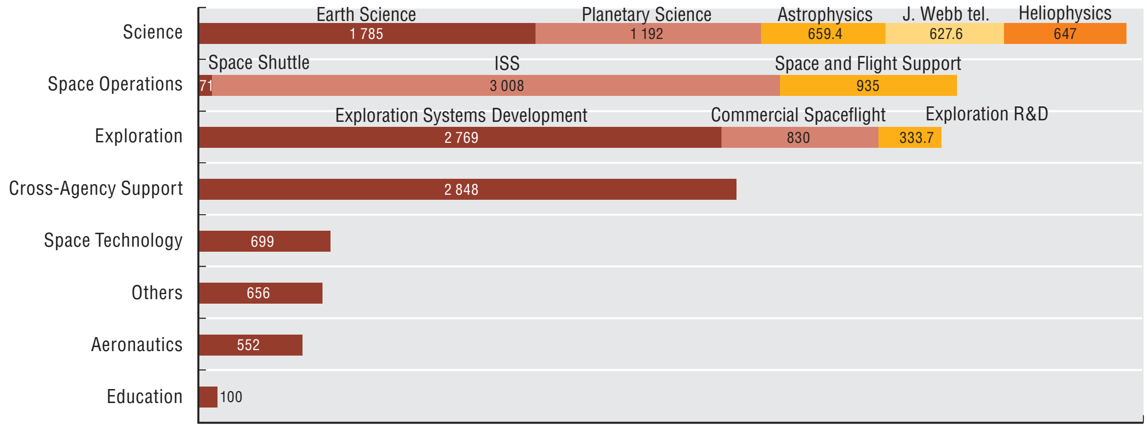
In billion USD (constant), 2007-13



Source: OECD calculations based on relevant space-related budgets from NASA, Department of Defense, Department of Commerce (NOAA), Department of Transportation (Federal Aviation Administration), Department of the Interior (US Geological Survey), and OECD consumer prices (all items), extracted from MEI database, June 2014.

36.3. NASA budget, breakdown by main programmes

In million USD (current), 2013



Source: Adapted from NASA, 2014. Note: "Others" include the budget lines: Construction, Environmental Compliance and Restoration, and Inspector General.

StatLink http://dx.doi.org/10.1787/888933142197

Employment numbers could be higher if other statistical categories are included (e.g. the category: Navigational, measuring, electromedical, and control instruments instruments manufacturing). In terms of revenues, the AIA reports space industry sales of around USD 43 billion in 2012. With its wider scope, including all commercial companies providing services to the core space industry, as well as the space manufacturing industry itself, the DoC found sales of around USD 52.1 billion in 2012. In terms of customers, these sales are distributed amongst US governmental defene programmes (41%), US governmental civilian programmes (33%) and commercial customers (25%) (U.S. Department of Commerce, 2013).

US Aerospace industry

Finally, a brief overview of the US aerospace sector provides the broader industry context for many space-related activities, since many of the large aerospace groups are involved in both aeronautics and space systems. Based on BLS data, some 3 100 commercial companies are active in the US aerospace sector, with around 497 000 employees in 2013 (BLS, 2014). In terms of revenues, when aggregating civilian and defence-related activities, sales amounted to some USD 222 billion in 2012, and USD 220 billion in 2013 (AIA, 2013). As of end-2013, the backlog for the US civil transport aircraft sector totalled some 4 700 aircraft, worth USD 344 billion (this is equivalent to production of around seven years), with 66% of those orders from foreign carriers. This can also be seen in terms of exports, as data coming from OECD databases show main US aerospace customers located in Japan, France, China and the United Arab Emirates, all homes to major airlines. In terms of major US imports, Japan, the United Kingdom and Germany are producing many components for the industry, while in the case of France and Canada, they have manufacturers of aircraft regularly purchased by US airlines. In 2012, the United States exported aerospace goods for a total value of USD 106 billion (more than a third of total OECD aerospace exports) and imported goods for USD 40 billion.

Sources

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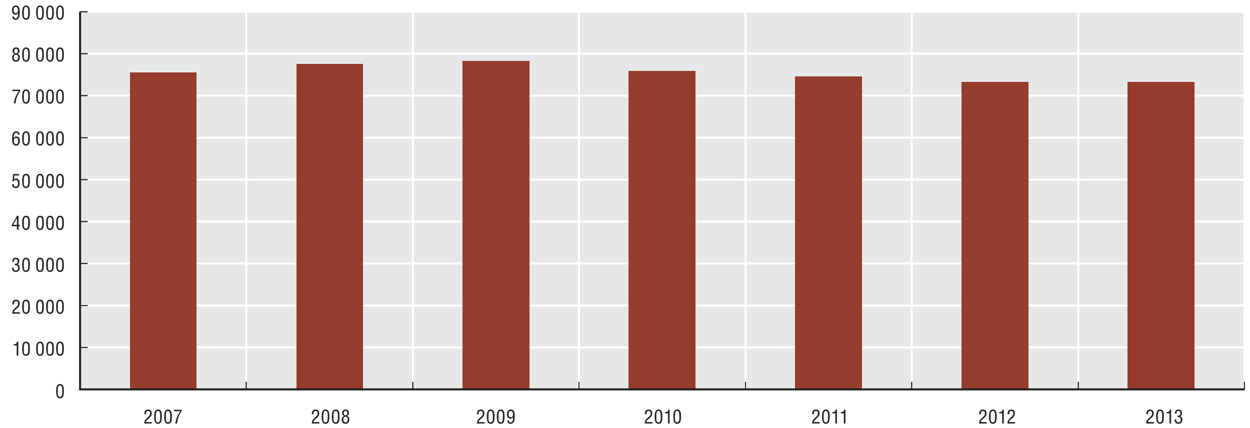
36.4. Space manufacturing employment in the United States

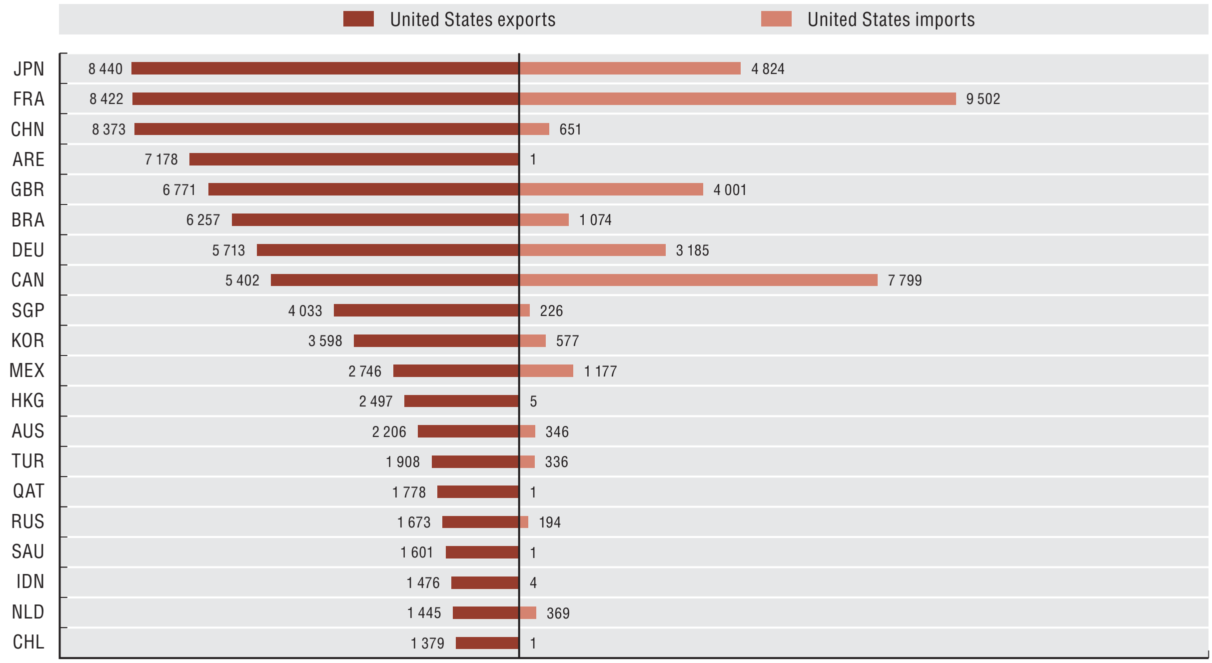
Number of full time equivalents, 2007-13



Source: Adapted from Aerospace Industry Association (AIA), 2013 and previous, based on data from the U.S. Bureau of Labor Statistics. Three industry groupings from the North American Industrial Classification System (NAICS) are used, which cover more than only space manufacturing: 336414 (Guided missiles and space vehicle manufacturing), 336415 (Guided missiles and space propulsion unit and propulsion unit parts manufacturing), and 336419 (Other guided missile and space vehicle parts and auxiliary equipment manufacturing).

36.5. United States' main aerospace partners

In million USD (current), 2012



Source: OECD STAN Database, 2014, *www.oecd.org/sti/btd.*

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