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# Space Policies, Issues and Trends in 2015-2016

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# Introduction

When reading this issue of Space Policy, Issues and Trends it should be kept in mind that there are remarkable variations and lack of consistency in the publicly available figures on space activity. This is attributable to differing methodologies used by data providers, currency conversion issues, and time period variances. The lack of consistency starts at the very top, where there can be differences of tens of billions of Euros between estimates of the overall size of the global space economy; and it continues down to company-to-company comparisons, where different accounting practices produce different sums. But it is, of course, commonplace that differences in purchasing power in different economies, and differences in wage and infrastructure cost make one-to-one comparisons very difficult. Also, some countries are very restrictive in providing institutional data, for instance on defence spending.

Notwithstanding the many data uncertainties, this issue of Space Policy, Issues and Trends identifies important trends and developments. As Winston Churchill noted, statistics must be taken with a grain of salt, yet purely by looking at relativities much can be learned.

This is not a reason to be complacent about the precision of figures. Space has great societal importance and the space community owes it to political decision makers to be able to provide standardised, accurate figures. In this aspect, the United States is clearly ahead of the game, and Europe must perhaps consider whether institutions such as Eurostat should not become more involved in data collection and processing for the space field

# 1. Global Political and Economic Trends

## 1.1 Global Economic Outlook

The United Nations Annual Report "World Economic Situation and Prospects" reported a slight stumble in global growth by the end of 2015, as the persistent effects of the financial crisis in 2007 continued to discourage investment and global growth. In mid-2015, the growth of World Gross Product (WGP) was estimated to be 2.8%, yet weak aggregate demand, falling commodity prices and increasing financial market volatility in major economies resulted in a year-end revision of WGP growth to 2.4%.[1]

Developed economies contributed more to WGP growth, reaching a 1.9% increase in global output in 2015; they will likely continue to pick up momentum in 2016, surpassing 2%, which has not been seen since 2010. In the eurozone, new EU Members showed the most growth at 3.2%, while Western European economies continued to be the main drivers of growth in the region with 1.8% for 2015; and the European Union as a whole reached 1.9% for 2015. U.S. growth in global output reached 2.4% in 2015, in line with the 2.4% in 2014, and is expected to contribute more in 2016. Japan's global output also increased by 0.5% in 2015, a notable change from the 0.1% decrease in 2014; Japan's GDP growth should reach 1.3% in 2016.[2]

Growth slowed in developing and transition economies to 3.8% and -2.8% respectively in 2015, due to the earlier-mentioned headwinds (i.e. sharply lower commodity prices, large capital outflows, and increased financial market volatility). While China may have contributed to a reduction of growth in East and South Asia, the region will likely remain the fasted growing as many of the region's economies will benefit from importing low-cost oil, metals, and food commodities. In contrast, Russia and Brazil were mired in severe economic downturns, accompanied by elevated inflation, reaching -3.8% and -2.8% in 2015 respectively.[3]

Generally less restrictive fiscal and still accommodative monetary stances worldwide are likely to support WGP growth by 2.9% in 2016 and 3.2% in 2017. That increased growth is also predicated on the easing of downward pressures on commodity prices and on the anticipated pace of normalization of the United States monetary policy stance that should help to reduce policy uncertainties. Yet, amid the moderate pace of global growth and in an environment of weak investment, employment figures continue to fall short of closing the gap in the employment rate that had opened up during the global financial crisis. In developed economies, particularly in the euro area, the pattern of work has been shifting towards more part-time employment, which raises concerns about job security, working poverty, and low long-term earnings. Moreover, given the sharp economic slowdown and declining labour force participation in several economies in the developing world, masked by large informal sectors in these regions, employment opportunities in the developing world for 2015 are likely to have deteriorated. The persistence of these factors may undermine the United Nations 2030 Agenda for Sustainable Development, which focuses on promoting "inclusive and sustainable economic growth, employment and decent work for all".[4]

## 1.2 Political Developments

### 1.2.1 Geopolitics

A number of significant world events in 2015 remained unresolved by year's end.

While the United States sought to unseat Islamic State (ISIS) terrorists from occupied territory in Syria throughout 2015, Russia's surprise airstrike intervention starting in September 2015 worked to muddle the opera-

[1] "World Economic Situation and Prospects 2016." 30 Nov. 2015. United Nations 20 June 2016 <http://www.un.org/en/development/desa/policy/wesp/wesp_current/2016wesp_full_en.pdf>.
[2] Ibid. at 2.
[3] Ibid.
[4] "World Economic Situation and Prospects 2016." 30 Nov. 2015. United Nations 20 June 2016: 1-8 <http://www.un.org/en/development/desa/policy/wesp/wesp_current/2016wesp_full_en.pdf>.

tion, as the U.S. targeted ISIS forces while Russian counterparts aimed at Syrian rebel groups seeking to oust Syria's President and long-time Russian ally, Bashar al-Assad. Russia's military operations were not coordinated with the U.S. and its allies which raised concerns of unintended confrontations, such as on 24 November when Turkish F-16s shot down a Russian Su-24 fighter jet following repeated warnings not to fly over Turkish airspace.[5] As the campaign went on throughout the year, ISIS terrorists also managed to carry out attacks in France, Turkey, and in the United States.[6] France experienced its first shock at the beginning of 2015, when gunmen attacked its satirical magazine Charlie Hebdo offices and a Jewish supermarket in Paris on 7 January 2015.[7] On 13 November 2015, three suicide bombings took place outside the Stade de France stadium during a football match while other ISIS fighters attacked young concertgoers, resulting in a death toll of 130 people, with another 351 injured.[8] In Turkey, a suicide-bomber with reported links to ISIS killed a group of 32 youth activists on 22 July 2015,[9] while in the United States, a self-radicalized couple killed 14 people and wounded another 21 in California on 4 December 2015.[10]

In Europe, Greece's debt crisis came back into the spotlight at the beginning of 2015 with the election of Syriza party leader Alexis Tsipras, who pledged to renegotiate the terms of the €240 billion ($268 billion) bailout Greece received in 2010 in the wake of the financial crisis.[11] His anti-austerity position worried investors and euro-zone supporters, and following a series of negotiations with Europe's so-called 'Troika' (EU, IMF, and ECB) and a four-month extension of the bailout to 30 June 2015, it became apparent that Greece might default on its June payment if it did not receive an infusion of cash from the final bailout instalment. The deadline was not met, and with Greek banks closed along with the threat of financial collapse and complete exit from the euro zone looming, Tsipras agreed to the Troika's conditions on measures, including taxes and pensions, along with intensive international oversight in order to qualify for the aid.[12] Yet even with its course correction, Greece's struggles with its bailout looked to be headed toward another 'Grexit' scenario from the eurozone near the end of the year[13], just as Europe was faced with a wave of refugees escaping the calamity in Syria and nearby regions.[14]

Early in 2015, an unprecedented influx of migrants began crossing the Mediterranean and travelling through the Balkans to enter Europe - sometimes at their peril.[15] In addition to violence in Iraq and Afghanistan, and abuses in Eritrea, the ongoing conflict in Syria became the biggest driver of migration in the year, amounting to a total of more than 1 million migrants coming by sea and land; by comparison, 280,000 migrants had entered Europe by sea and land in 2014.[16] More than 800,000 people crossed by sea from Turkey to Bulgaria and Greece – half of whom were Syrian asylum seekers – other migrants travelled by water to Spain and Italy from Morocco, Tunisia, Libya, and Egypt, while just 34,000 migrants crossed by land to Bulgaria or Greece travelling from Turkey.[17] European countries struggled with the influx, sparking divisions in the EU on how best to deal with resettling people; Germany alone received more than 476,000 asylum applications in 2015. As tensions rose in the EU due to the disproportionate burden placed on some of its member states, minis-

[5] "Turkey's downing of Russian warplane - what we know." 1 Dec. 2015. BBC News 23 June 2016 <http://www.bbc.com/news/world-middle-east-34912581>.
[6] Lindsay, James M. "Top Ten Most Significant World Events in 2015." 15 Dec. 2015. Council on Foreign Relations 22 June 2016 <http://blogs.cfr.org/lindsay/2015/12/15/ten-most-significant-world-events-in-2015/>.
[7] "Charlie Hebdo attack: Three days of terror." 14 Jan. 2015. BBC News 23 June 2016 <http://www.bbc.com/news/world-europe-30708237>.
[8] Fuller, Jaime. "Paris Attacks Death Toll Rises to 130." 20 Nov. 2015. New York Magazine 23 June 2016 <http://nymag.com/daily/intelligencer/2015/11/paris-attacks-death-toll-rises-to-130.html>.
[9] "Suruc massacre: 'Turkish student' was suicide bomber." 22 July 2015. BBC News 23 June 2016 <http://www.bbc.com/news/world-europe-33619043>.
[10] Schmidt, Michael S., and Richard Pérez-Peña. "F.B.I. Treating San Bernardino Attack as Terrorism Case." 4 Dec. 2015. The New York Times 23 July 2016 <http://www.nytimes.com/2015/12/05/us/tashfeen-malik-islamic-state.html>.
[11] "Greece election: Syriza leader Tsipras vows to end austerity 'pain'." 26 Jan. 2015. BBC 22 June 2016 <http://www.bbc.com/news/world-europe-30978052>.
[12] Daley, Suzanne and Liz Alderman. "Premier of Greece, Alexis Tsipras, Accepts Creditors' Austerity Deal." 13 July 2015. The New York Times 22 June 2016 <http://www.nytimes.com/2015/07/14/world/europe/greece-debt-plan.html>.
[13] Khan, Robert. "Greece's Bailout Dead End." 9 Nov. 2015. Council on Foreign Relations 23 June 2016 <http://blogs.cfr.org/kahn/2015/11/09/greeces-bailout-dead-end/>.
[14] Lindsay, James M. "Top Ten Most Significant World Events in 2015." 15 Dec. 2015. Council on Foreign Relations 22 June 2016 <http://blogs.cfr.org/lindsay/2015/12/15/ten-most-significant-world-events-in-2015/>.
[15] "European leaders fret over porous borders." 12 Mar. 2015. CBS News 23 June 2016 <http://www.cbsnews.com/news/eu-borders-isis-migrants-refugees-smuggling-human-trafficking-libya/>.
[16] "Migrant crisis: Migration to Europe explained in seven charts." 4 Mar. 2016. BBC News 23 June 2016 <http://www.bbc.com/news/world-europe-34131911>.
[17] "Migrant crisis: One million enter Europe in 2015." 22 Dec. 2015. BBC News 23 June 2016 <http://www.bbc.com/news/world-europe-35158769>.

ters had to find a way to relocate and integrate refugees throughout Europe; of the 292,540 asylum applications approved in 2015, 48.2% were granted by Germany, 11.0% Sweden, 10.1% Italy, 7.1% France, 5.6% Netherlands, 4.8% UK, with the remaining 13.3% granted by other EU member states.[18]

Iran and the five permanent members of the United Nations Security Council[19] (UNSC) plus Germany (P5+1) reached a long awaited agreement on scaling back Iran's Nuclear Programme on 14 July 2015. In development since 2003, the agreement, known as the Joint Comprehensive Plan of Action (JCPOA), was endorsed by the UNSC by 20 July 2015.[20] Yet, concerns over the JCPOA's viability existed while the agreement underwent a 60-day Congressional Review Period in the U.S., during which Republicans in both the House and Senate sought unsuccessfully to block the agreement through various motions.[21] In return for sanctions relief, Iran has agreed to give up 97% of its stockpile of enriched uranium, cut its number of centrifuges by two-thirds, shut down a heavy water reactor, and allow onsite inspections by the International Atomic Energy Agency (IAEA), with some provisions lasting into 2040.[22]

China continued to rapidly form 7 new islands, piling sand dredged from the ocean floor on what were previously coral reef beds in the Spratly Island region of the South China Sea. Those new islands are among a number of other nearby islands claimed by the Philippines, Malaysia, Vietnam, Brunei and Taiwan, and appear to be meant more for asserting China's territorial claims in the region, as demonstrated by sustained Chinese air and sea patrols of the area, than to support large military units.[23] China also claimed the 12 nautical miles surrounding each island as its exclusive territorial waters; a position China's neighbours contested, and the U.S. considers has no basis in international law.[24] At the heart of their concern is whether China will try to use the islands to choke off freedom of navigation in that strategic area where more than $5 trillion in trade passes through each year, while also containing rich fisheries and the potential for vast oil and mineral deposits.[25] That prospect seems particularly unsettling for the U.S. which has about $1.2 trillion in trade travelling through the South China Sea each year, and which also in October finally reached an agreement on the Trans-Pacific Partnership (TPP) trade deal with eleven other Pacific Rim nations (including Canada, Mexico, Peru, Chile, Japan, Vietnam, Malaysia, Brunei, Singapore, Australia, and New Zealand).[26] If approved by the U.S. Congress, the TPP would set trade rules that govern roughly 40% of the global economy.[27]

### 1.2.2 Environment

The 21st UN Framework Convention on Climate Change Conference of Parties (UN FCCC/COP), which took place in Paris, France from 30 November to 12 December 2015, reached a landmark agreement among 195 Parties on 12 December 2015.[28] The Paris Agreement aims to keep global average temperature increases to below 2°C above pre-industrial levels, and to make more ambitious efforts to limit the temperature increases even further to 1.5°C and eliminate the increase of greenhouse gas emissions in the

[18] "Migrant crisis: Migration to Europe explained in seven charts." 4 Mar. 2016. BBC News 23 June 2016 <http://www.bbc.com/news/world-europe-34131911>.
[19] Namely China, France, Russia, the United Kingdom, and the United States
[20] Williams, Jennifer R. "A comprehensive timeline of the Iran nuclear deal." 21 July 2015. The Brookings Institution 22 June 2016 <http://www.brookings.edu/blogs/markaz/posts/2015/07/21-comprehensive-timeline-iran-nuclear-deal>.
[21] Demirjian, Karoun. "Senate rejects attempt to derail Iran deal in victory for Obama." 10 Sept. 2015. The Washington Post 22 June 2016 <https://www.washingtonpost.com/news/powerpost/wp/2015/09/10/senate-set-to-vote-on-iran-nuclear-deal/>.
[22] Lindsay, James M. "Top Ten Most Significant World Events in 2015." 15 Dec. 2015. Council on Foreign Relations 22 June 2016 <http://blogs.cfr.org/lindsay/2015/12/15/ten-most-significant-world-events-in-2015/>.
[23] Watkins, Derek. "What China Has Been Building in the South China Sea." 27 Oct. 2015. The New York Times 23 June 2016 <http://www.nytimes.com/interactive/2015/07/30/world/asia/what-china-has-been-building-in-the-south-china-sea.html>.
[24] Lindsay, James M. "Top Ten Most Significant World Events in 2015." 15 Dec. 2015. Council on Foreign Relations 22 June 2016 <http://blogs.cfr.org/lindsay/2015/12/15/ten-most-significant-world-events-in-2015/>.
[25] Glaser, Bonnie S. "Conflict in the South China Sea." 7 Apr. 2015. Council on Foreign Relations 23 June 2016 <http://www.cfr.org/asia-and-pacific/conflict-south-china-sea/p36377>.
[26] Calmes, Jackie. "Trans-Pacific Partnership Is Reached, but Faces Scrutiny in Congress." 5 Oct. 2015. The New York Times 23 June 2016 <http://www.nytimes.com/2015/10/06/business/trans-pacific-partnership-trade-deal-is-reached.html>.
[27] Lindsay, James M. "Top Ten Most Significant World Events in 2015." 15 Dec. 2015. Council on Foreign Relations 22 June 2016 <http://blogs.cfr.org/lindsay/2015/12/15/ten-most-significant-world-events-in-2015/>.
[28] "OUTCOMES OF THE U.N. CLIMATE CHANGE CONFERENCE IN PARIS | 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 21) November 30-December 12, 2015." 12 Dec. 2015. Centre for Climate and Energy Solutions 24 June 2016 <http://www.c2es.org/international/negotiations/cop21-paris/summary>.

second half of the century.[29] Around 188 countries contributed intended nationally determined contributions (INDCs), essentially national climate action plans that that will be updated and enhanced every five years – the next occurring in 2020. The members will also continue to address mitigation and adaptation opportunities, in addition to developing a clear roadmap for obtaining $100 billion in climate funding by 2020, while also setting another $100 billion floor before 2025.[30] Yet for now, the requirements of the Paris Agreement are non-binding until 30 days after the date on which at least 55 Parties accounting in total for at least an estimated 55% of total global greenhouse gas emissions have deposited their instruments of ratification, acceptance, approval or accession[31]; reaching that goal will be challenging without having China, the U.S. or the EU on board, which together account for 45% of the world's greenhouse emissions.[32] And while the regular review and submission of emission reduction targets and the $100 billion fund from developed economies to help emerging and developing nations decarbonise their energy mix will be binding, each country's INDC targets will not be binding.[33]

### 1.2.3 Energy

There were increasing signs of change in global energy throughout 2015, following a steep drop in oil prices at the beginning of the year, along with corresponding fluctuations in other fuel prices in many parts of the world. Some signs of stability emerged, as mandatory energy efficiency regulations grew to cover more than 25% of global consumption, and renewable energy contributed to almost half of the world's new power generation capacity in 2014. Yet energy demand is expected to grow by one-third over the period to 2040, with that increase driven mainly by India, China, and other non-OECD countries in Africa, the Middle East, and Southeast Asia. In contrast, the European Union is expected to decrease its consumption by 15% over the period to 2040, followed by Japan by 12%, and the U.S. by 3%.[34]

India is entering a period of rapid sustained growth, contributing around one quarter of the growth in global energy demand, including oil demand that was higher than any other country in 2015. Meanwhile, China has started to transition to a less energy-intensive phase in its growth, shifting from heavy industry to the service sector; it will be the largest oil-consuming country by the 2030s, and in 2040 its total energy demand will be nearly twice that of the United States. China and the Middle East were the drivers of natural gas demand growth in 2015, surpassing the European Union whose demand for natural gas peaked in 2010, yet the long-term supply of natural gas remains a concern, constrained by efficiency policies and deferred investment in the current low-price environment, which could bring tighter markets in the 2020s. Yet even with low oil prices, and the return of Iran into the hydrocarbon market, an estimated $2.8 trillion of investment will be needed to meet projected energy demand in 2040.[35]

China was both the world's largest producer and consumer of coal in 2015; it has also deployed more renewable power generation capacity than any other country. Moreover, India was the largest source of growth in global coal use in 2015, increasing the demand for coal in power generation and industry to almost half of the global energy mix for the year. India is now the second-largest coal producer in the world, and will overtake Japan, the EU and China as the world's largest coal importer by 2020. Yet renewable energy contributed nearly half of the world's new power generation capacity in 2014, and is projected to have a 50% a share of generation in the EU, around 30% in China and Japan, and above 25% in the U.S. and India by 2040. In order to meet the anticipated one-third growth in world energy demand by 2040, more renewable power generation capacity needs to be added.[36]

[29] "The Paris agreement marks an unprecedented political recognition of the risks of climate change." 12 Dec. 2015. The Economist 24 June 2016 <http://www.economist.com/node/21683990/>.
[30] UN Climate Change Newsroom. "Historic Paris Agreement on Climate Change | 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius." 12 Dec. 2015. UNFCCC 24 June 2016 <http://newsroom.unfccc.int/unfccc-newsroom/finale-cop21/>.
[31] United Nations Framework Convention on Climate Change | Conference of the Parties. Adoption of the Paris Agreement, Held in Paris from 30 November to 11 December 2015. UN Doc. FCCC/CP/2015/L.9/Rev.1 of 12 December 2015. United Nations (Annex | Paris Agreement, Article 21.1).
[32] Kinver, Mark. "COP21: What does the Paris climate agreement mean for me?" 14 Dec. 2015. BBC News 24 June 2016 <http://www.bbc.com/news/science-environment-35092127>.
[33] Ibid.
[34] "International Energy Agency. World Energy Outlook 2015 – Executive Summary" 10 Nov. 2015. IAE 3 Dec. 2015 <http://www.iea.org/publications/freepublications/publication/WEB_WorldEnergyOutlook2015ExecutiveSummaryEnglishFinal.pdf>.
[35] Ibid.
[36] Ibid.

### 1.2.4 Resources

The growth of international trade remained lacklustre continuing at a rate of 2.3% in 2014, from 2.2% in 2013; while initial estimates for 2015 expected the rate of growth of international trade to be close to that of global output (2.5%), this is still well below the 4.0% growth posted in the years immediately preceding the financial crisis.[37] Developed economies experienced considerable growth in the volume of imports, with the EU and Japan increasing 2.8%, while the U.S. had an even higher increase of 4.7% in part due to the increasing value of the dollar. The volume of exports from developed countries also showed signs of acceleration, with the biggest uptick in Japan, whose export growth of 0.6% seemed to recover from a slump in previous years. Europe's exports to China and the U.S. also showed resiliency at 1.5% growth, while U.S. exports have been showing signs of deceleration in recent years hovering at 3.1%. By contrast, import volumes in transition economies dropped by 8.5% in 2014, and were anticipated to have contracted even further in 2015, due mainly to the economic and financial difficulties involving Russia and Ukraine; and export volumes growth of 0.2% showed almost no change from 2013. Developing economies also continued to show deceleration, of which only South Asia departed from the downward trend. Overall, developing countries' growth in volume of imports for 2014 slowed to 2.0% from 6.1% in 2013; their volume of exports had a similar outcome in 2014 growing by 2.9% from 4.2% in 2013.[38]

By the start of 2015, crude oil prices had dropped to $48 per barrel, dropping by 56.7% from a monthly average of $112 per barrel as at June 2014 - lows not seen since 2009. According to the United Nations Conference on Trade and Development (UNCTAD), the plunge in prices was caused by greater global production, particularly by the United States' 15.9% increase in shale oil production in contrast to 2.3% increase by the rest of the globe in 2014. The U.S. had increased production by 50.6% from 2011 until mid-2014, which helped to stabilize global oil prices during production disruptions in other countries, but this led to an oversupply when disruptions became less of a problem. Prices began to fall even quicker following OPEC's decision not to change production quotas in November 2014; that decision was upheld in OPEC's following meeting in June 2015, in effort to undercut higher cost -shale oil, tar sands, and deep-water oil producers. While prices increased to $65 per barrel between the end of April and June 2015, by the end of 2015 the price of a barrel of oil dropped further to $37.28 per barrel.[39]

The decline in oil prices also had an effect on the prices of non-oil commodities, such as in reducing transportation and fertilizer prices, in addition to becoming more competitive with biofuels; however, prices in agriculture markets were still mainly determined by their own supply situation and weather conditions. Favourable weather conditions in 2014 and the first half of 2015 led to ample levels of food commodities, but adverse conditions in mid-2015 and the return of the El-Niño phenomenon raised levels of uncertainty in agricultural markets. The percentage change of non-oil commodity prices continued to contract, decreasing by 6.1% in 2014, following a 6.7% reduction in 2013; it also showed a 13.1% reduction for the first half of 2015.[40] The plentiful supply of agricultural products resulted in production exceeding consumption, with prices driven down due to weak demand and excess stock. The price of metals and minerals also continued to contract, decreasing by 8.5% in 2014, following a 5.1% reduction in 2013; it also showed a 15.81% reduction for the first half of 2015. Zinc, Nickel, and to a lesser extent Aluminium, were the outliers in 2014, showing positive growth in prices with 13.2%, 12.3%, and 1.1% respectively; but had joined the throng of metals and minerals whose prices decreased in 2015.[41] The indexes for gold, silver, and platinum continued their downward trend in 2015, decreasing by 8.3%, 17.6%, and 23.9% respectively in 2015; they are expected to drop even further by 7.3%, 10.9%, and 9.8% in 2016 mainly due to reduced investment demand.[42]

### 1.2.5 Knowledge

By now the advantages of higher education should be seen as worth the effort as employment rates and earnings tend to increase as an adult's level of education and skills increases; moreover, the labour market still regards a diploma or degree as the primary indication of a worker's skills. For Europe, the expansion of its pool of highly skilled and

[37] According to the latest data available from UNCTAD.
[38] United Nations Conference on Trade and Development. Trade and Development Report, 2015. Geneva: UNCTAD, 2015. 1-18.

[39] Friedman, Nicole. "U.S. Oil Prices End 2015 Down 30% for the Year." 31 Dec. 2015. The Wall Street Journal 27 June 2016 <http://www.wsj.com/articles/oil-prices-rise-but-supply-glut-caps-gains-1451560147>.
[40] United Nations Conference on Trade and Development. Trade and Development Report, 2015. Geneva: UNCTAD, 2015. 12.
[41] Ibid.
[42] World Bank Group. Commodity Markets Outlook. January 2016. Washington, DC: World Bank, 2016: 30-35.

specialised scientists and professionals should be a constant priority if it is to remain a leading actor in the field of space-related scientific and technological R&D. By 2015, 32% of the European working age population (not including Bulgaria, Cyprus, Malta, Latvia, Lithuania, Romania, and Croatia) held a higher education degree compared to 44% in the U.S. and 54% in Canada.[43] Several European countries, including Belgium, Denmark, Estonia, Finland, Ireland, Luxembourg, Norway, Sweden, and Switzerland performed well above the OECD average of 33% of the working age population (between 25-to-64 years of age) with a higher education degree. However, when looking at the percentage of the working age population (between 25-to-34 years of age) with a higher education degree, other European countries, including the Czech Republic, Germany, Hungary, Italy, Portugal, and Slovakia appeared at risk of falling further behind the that OECD average.[44]

According to the OECD, over 80% of tertiary-educated adults are employed, compared to over 70% of people with upper secondary or post-secondary non-tertiary education, and less than 60% of adults without upper secondary education.[45] According to an earlier study by the European Centre for the Development of Vocational Training, while employment is projected to grow by 2% over the period 2013-2020, the European skills forecast indicates that the EU will miss its target of reaching 75% employment by 2020, reaching instead 68.5% due to weak demand for labour following the financial crisis and the modest recovery and average GDP growth rates. Prior to the financial crisis, between 2000 and 2008, the employment rate increased by 3.7%. Between 2013 and 2020, average employment growth in Europe is expected to be around 0.35% per year, wherein the number of high qualification job openings is expected to exceed 55,000 (combining replacement needs and expansion demand), whereas medium qualification openings will be over 40,000 (coming mainly from replacement needs), and low qualification jobs will be lower than 10,000 (due to shrinking demand offsetting replacement needs). In fact, the overall share of the labour force with low qualifications is forecast to fall from 22% in 2013 to 16.8% in 2020. The largest relative growth of jobs between 2013 -2020 will be in Luxembourg, followed by Ireland, Slovakia, Latvia, and France in the top five positions, while only Hungary, Poland, Cyprus, Bulgaria, and Germany are expected to have a decrease in job growth during that period. And while the EU is on course to surpass its education goal of 40% of 30-34 year-olds having completed higher education by 2020, possibly reaching 45% by that time, weak high-skilled labour demand could mean that there will be an increased risk of skill mismatch due to the over-qualification of highly skilled labour that has no alternative than to accept lower skilled employment.[46]

### 1.2.6 Mobility

Maritime transport is the most commonly used form of transport for international trade, accounting for about 80% of global trade by volume (90% volume in the case of most developing countries) and over 70% of global trade by value.[47] Growth in global trade and shipping proceeded at a moderate pace in 2014 and was expected to continue into 2015; however, the risk of continued moderate growth in global demand and merchandise trade, the fragile recovery in Europe, diverging outlooks for net oil consumers and producers, geopolitical tensions, and a potential faster slowdown in developing economies, kept that outlook uncertain. Between 2014 and 2015, the world order book declined for most vessel types except for oil tankers, and stood far below the order peak of 2008–2009. During the 12 months to 1 January 2015, the global fleet of vessels increased by 3.5%, the lowest annual growth rate in over a decade. In terms of the types of vessels in operation for the year, dry-bulk carriers accounted for 43.5% of the world fleet capacity, increasing at a rate of 4.4% from the previous year. Oil tankers accounted for 28.0% of the share of the world fleet, with only a 1.4% increase from the previous year. Container vessels accounted for a 13.0% share, with a substantial increase of 5.5% in 2015, while general cargo vessels continued to diminish, accounting for a 4.4% share, down by 1.0% from 2014. Additionally, the number of ships sold for demolition decreased by 22.9% to 22,394 in 2014 from 29,052 in 2013. In 2014, dry-bulk carriers accounted for 40.6% of the total quantity of

[43] OECD. Education at a Glance 2015: OECD Indicators, OECD Publishing, 2015: 41 <http://download.ei-ie.org/Docs/WebDepot/EaG2015_EN.pdf>.
[44] OECD. Education at a Glance 2015: OECD Indicators, OECD Publishing, 2015: 41 <http://download.ei-ie.org/Docs/WebDepot/EaG2015_EN.pdf>.
[45] OECD. Education at a Glance 2015: OECD Indicators, OECD Publishing, 2015: 27 <http://download.ei-ie.org/Docs/WebDepot/EaG2015_EN.pdf>.
[46] "Cedefop's latest skill supply and demand forecasts highlight Europe's employment challenge." 1 Apr. 2014. CEDEFOP 7 May 2015 <http://www.cedefop.europa.eu/node/12684>.
[47] United Nations Conference on Trade and Development. Review of Maritime Transport 2015. Geneva: UNCTD, 2015. 48.

tonnage sold for demolition, followed by container ships at 21.3%, and oil tankers at 20.0%. As the rate of vessel demolitions decreases, a resulting oversupply of vessels may lead to downward pressure on freight and charter rates.[48]

Supply chain security is another challenge for the maritime industry, as there is heightened exposure and vulnerability to piracy, armed robbery, and other crimes. Between 2003 and 2012, around 3,436 acts of piracy were reported worldwide.[49] In that period, piracy incidents in East Africa, particularly off the Somalia coast, the Gulf of Aden and the Indian Ocean were particularly alarming, especially since they exceeded those in some of the traditional regions for piracy including Indonesia, Malaysia, Singapore, and the Philippines. Indeed, between 2005 and 2012, piracy off the coast of Somalia accounted for nearly 50% of all recorded hijackings. This spurred an increased international military presence in this region and together with preventative measures by merchant ships that privately contracted armed personnel, reduced Africa's share of piracy incidents from 50% in 2008 to 17.3% in 2012.[50] The downward trend continued into 2014, with just 245 reported piracy incidents during the year. Moreover, the number of Somalia-based piracy incidents dropped from 49 in 2012 to 3 in 2014, although it continued to increase in East Asian waters.[51]

[48] United Nations Conference on Trade and Development. Review of Maritime Transport 2015. Geneva: UNCTD, 2015. 29-45.

[49] United Nations Conference on Trade and Development. Maritime Piracy | Part 1: An Overview of Trends, Costs and Trade-related Implications. Geneva: UNCTAD, 2014. 3.

[50] Ibid.

[51] ICC International Maritime Bureau. Piracy and Armed Robbery Against Ships: Report for the Period 1January – 31 December 2014. Jan. 2015. ICC-CSS 11 May 2015 <http://www.hellenicshippingnews.com/wp-content/uploads/2015/01/2014-Annual-IMB-Piracy-Report-ABRIDGED.pdf>.

# 2. Global Space Economy

Chapter 2 covers the 2015 public budgets and commercial revenue related to space activity. There will be a brief discussion of space related public budgets and commercial revenue with a quantitative assessment of the overall market value and financial performance of space activities in the last 12 months.

In the absence of internationally uniform standards, developing an accurate estimate of financial and market figures of global space activities is a complicated task, especially when considering that most countries and space research institutions adopt their own distinct methods of categorising and distributing funding for space activity. Likewise, the lack of transparency in certain government space programmes, e.g. military space projects, further complicates calculations. And an additional degree of distortion is introduced by floating currency exchange rates, as all numbers are reflected in terms of U.S. dollars. Moreover, commercial companies publish their financial figures regularly, but not in a uniform and synchronised way that would allow direct horizontal industry comparisons.

## 2.1 Global Space Budgets and Revenue

Total government space expenditure was $76.52 billion in 2015, down from $80.42 billion in 2014 – the reduction is explained in part by currency fluctuations resulting from the strengthened U.S. dollar to the currencies of many spacefaring countries.[52] Total government expenditure for civil space programs decreased by 3.4% to $42.37 billion from $43.84 billion in 2014. The compound annual growth rate (CAGR) of the entire space industry, including commercial revenues and government expenditure appeared to decrease by 2.1%, masking the growth experienced by most of the global space sector whose financial activity is conducted in other currencies.[53] The following section provides a more detailed analysis of institutional budgets.

The Space Report 2016 noted that the total revenue of commercial satellite services, including telecommunications, Earth observation and positioning services, increased by 3.65%, to $126.33 billion in 2015 from $121.88 billion in 2014. However, revenue from space-related commercial infrastructure, including manufacturing of spacecraft and in-space platforms, launch services as well as ground equipment decreased by 5.22% to $120.09 billion in 2015 from $126.71 billion in 2014; the decrease mainly came from the revenue of GNSS receivers which is benchmarked in euros hence subject to the same currency fluctuation. Overall, total commercial space revenue decreased by 0.9% to $246.42 billion in 2015 from $248.59 billion in 2014.[54]

## 2.2 Overview of Institutional Space Budgets

From the Space Report 2016, total institutional spending on space programs in 2015, including that of intergovernmental organisations, decreased by 4.9% to $76.52 billion from $80.42 billion in 2014; the decrease is attributable to dollar exchange rates, which saw investment by non-U.S. government space actors decrease by 14.2% to $31.95 billion from $37.24 billion in 2014.[55] Around 55.4% of the total institutional space expenditure went toward civil expenditure ($42.37 billion), while 44.6% of the spending went to defence expenditure ($34.15 billion), showing no change in the ratio of civil and defence spending from 2014.[56]

The Space Report 2016 also estimates that worldwide defence related expenditure lowered to $34.15 billion in 2015, with the United States accounting for 69.0% (i.e. $23.75 billion) for space security programmes under its Department of Defence (DoD). The U.S. DoD's space budget funds its

[52] The Space Report 2016. Colorado Springs: The Space Foundation, 2016: 16.
[53] Ibid.
[54] Ibid.
[55] Ibid. at 38.
[56] Ibid.

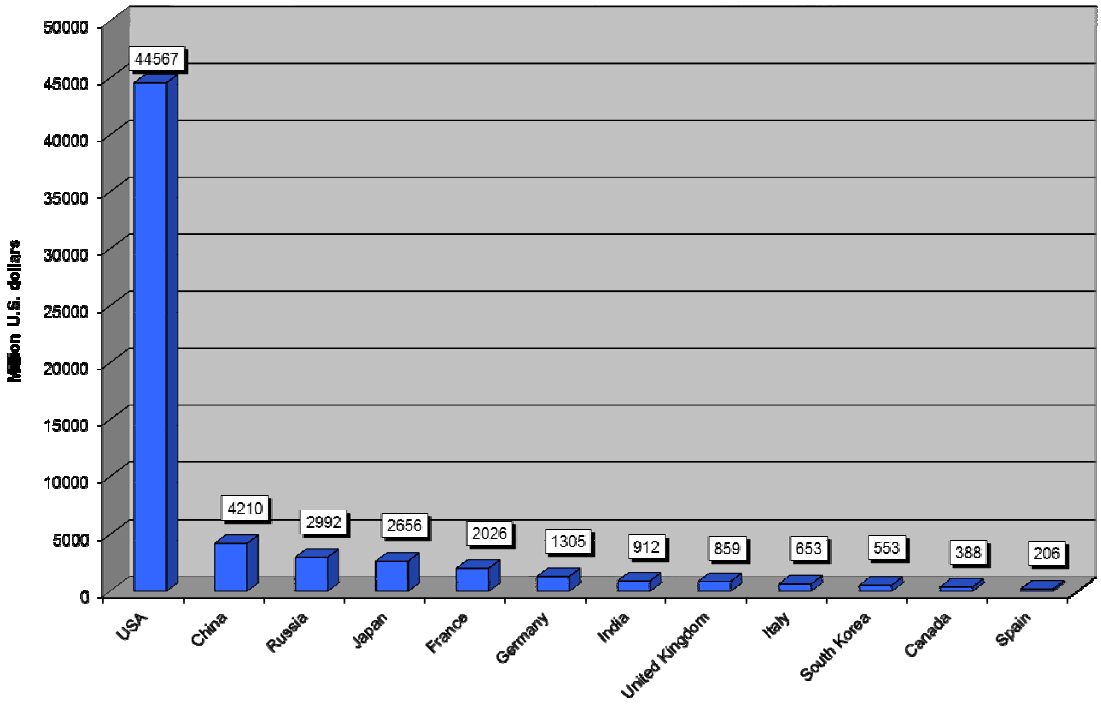


Figure 2.1: Public space budgets of major space powers in 2015 (Based on Space Report 2016 and ASD-Eurospace data).

military space programmes, in addition to organisations such as the National Reconnaissance Office (NRO) and the National Geospatial-Intelligence Agency (NGA). Defence spending by non-U.S. government space actors accounted for the remaining 31.0% (or $10.58 billion), a notable drop from its 36.4% share in 2014, attributable to the fluctuations in currency values.[57] Moreover, it should be noted that a degree of uncertainty exists regarding expenditures on defence space activities as not all relevant funding is made public.

The following diagrams present a relative picture of the space sector. They should be viewed holistically, and compared to each other as a single diagram may not reflect the real output of spacefaring countries.

While spending among space actors saw significant changes in 2015, they should not be ranked against each other given the uncertainties due to exchange rates and different purchase power parities (Figure 2.1).[58] The United States continued to have the largest space budget, increasing its civilian space spending to $20.995 billion, and defence spending to $23.572 billion, while China's space budget is based on a modest expenditure estimate of at least 26.1 billion Yuan ($4.21 billion) according to the Space Report 2016.[59] Next, with the weaker value of the rouble in 2015, Russia's budget of 165.814 billion roubles ($2.992 billion) in 2015 stayed level with the 165.814 billion roubles ($4.88 billion) spent in 2014.[60] And Japan's space budget was ¥324.5 billion ($2.656 billion), followed by France, Germany and India.[61] Estimates for European countries are slightly more conservative than in previous years, which is more reflective of a change in data authorities than in yearly spending by the individual countries.

The 2015 expenditure of the European Space Agency increased by 8.1% to €4.433 billion ($4.944 billion) from €4.102 billion ($5.65 billion) in 2014, following a substantial 65.2% increase in spending by the EU directed toward its Galileo and Copernicus Flagship programmes. ESA member state spending decreased by 2.9% in 2015, reaching €3.241 billion ($3.61 billion from $3.339 billion

[57] Ibid.
[58] N.B.: Figures in this section are based on ASD-Eurospace estimates for European countries (at an €:$ exchange rate of 1:1.1153) and Space Report 2016 data for all non-European spacefaring countries (i.e. U.S.A, Russia, Japan, China, India, Canada, and South Korea). Moreover, the different currencies in other sections of this report were not converted to a baseline currency (except for comparison purposes) as recent currency fluctuations skewed the changes in the spending by other countries.

[59] The Space Report 2016. Colorado Springs: The Space Foundation, 2016: 38.
[60] Ibid.
[61] Ibid.

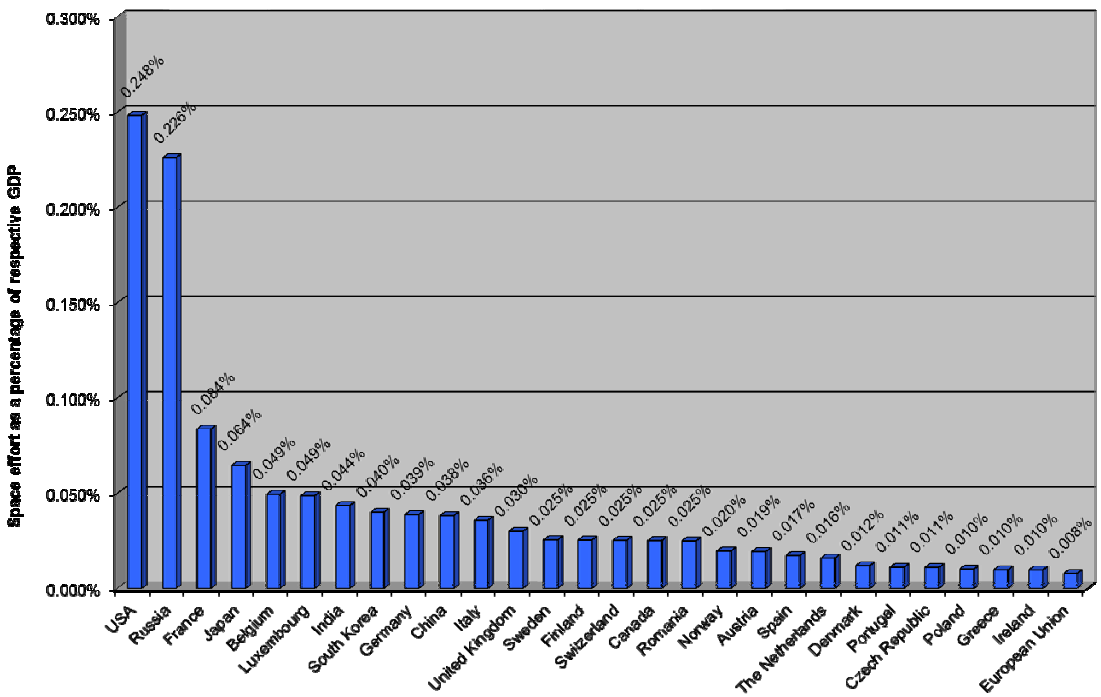


Figure 2.2: Public space budgets (selection) as a share of nom. GDP in 2015 (source: The Space Report/Eurospace/IMF)

($4.60 billion) in 2014.[62] While the European Union is the largest contributor to ESA, providing €1.031 billion in 2015 or 23.2%, the next five largest contributors among ESA member states, to the total ESA budget were Germany 18.0%, France 16.2%, Italy 7.4%, the UK 7.3%, and Belgium 4.3%. Switzerland was the next highest contributor at 3.0%, followed closely by Spain in the 2015 budget.[63]

Additional perspective can be gained by measuring the investment of countries in the space sector with regard to GDP generated in the 2015 (Figure 2.2).

The U.S. maintained its spot as pack leader in space spending as a share of GDP in 2015, increasing to 0.2483% from 0.2466% in 2014. Russia's spending as a share of its GDP kept it in second position, but had decreased to 0.2259% from 0.2372% in 2014. France remained in the third position in 2015, with spending at 0.0837%, while Japan maintained its fourth spot with 0.0644% in space spending as a share of GDP in 2015. Other leading space countries in Europe and the rest of the globe invested less than 0.05% of their GDP in space activity, while the European Union overall spent an estimated 0.00783% of its GDP on space. It should be noted that the GDP of the U.S. for 2015 was $17.947 trillion while the European Union's GDP for the year was slightly less at $16.220 trillion.

When looking at space spending in terms of US$ per capita investment, a different ordering becomes visible. U.S. per capita spending increased by 2.6% in 2015, reaching $138.75 from $135.21 in 2014. The United Kingdom also had an increase of 7.5% in its spending, while South Korea's spending grew by 19.8%, and Portugal increased by 5.8%. France's per capita expenditure reduced to $31.51 in 2015, while Germany's spending lowered further to $16.09 partially due to the change in currency values. Japan's expenditure overtook Russia, with $20.93 per capita compared to $20.73 respectively. Moreover, per capita spending by Switzerland and Belgium were nearly on par, with Switzerland edging ahead by 0.03 at $20.12 in 2015.

[62] "ESA Budget for 2015." 24 Feb. 2015. ESA 28 June 2016 <http://www.esa.int/For_Media/Highlights/ESA_budget_2015>.
[63] Ibid.

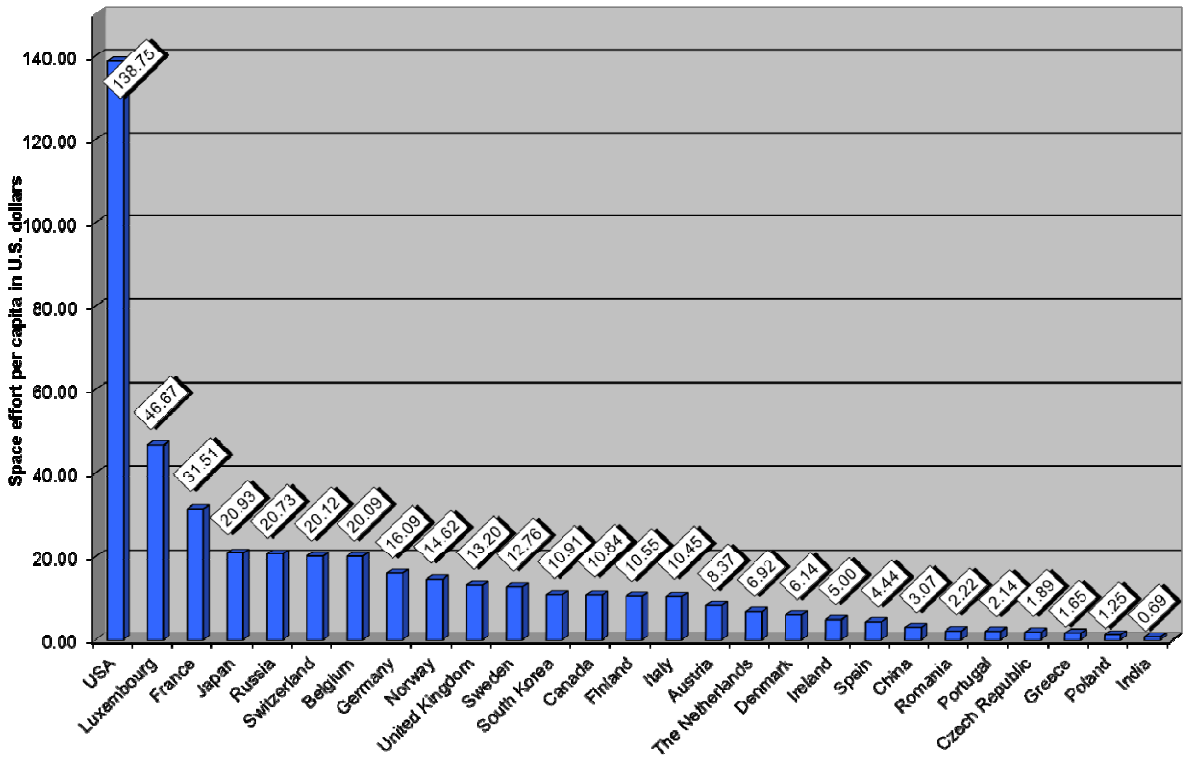


Figure 2.3: Public space budgets per capita (selection) in 2015 (source: The Space Report/Eurospace/PRB)

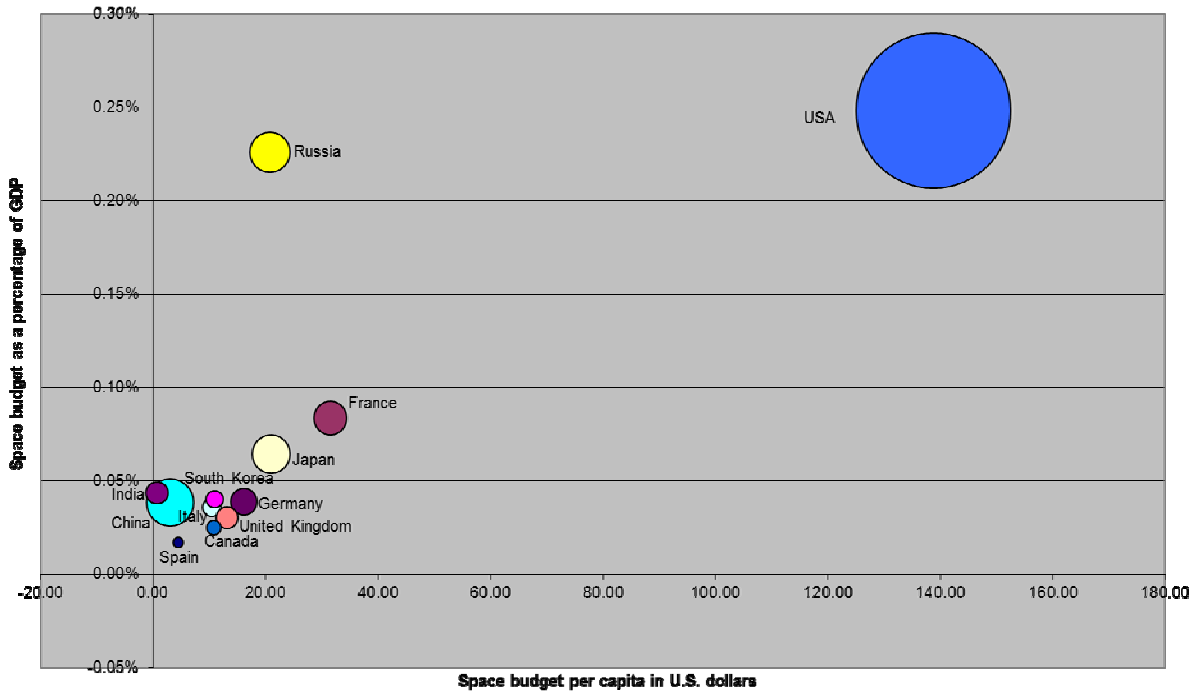


Figure 2.4: Public space budgets as share of GDP mapped against space budgets per capita in 2015. The bubble size indicates the absolute space budget (Based on the Space Report 2016, Eurospace, and publicly available data)

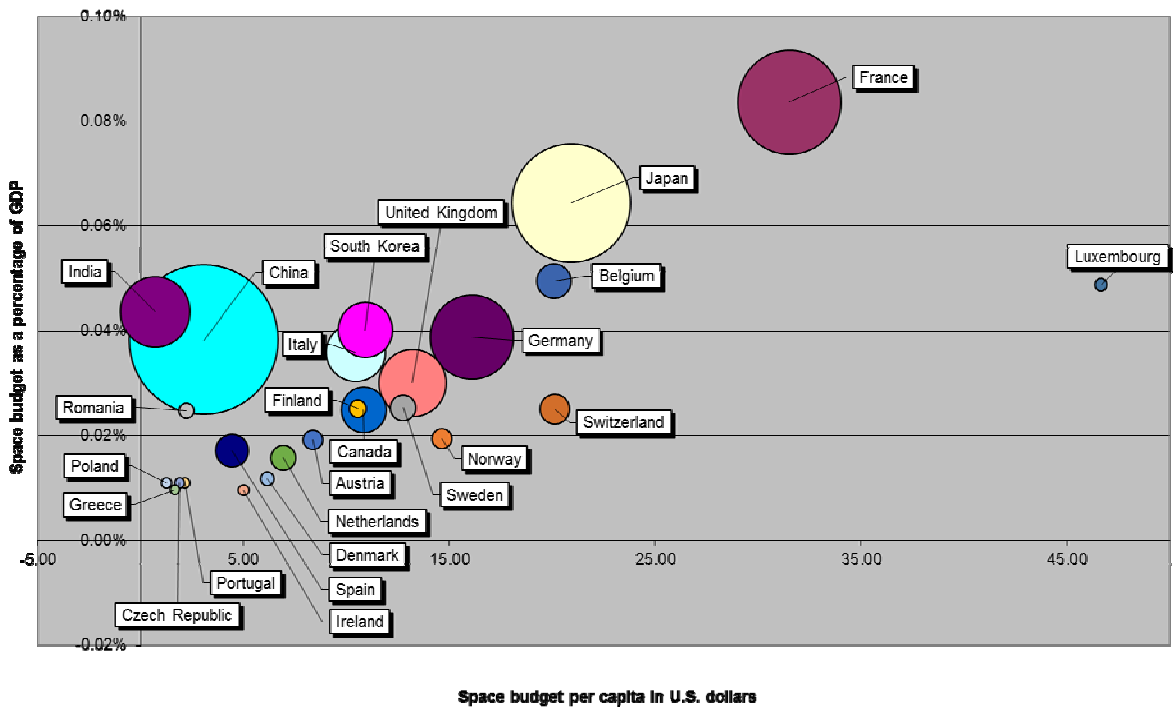


Figure 2.5: Magnification of public space budgets as a share of GDP mapped against space budgets per capita in 2015, not including the U.S. and Russia. The bubble size indicates the absolute space budget (Based on the Space Report 2016, Euro-space, and publicly available data)

Contrasting the GDP share of public space funds and per capita public space funds provides another picture of institutional investment in space, (see Figures 2.4 and 2.5). Here, the U.S. continues to excel by a significant margin, matched by Russia in the percentage of its GDP spent on the space sector, but outdoing all countries in terms of space spending per capita and in its overall space budget. France holds the third position both in space budget per GDP and space budget per capita, but trails the U.S., China, Russia, and Japan in its total space budget. Yet, some caution is needed when considering these figures, due to fluctuating exchange rates, and the uncertainty of reported values.

## 2.3 Overview of Commercial Space Markets

The Satellite Industry Association (SIA) reported that global industry revenues from satellite services, satellite manufacturing, launch industry, and ground equipment grew by 2.6% in 2015 reaching $208.3 billion from $203.0 billion in 2014.[64] Yet according to the Space Report 2016, the combined revenue from commercial space products and services, and from commercial infrastructure and support industries, decreased by 1.8% to $246.42 billion in 2015 from $250.83 billion in 2014.[65] It should be noted that these authorities use different methodologies in reaching their assessments, and there is continued discrepancy in the findings of SIA and the Space Report, resulting in a difference of $38.12 billion in the figures for 2015, from $47.83 billion in 2014, and $44.87 billion in 2013.

The following section presents key figures and data on commercial space activities divided by field of activity, based primarily on available SIA figures generated by the Tauri Group, in addition to previous Futron reports.

### 2.3.1 Satellite Services

The revenue earned from satellite services grew by 3.7% to $127.4 billion in 2015, from the $122.9 billion earned in 2014, with consumer services continuing as a key driver for the overall satellite industry.[66] The rate of revenue growth in satellite services appears

[64] "2016 State of the Satellite Industry Report." 2 June 2016. Satellite Industry Association and The Tauri Group 5 Sept. 2016 <http://www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf>.

[65] C.f. The Space Report 2016. Colorado Springs: The Space Foundation, 2016: 16, and The Space Report 2015. Colorado Springs: The Space Foundation, 2015, 14.

[66] "2016 State of the Satellite Industry Report." 2 June 2016. Satellite Industry Association and The Tauri Group 5 Sept. 2016: 11 <http://www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf>.

to have plateaued since its deceleration, remaining steady with 3.6% growth in 2014, from 4.5% in 2013, and 5.2% in 2012. The bulk of revenue comes from the consumer services subgroup (consisting of satellite television, satellite radio, and satellite broadband services), which accounted for 81.9% of the revenue earned by satellite services. According to SIA, consumer services alone accounted for 50.1% of the total revenue earned by the global satellite industry in 2015.[67]

Satellite services can further be deconstructed into their component parts, including consumer services (satellite radio (DARS), and consumer satellite broadband), fixed satellite services (e.g. transponder agreements, and managed services), as well as mobile services (voice and data), and remote sensing. The following is a breakdown of the industry's key developments and trends, according to the nature of the services provided.

#### Consumer Services

As mentioned above, consumer services are made up of satellite television, radio, and broadband services. The $104.3 billion in downstream consumer services revenue continued to surpass the combined revenues of upstream satellite industry segments (i.e. manufacturing, launch services, and ground equipment) in 2015, 93.8% of that consumer revenue came from satellite television services (DBS/DTH). With about 230 million satellite television subscribers worldwide, it is a key driver in consumer services revenue, with increasing growth in emerging markets. In 2015, the U.S. attributed for about 42% of global revenues from satellite television services. The overall rate of growth increased by 3.4% in 2015, from 2.6% in 2014, while satellite radio revenue grew by 9.5% to $4.6 billion in 2015 from $4.2 billion in 2014 and satellite broadband revenue increased by 5.6%, reaching $1.9 billion from $1.8 billion in 2014.[68] Satellite radio and broadband services amount to 6.2% of the consumer services segment, with 29.6 million and 1.8 million subscribers respectively, each mainly coming from the U.S.[69]

#### Fixed Satellite Services

Fixed Satellite Services (FSS) refers to the use of spacecraft that utilise land terminals in fixed positions to broadcast. Whereas Consumer Services covers satellite broadband Internet, communications and network television and radio broadcasts, FSS relates to commercial signal agreements, such as transponder agreements and managed network services. The FSS segment saw unequal growth in 2015, with revenue for transponder agreements increasing by about 1% to reach $12.4 billion from $12.3 billion in 2014, whereas revenues from managed services, mainly from airborne services grew by 15% in 2015 to $5.5 billion from $4.8 billion in 2014.[70]

#### Mobile Satellite Services

Mobile Satellite Services (MSS) offer both mobile data service and mobile voice service (including satellite phones). MSS revenue grew by 3.0% in 2015, earning $3.4 million, a modest increase from the 26.9% growth in revenue in 2014. Here, mobile voice services grew by 9% in 2015 from 19% in 2014, whereas mobile data services grew by 4.3% in 2015, from 27% in 2014. Mobile voice services revenue reached $1.0 billion in 2015, from $900 million in 2014, while mobile data service revenue, used heavily in the aviation sector, grew to $2.4 billion in 2015, from $2.3 billion in 2014. This latter segment comprised 70.6% of all mobile satellite services revenue.[71]

#### Earth Observation Services

Earth observation services refers to commercial companies that provide optical and radar images to the open market; however, demand for such services is mostly driven by government entities. Nevertheless, new entrants such as Terra Bella (formerly known as Skybox Imaging) and Planet Labs have continued to raise capital, and have begun to deploy initial constellations. Earth observation services revenue increased by 12.5% in 2015, reaching $1.8 billion from $1.6 billion in 2014.[72]

### 2.3.2 Satellite Manufacturing

The total revenue of satellite manufacturers that built satellites both for governmental and commercial customers reached $16.6 billion in 2015, an increase of 4.4% from the $15.9 billion generated in 2014. Whereas U.S. generated revenue of $10 billion for 2015 remained on par with 2014, non-U.S. revenue increased by 11.9% to $6.6 billion in 2015 from $5.9 billion in 2014, marking steady growth over the past three years. The SIA reports that 42% of the total revenue generated from all satellites manufactured in 2015

[67] Ibid. at 4.
[68] Ibid. at 11.
[69] Ibid. at 12.
[70] Ibid. at 13.
[71] Ibid. at 11.
[72] Ibid. at 13.

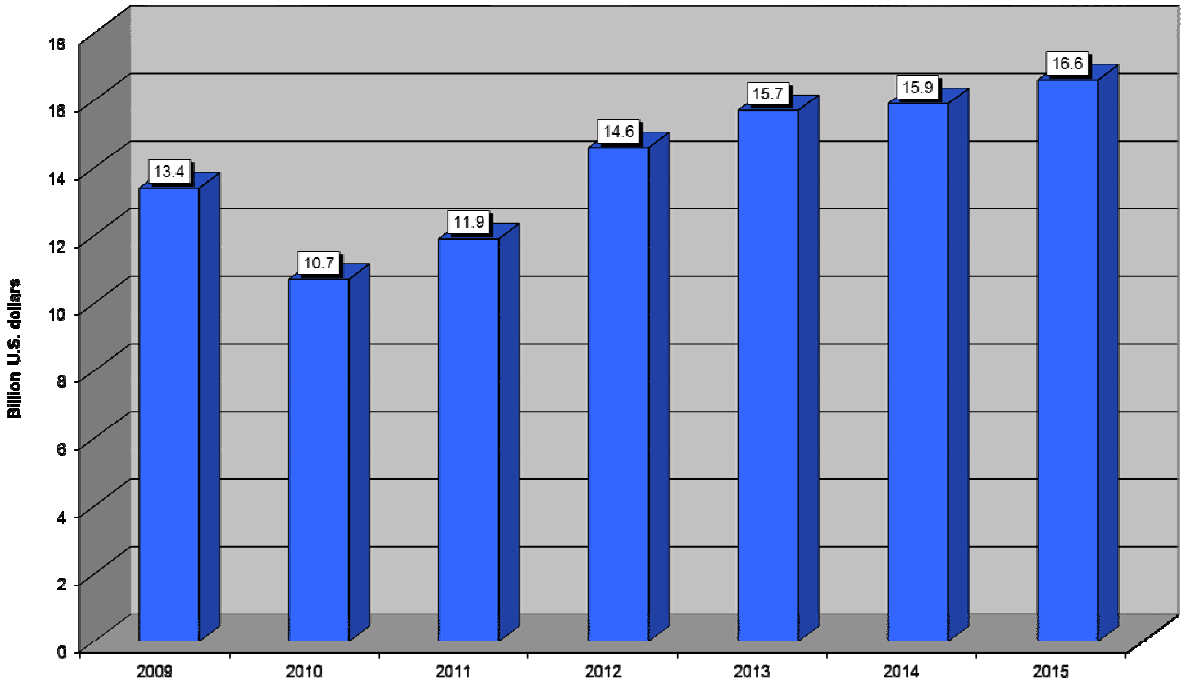


Figure 2.6: World satellite manufacturing revenue (Source: SIA)

came from communications satellites (i.e. 24% from commercial communications, while 18% were for civil/military communications). Next, military surveillance satellites accounted for 36% of the revenue for the year, while navigation satellites were 9% and Earth Observation satellites were 8%. Meteorology satellites and scientific satellites each represented 2% of the revenue for the year, while satellites developed for R&D purposes amounted to 1%. Cubesats continued to represent less than 1% of the total revenue generated for the year.[73]

### 2.3.3 Launch Sector

There were 22 commercial launches in 2015; with two failures including the Proton M carrying the MexSat-1 communications satellite for Mexico's government, and the failure of SpaceX's Dragon CRS-7 ISS resupply mission which carried ISS equipment and an allotment of 8 Planet Labs cube satellites intended to be released from the ISS. The remaining 20 successful commercial launches carried 36 commercial services payloads into orbit (in addition to 29 commercial cube satellites intended to be released from the ISS). Commercial launches accounted for 25.3% of the total 87 launches in 2015; and amounted to 23.8% of the 265 payloads launched. Of the 265 payloads that were launched in 2015, 78 were cube satellites launched directly into orbit (including the failed maiden launch of the Super Strypi that resulted in the destruction of 13 cube satellites), while another 65 cube satellites were intended to be released into orbit from the ISS (8 cube satellites were destroyed, along with equipment intended for the ISS during the launch of the Dragon CRS-7). When not considering cube satellites, the percentage of commercial payloads launched amounted to 25.4%, or 31 commercial payloads out of a total of 122 non-cube satellite payloads.

In 2015, Europe conducted 6 commercial launches out of a total of 12 in 2015; increasing its share of total commercial launches to 27.3% for the year (not counting the actual number of payloads launched). U.S. launch providers conducted 8 commercial launches out of a total of 20 launches; the U.S. share of total commercial launches decreased to 36.4% for the year. Russia had the most launches in 2015, but only 5 out of its 26 launches were for commercial purposes; its share of total commercial launches increased to 22.7% for 2015. Next, China conducted 19 non-commercial launches, but did not have any commercial launch activity fin 2015. And finally, 2 out of 5 launches by India were commercial, amounting to a 9.1% share; while 1 of the 4 launches by Japan was commercial, amounting giving it a 4.5% share. Iran's single launch for the year was non-commercial.

[73] Ibid. at 18.

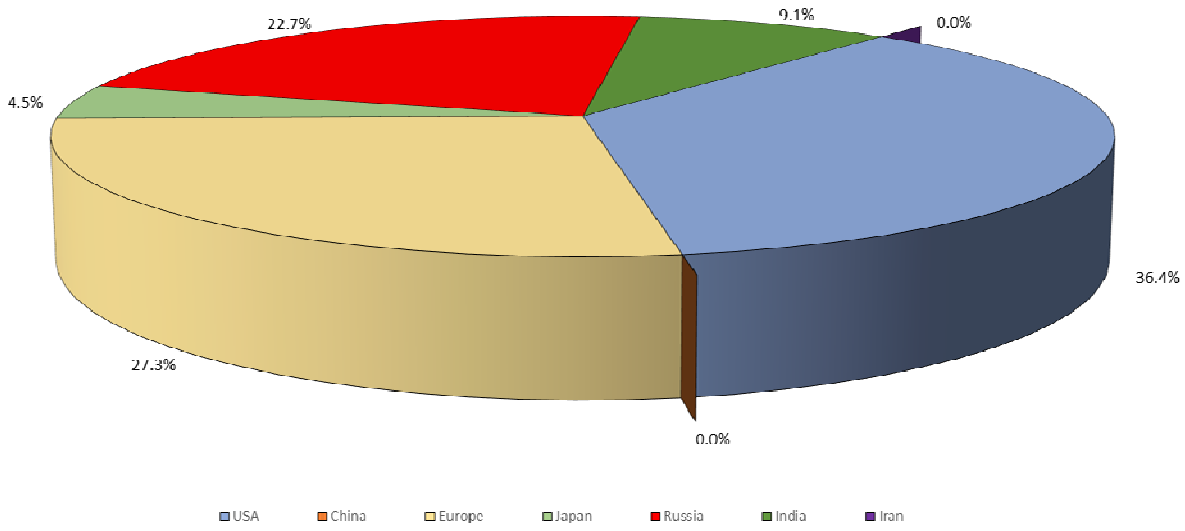


Figure 2.7: Commercial Launch Activity by Country in 2015 (Source: FAA)

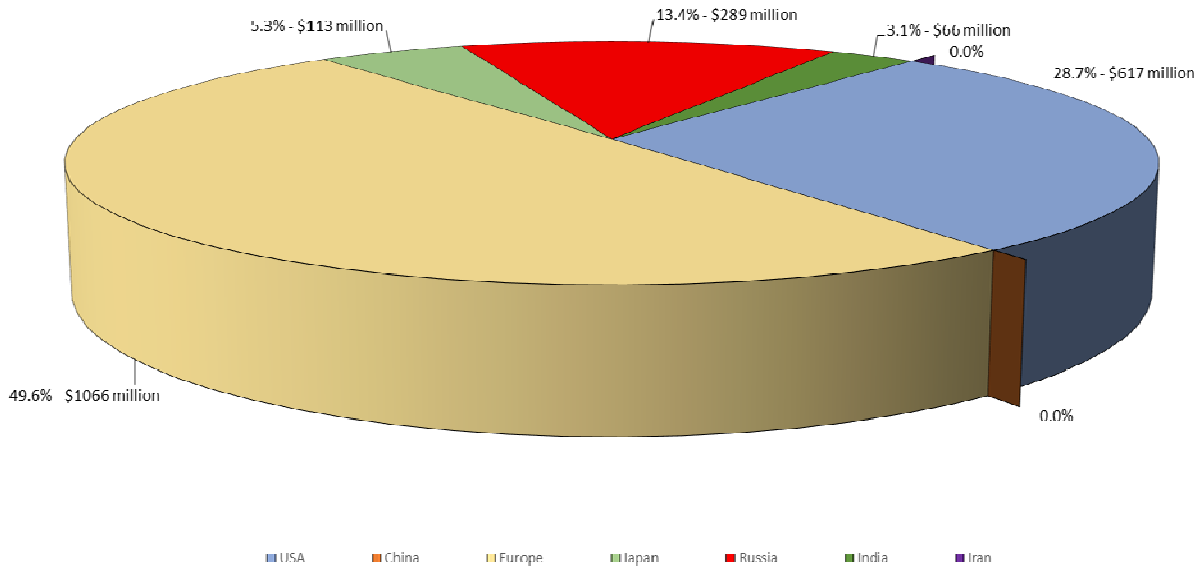


Figure 2.8: Commercial Launch Revenues by Country in 2015 (Source: FAA)

The total estimated revenue from the 22 launches amounted to $2.15 billion, an 8.9% decrease from the $2.36 billion earned in 2014. Europe generated the most commercial launch revenue for 2015, earning $1.066 billion – an increase of 15.9% from the $920 million earned in 2014. The U.S. earned $617 million in 2015, a drop of 44.3% from the $1.107 billion it earned in 2014. Russia held the third position earning $289 million, an increase of 32.6% from the $218 million earned in 2014. Japan returned to the commercial launch scene in 2015, earning $113 million, while India earned an estimated $66 million in 2015, more than three times the revenue earned in 2014, marking a shift in reliance on the low-cost launch provider.[74]

In 2015, Arianespace conducted a total of 12 launches from French Guiana. Its Ariane 5 ECA launcher had 6 launches, which lifted 9 commercial telecommunications satellites, the Franco-Italian SICRAL-2 military communications satellite, Eumetsat's MSG-4 meteorology satellite, and 1 civil government communications satellite into GEO orbit. The Europeanized Soyuz had three launches, which placed 6 Galileo navigation satellites

[74] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 40.

| | Total Revenue | 2015 | 2014 |
|---|---|---|---|
| **TomTom** | | €1.007 billion ($1.123 billion) | €950.292 million ($1.155 billion) |
| **Garmin** | | $2.820 billion | $2.871 billion |
| | **Geographical Sales** | | |
| **TomTom** | Europe | €771.491 million ($860.444 million) | €718.767 million ($873.647 million) |
| | North America | €186.115 million ($207.574 million) | €163.461 million ($198.684 million) |
| | Rest of World | €49.001 million ($54.651 million) | €68.064 million ($82.730 million) |
| **Garmin** | Europe/Middle East/Africa | $1.013 billion | $1.054 billion |
| | Americas | $1.469 billion | $1.538 billion |
| | Asia Pacific region | $337.888 million | $278.092 million |

Table 2.1 Understanding TomTom & Garmin variables

(Galileo FOC-3 to -6, -8, and -9) to medium Earth orbit (MEO) for the European Commission. And three launches were conducted by the Vega launcher which lifted the IXV spacecraft and its AVUM VV04 upper stage on a suborbital trajectory; it also launched the Sentinel 2A into SSO and the LISA Pathfinder mission beyond Earth orbit for ESA.

### 2.3.4 Ground Equipment

Ground equipment revenue includes infrastructure elements, such as mobile terminals, gateways and control stations, and consumer equipment, such as very small aperture terminals (VSAT), ultra small aperture terminals (USAT), DTH broadcast dishes, satellite phones and digital audio radio satellite (DARS) equipment. Portable Navigation Devices (PND) form one of the sub-segments of end-user electronics that incorporate GNSS chip sets.

Ground equipment revenues for 2015 increased only slightly from 2014 stemming from growth solely in network equipment and broadband equipment revenues, whereas consumer equipment for satellite navigation revenue remained flat reflecting continued migration from standalone devices to embedded chipsets for devices such as smartphones.[75] Network equipment revenue grew by 3.2% in 2015, reaching $9.6 billion from $9.3 billion in 2014, while consumer broadband equipment revenue grew by 2.2% in 2015, reaching $18.3 billion from $17.9 billion in 2014. In contrast, consumer equipment revenue continued to lower slightly, reducing by 0.3% to $31.0 billion from $31.1 billion in 2014; even so, the segment represents more than half of the overall ground equipment revenue of 2015. Lastly, overall ground equipment revenues grew by 1.0% to $58.9 billion in 2015 from $58.3 billion in 2014, constituting a 28.3% share of the $208.3 billion world satellite industry revenue in 2015.

Garmin and TomTom, the two companies leading the PND market, seemed to switch roles in growth for 2015. Garmin experienced a 1.8% decrease in revenue in 2015, amounting to $2.820 billion from $2.871 billion in 2014. The loss came mainly from a 15% reduction in revenue from its automotive sector, whose impact would have been greater were it not offset by revenue gains of 16% in its fitness segment, and 15% in its marine segment.[76] In contrast, TomTom's revenue noted a 5.9% uptick in revenue for 2015, amounting to €1.007 billion ($1.123 billion) from €950.292 million ($1.155 billion) in 2014. That growth mainly came from revenue gains of 27.3% in its licensing segment, and 22.5% in its telematics segment, while its consumer segment grew by just 0.7%, and automotive decreased by 3.2% in 2015.[77]

[75] "2016 State of the Satellite Industry Report." 2 June 2016. Satellite Industry Association and The Tauri Group 5 Sept. 2016: 29 <http://www.sia.org/wp-content/uploads/2016/06/SSIR16-Pdf-Copy-for-Website-Compressed.pdf>.

[76] "Garmin Reports Q4 and Fiscal 2015 Results." 17 Feb. 2016. Garmin 3 July 2016 <http://newsroom.garmin.com/press-release/earnings/garmin-reports-q4-and-fiscal-2015-results>.

[77] "TomTom Annual Report 2015." 19 Feb. 2016. TomTom 3 June 2016: 33 <http://files.shareholder.com/downloads/TOMTOM/194182

### 2.3.5 Insurance Sector

Several launch failures in 2015 appear likely to result in another losing year for insurance providers, which could mean that insurance premiums will increase in coming years. The 16 May 2015 failure of the Russian Proton-M, due partly to the collapse of a turbopump in the rocket's third stage engine, resulted in the total loss of the Mexican government's Centenario mobile communications satellite. Despite the launch failure, the Mexican government can expect to receive a $390 million insurance pay-out for the loss, after having made the atypical decision of purchasing full insurance coverage for the satellite, including $300 million for the satellite and $90 million for the launch.[78] Moreover, the Tel Aviv, Israel-based Spacecom, which is vying for an increased share of the African satellite communications market, filed a total loss claim to its insurance underwriters amounting to $158 million (including $50 million for the satellite's propulsion system) for the loss of its Amos-5 which stopped communicating from its Geostationary orbit on 21 November 2015. While Amos-5's propulsion unit had experienced a glitch in 2013, causing Spacecom's insurers to place exclusions on claims based on any similar events in the future, this latest event was determined to be unrelated to its propulsion system, although its Russian manufacturer ISS Reshetnev has been unable to pinpoint another possible cause.[79]

The insurance sector seems to be evolving as operators seek to lower their insurance premiums while taking on higher risk. In late October 2015, the mobile satellite services provider Iridium announced an agreement with its creditors on a revised insurance regime for its second-generation Next constellation. In an aggregated approach, Iridium must secure insurance for the first 3 of 10 satellites to be launched for the 81 satellite Next constellation, and secure insurance for the rest of the block shortly after those initial launches. Here, insurance companies would not be required to cover the failure of up to two of those initial satellites, but the failure of a third satellite would require insurers to compensate Iridium for all three lost satellites in addition to a pro rata share of the launch costs.[80] Orbcom has a similar three satellite insurance deductible for its 17 small satellite constellation, however its insurance policy covers the full second-generation constellation and its launches.[81] According to an estimate by Eutelsat, insurance charges and other diverse expenses make up a 20% share of the total cost of placing a typical GEOCOM satellite into orbit, while 30% of the cost goes toward its launch, and 50% goes toward its construction.[82]

On 6 August 2015, Orbital ATK, NASA and the State of Virginia agreed to split the $15 million cost of repairing Pad 0A of the Mid-Atlantic Regional Spaceport in Wallops Island, Virginia, following the 28 October 2014 explosion of Orbital ATK's Antares rocket NASA commercial resupply services (CRS) mission to the ISS. While at the time of the explosion, the state-owned launch pad had been uninsured, leading to dispute between the U.S. federal government, the state of Virginia, and Orbital ATK over responsibility for repairs and clean-up costs, under the terms of the new agreement, Orbital ATK will now secure launch insurance for Virginia assets, the launch pad and systems.[83]

## 2.4 Sectoral Overview

### 2.4.1 Launch Sector

The launch sector is seen as an enabler rather than as a primary economic activity. Yet, with the growth of low-cost launch services, the revenue it will generate in the coming years will continue to attract greater attention.

Launch activity decreased in 2015, with a total of 87 launches conducted by launch providers from Russia, the United States, China, Europe, India, Japan, and Iran. Amid the positive developments to be presented in this section, there were also some notable setbacks that affected the launch sector in

5123x0x876179/DC922427-C53C-4CE9-A5CC-43EB2855F9C7/TomTom_Annual_Report_2015.pdf>.

[78] De Selding, Peter B. "Latest Proton Failure Leaves Customers, Insurers in a Bind." 29 May 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/proton-failure-leaves-customers-insurers-in-a-bind-2/>.

[79] De Selding, Peter B. "After Amos-5 Loss, Competitors Lure Spacecom Customers with Below-cost Pricing." 24 Nov. 2015. SpaceNews 14 Jan. 2016 <http://spacenews.com/after-amos-5-loss-competitors-lure-spacecom-customers-with-below-cost-pricing/>.

[80] De Selding, Peter B. "Component Issue Delays Iridium Next Launches by Four Months." 29 Oct. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/component-issue-delays-iridium-next-launches-by-four-months/>.

[81] De Selding, Peter B. "After Failure, Orbcomm Touts Constellation Resiliency." 10 Aug. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/after-failure-orbcomm-touts-constellation-resiliency/>.

[82] De Selding, Peter B. "Eutelsat Does the Math on Reducing Future Satellite Costs." 3 Dec. 2015. SpaceNews 14 Jan. 2016 <http://spacenews.com/eutelsat-does-the-math-on-reducing-future-satellite-costs-by-at-least-20-percent/>.

[83] Leone, Dan. "Orbital ATK, Virginia Reach Accord on Pad Repair Bill, Insurance." 7 Aug. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/orbital-atk-virginia-reach-accord-on-pad-repair-bill/>.

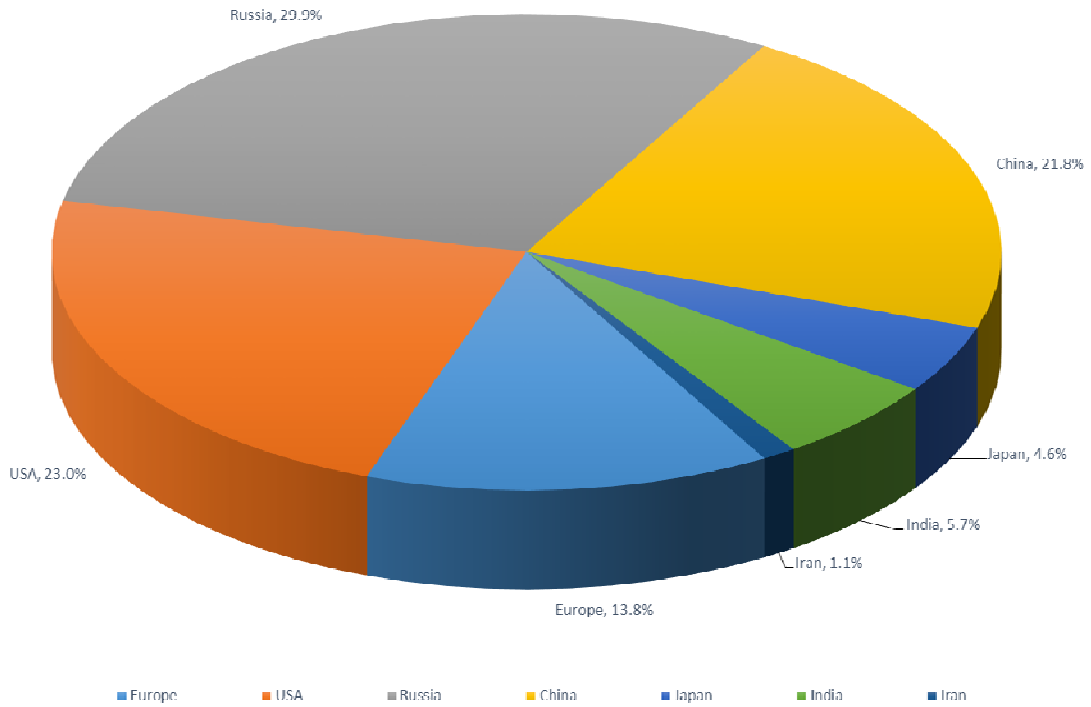


Figure 2.9: Worldwide launches by country in 2015 (Source: FAA)

2015. There were four launch failures in 2015, resulting in the loss of two ISS resuply missions, and up to 25 payloads of various sizes. The first failure occurred on 28 April 2015, with the Progress M-27M ISS resupply mission, which reached orbit, but lost telemetry just before separating from the Soyuz 2.1a upper stage. The next ISS resupply mission, SpaceX's Dragon CRS-7 valued at $61.2 million, also failed on 28 June 2015 due to the presence of too much pressure in the Falcon 9's upper stage liquid oxygen tank about 139 seconds into the flight. The failure of the third stage of the Proton M Briz-M (Ph.3) on 16 May 2015 resulted in the loss of the MexSat 1 communications satellite intended to secure communications for Mexico's national security needs. There was also the failed maiden launch of the three-stage Super Strypi small satellite launch vehicle on 4 November 2015, which malfunctioned during its stage one burn.

When looking into the launches of specific countries (Table 2.2), Russia was once again the world leader in the number of launches for 2015, conducting 30.2% of total launches. The United States remained in second position with a 23.3% share, followed closely by China which had a 22.1% share of the total. Europe stayed in fourth position with a 12.8% share, ahead of India with a 5.8%, Japan with a 4.3% share, and Iran which accounted for 1.2% of the total launch figure (see Figure 2.9).[84]

Russia conducted 26 launches using eleven different launch system configurations.[85] The United States also used eleven different launch system configurations for its 20 launches.[86] China used seven different launch configurations for its 19 launches.[87] Europe relied on its workhorse Ariane 5 ECA launcher, in addition to its Vega launcher and Europeanized Soyuz 2.1b and Soyuz STB Fregat-MT to have 12 launches (6 Ariane 5 ECA, 3 Vega, 1 Soyuz 2.1b, and 2 Soyuz STB Fregat-MT). India used three launcher configurations (i.e. 3 PSLV XL, 1 PSLV CA, and 1 GSLV MK2) for its 5 launches; while Japan used three launcher configurations (i.e. 2 H-IIA 202, 1 H-IIA-204, and 1 H-IIB 304) for its 4 launches. And Iran's single launch was conducted using its Safir 2 launcher.

[84] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 39.
[85] i.e. Dnepr, Proton M Blok DM 03, Proton-M Briz-M (Ph.1 mod. 2), Proton M Briz-M (Ph.3), Rokot KM, Soyuz 2.1a, Soyuz 2.1b, Soyuz 2.1v Volga, Soyuz FG, Soyuz U, and Zenit 3F.
[86] i.e. Atlas 5 (401), Atlas 5 (421), Atlas 5 (501), Atlas 5 (551), Delta 4 Medium+ (4,2), Delta 4 Medium+ (5,4) (upgrade), Delta II 7320-10C, Falcon 9 v1.1, Falcon 9 v1.1(R), Falcon 9FT, and Super Strypi.
[87] i.e. Long March 11, Long March 2D, Long March 3B, Long March 3C, Long March 4B, Long March 4C, and Long March 6.

Launch system utilization moved back to 40 active launch systems in 2015 from 36 used in 2014. Russia, the U.S., and China accounted for 75.9% of the number of launches for 2015 while launch activity in Europe, India, and Japan steadily developed. Moreover, what is not reflected when looking at the number of launches is the fact that certain launchers have dual-launch capabilities such as Europe's Ariane 5 ECA, which can lift two standard-size payloads to geostationary orbit. Hence the number of launches does not reflect the number of payloads brought to orbit.

| Launchers | Number of launch systems active in 2015 | Total number of launches | Commercial launches | Non-commercial launches |
|---|---|---|---|---|
| Russia | 11 | 26 | 5 | 21 |
| USA | 11 | 20 | 8 | 12 |
| China | 7 | 19 | 0 | 19 |
| Europe | 4 | 12 | 6 | 6 |
| India | 3 | 5 | 2 | 3 |
| Japan | 3 | 4 | 1 | 3 |
| Iran | 1 | 1 | 0 | 1 |
| **Total** | **40** | **87** | **22** | **65** |

Table 2.2: Worldwide launches in 2015 per country, number of launched systems, and commercial status (Source: FAA)

The FAA's Annual Compendium of Commercial Space Transportation noted that 22 commercial launches occurred in 2015; however, it should be noted that its definition of a commercial launch includes either one where the primary payload's launch contract was award according to a fair and open process, or one where the launch is privately financed by a private actor without government support.[88] While Europe had the second highest number of commercial launches in 2015, its Ariane 5 dual payload capability helped it to earn the greatest amount of commercial launch revenue for the year. Inversely, the U.S. conducted the most commercial launches, but was in second position in terms of launch revenue in 2015. Russia increased its number of commercial launches to five, placing it at third position in terms of commercial revenue generated. And Japan's single commercial launch placed it in fourth position in terms of commercial launch revenue, while India's two commercial launches placed it at the end of the pack of commercial launch providers. When considering non-commercial launches, Russia had a substantial lead, conducting 32.3% of the launches, China was in second position with 29.2%, followed by the U.S. with an 18.5% share. The remaining 20% of non-commercial launches was split by Europe, India, Japan, and Iran.

The ratio of commercial launches to non-commercial launches was unchanged in 2015, with an equilibrium of 1 commercial launch for every 3 non-commercial launches. Yet, in 2015 the number of payloads launched decreased to 265 from 295 in 2014, which can be attributed to the reduced number of cube satellites intended to be released from the International Space Station.

In terms of the global share of payloads launched in 2015 (Figure 2.10), the U.S. was first in the number of payloads it placed in orbit, lifting 123 payloads, which represents 46.4% of the total. China moved to second place, launching 45 payloads (nearly doubling its number in 2014) resulting in a 17.0% share. Russia was in third position, launching 32 payloads, which amounted to a 12.1% share. Europe and Japan came in fourth position, each with 22 payloads (8.3%), followed closely by India with 20 payloads (7.5%), and Iran with 1 payload (0.4%). The global share of payloads launched changes considerably when excluding the total 143 cube satellite payloads from the assessment. In this case, the U.S. remained in first position with a decreased 29.5% share, followed by Russia whose share increases to 24.6% of the total. Moreover, Europe and China tie in third position, each with an 18.0% share, while India's share drops to fourth position with 6.6%, followed by Japan with a 3.3% share; Iran's cube satellite is not considered in this scenario.

[88] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 57.

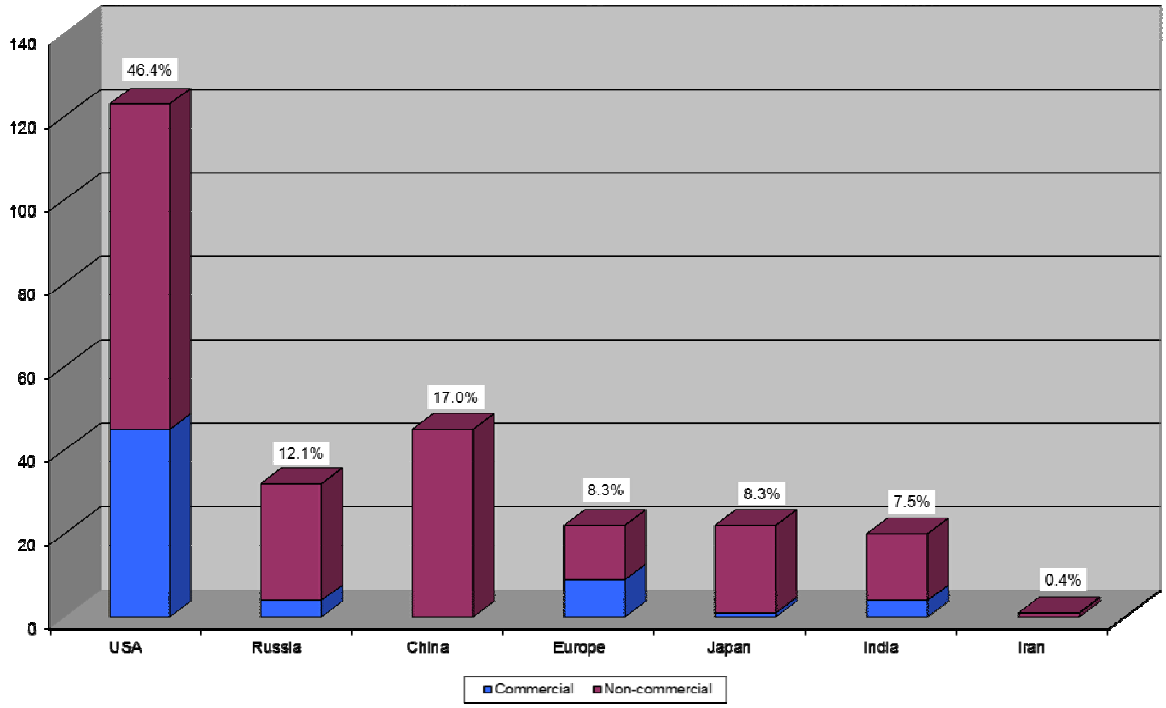


Figure 2.10: Total payloads launched in 2015 by country, share and commercial status (Source: FAA)

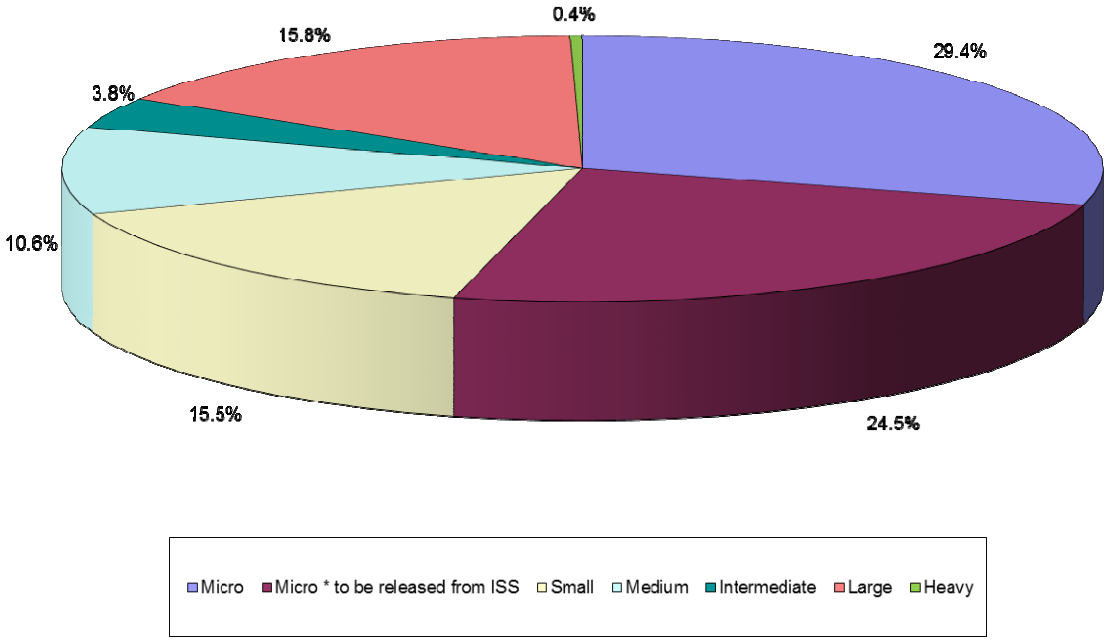


Figure 2.11: Distribution of the payloads launched in 2015 by mass class (Source: FAA)

| Payloads by mass class | 2015 | Percentage | Average Mass (kg) | Mass Sum (kg) |
|---|---|---|---|---|
| Micro | 78 | 29.4% | 10.1 | 791.4 |
| Micro * to be released from ISS | 65 | 24.5% | 6.1 | 395.0 |
| Small | 41 | 15.5% | 373.4 | 15,308.0 |
| Medium | 28 | 10.6% | 1,533.4 | 42,936.0 |
| Intermediate | 10 | 3.8% | 3,143.1 | 31,431.0 |
| Large | 42 | 15.8% | 6,107.4 | 256,510.0 |
| Heavy | 1 | 0.4% | 16,500.0 | 16,500.0 |
| | **265** | **100.00%** | **1,373.1** | **363,871.4** |

Table 2.3: Distribution of the payloads launched in 2015 by mass class (Source: FAA and Gunter's Space Page)

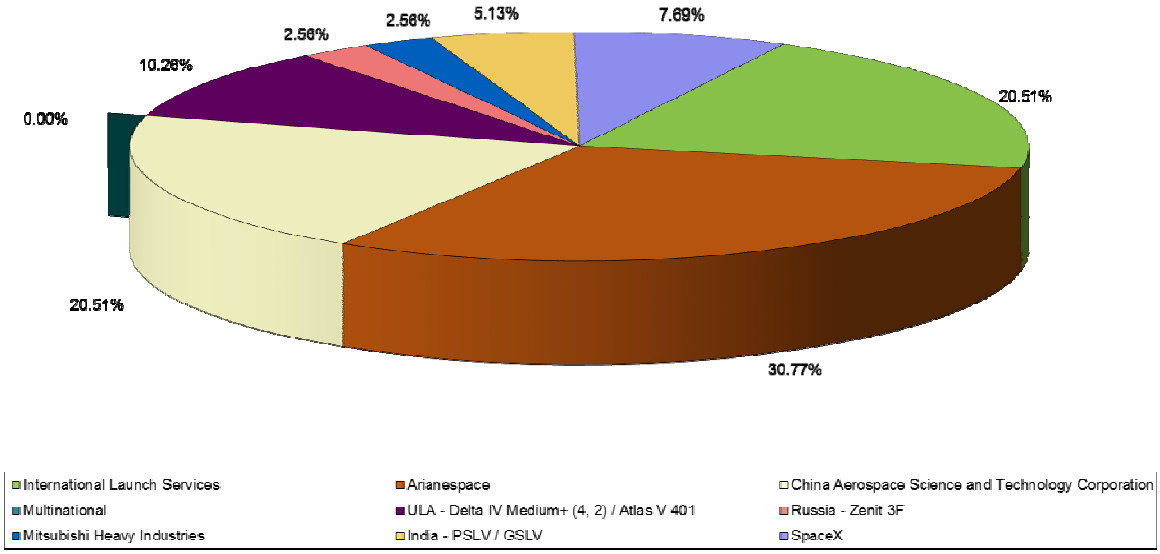


Figure 2.12: Share of launch contracts for GEO satellites in 2015 by launch service provider

There were also some changes in the distribution of payload sizes in 2015 (Figure 2.11 and Table 2.3). The number of "Micro" sized payloads reduced to 143, accounting for 54.0% of the total payloads launched in 2015. The average mass of these cube satellite payloads was around 8.3 kg, with the sum of their mass reaching 1186.4 kg. In 2015, 65 cube satellites were launched to the ISS to be later ejected into orbit, however 8 cube satellites were destroyed in the failed launch of the Dragon CRS-7 on 28 June 2015. "Large" satellites entered into second position, marking a significant increase in 2015 with 42 payloads launched; a share of 15.8%. "Small" mass class was in third position with 41 payloads at 15.5%. Medium payloads were in the fourth position with 28 payloads, at 10.6%; 10 "Intermediate" payloads followed at 3.8%, and finally 1 "Heavy" payload accounted for 0.4% of the payloads launched in 2015.[89]

[89] Micro payloads have a mass of 91 kg or less, and are mainly science satellites, technological demonstrators or small communications satellites. Small payloads weigh between 92 and 907 kg and are very often Earth Observation satellites, similar to the Jason or the RapidEye series. Medium payloads weigh between 908 and 2,268 kg, and feature the most diverse set of satellites, including small satcoms in geostationary orbit, Earth Observation satellites, and most of the Russian military satellites from the Kosmos series. Intermediate payloads, weighing between 2,269 and 4,536 kg, comprise medium satcoms and big scientific satellites. Large payloads, between 4537 and 9,072 kg, refer to big satcoms, as well as to the Soyuz and Progress spacecraft flying to the ISS. Finally, Heavy payloads, exceeding 9,072 kg, are linked to ISS activity, such as the cargo spacecraft, ATV, HTV, etc. *See* Commercial Space Transportation: 2011 Year in Review, 32.

| Launch services provider | Launches | Payloads | Percenage |
|---|---|---|---|
| Arianespace | 6 | 12 | 30.77% |
| China Aerospace Science and Technology Corporation (CASC) | 8 | 8 | 20.51% |
| International Launch Services (ILS) | 8 | 8 | 20.51% |
| United Launch Alliance (ULA) | 4 | 4 | 10.26% |
| SpaceX | 2 | 3 | 7.69% |
| India | 2 | 2 | 5.13% |
| Mitsubishi Heavy Industries | 1 | 1 | 2.56% |
| Russia | 1 | 1 | 2.56% |
| | **32** | **39** | **100.00%** |

Table 2.4: Share of launch contracts for GEO satellites in 2015 by launch service provider (Source: FAA)

In 2015, Arianespace conducted the most launches in GEO, with a 30.8% share, followed by the China Aerospace Science and Technology Corporation (CASC), and the Russian International Launch Services (ILS), each with 20.5% (Figure 2.12 and Table 2.4). Arianespace placed 10 communications satellites, along with the Italian/French Sicral 2 military communications satellite, and Eumetsat's MSG-4 meteorological satellite into GEO orbit using six Ariane 5 ECA launchers. China's CASC launched four communication satellites, two Beidou navigation satellites, its Gaofen 4 remote sensing satellite, and its TJSSW 1 early warning satellite to GEO orbit mainly on Long March 3B launchers, and one 3C launcher. The Russian ILS launched 8 GEO communication satellites on eight Proton M launchers; including a failed launch of the MexSat 1 satellite. The U.S. ULA had four launches to lift 4 communications satellites (MUOS 3, MUOS 4, WGS 7, and MexSat 3) into GEO orbit. And the SpaceX Falcon 9 was used twice to launch three commercial communications satellites (ABS 3A, Eutelsat 115, and TürkmenÄlem 52E/MonacoSat-1) into GEO orbit. India's PSLV XL launcher lifted the IRNSS 1D navigation satellite to GEO orbit, while its GSLV Mk.2 launched the GSAT 6 communications satellite. Lastly, Japan used its H-IIA 204 launcher to launch the Telstar 12V commercial communications satellite into GEO orbit, while the Russian Zenit 3F placed the Elektro-L No. 2 meteorology satellite into orbit.

### 2.4.2 Manufacturing Sector

Looking at the market share of satellites launched and ordered in a given year provides a good indication of the vitality of domestic space industries, while also providing clues to global trends in the space industry.

In 2015, 265 payloads were launched (including an estimated 143 cube satellites, 15 crewed, cargo, or hardware missions to the ISS, and the test launch of the Europe's IXV spacecraft and its AVUM VV04 upper stage). The U.S. manufactured 52.1% of the launched payloads (including 104 cubesats), while China accounted for 17.0%, and Russia produced 10.2%. Europe, with its 24 satellites mostly built for navigation and communication purposes, accounted for 9.1% of the payloads launched, while Japan and India each accounted for 1.5%. The remaining 8.7% of payloads were from various parts of Asia, the Middle East, and the Americas.[90]

Of the 248 satellites launched in 2015[91], 166 were non-commercial. Among the large satellite integrators, China's CAST was once again in first position in manufacturing 16 non-commercial satellites, followed by the Reshetnev Company which produced 10 non-commercial satellites, while the regions of Asia, North America, Europe, and Russia also showed a strong presence in this market. About 16 of the 24 European manufactured satellites were non-commercial. Boeing produced 7 non-commercial satellites, followed by OHB Systems with 6 non-commercial satellites. ISRO produced 4 non-commercial satellites, while 3 were developed each by Airbus Defence & Space and Lockheed Martin, along with 2 developed each by Thales Alenia Space and Mitsubishi, and 1 non-commercial satellite developed by Orbital ATK (Figure 2.13).[92]

[90] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 65-69. Payloads are assigned to the nation that commissioned them, not according to the nationality of the manufacturer.
[91] i.e. not counting the 15 crewed, cargo, or hardware missions to the ISS, and the test launch of the Europe's IXV spacecraft and its AVUM VV04 upper stage.
[92] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 65-69.

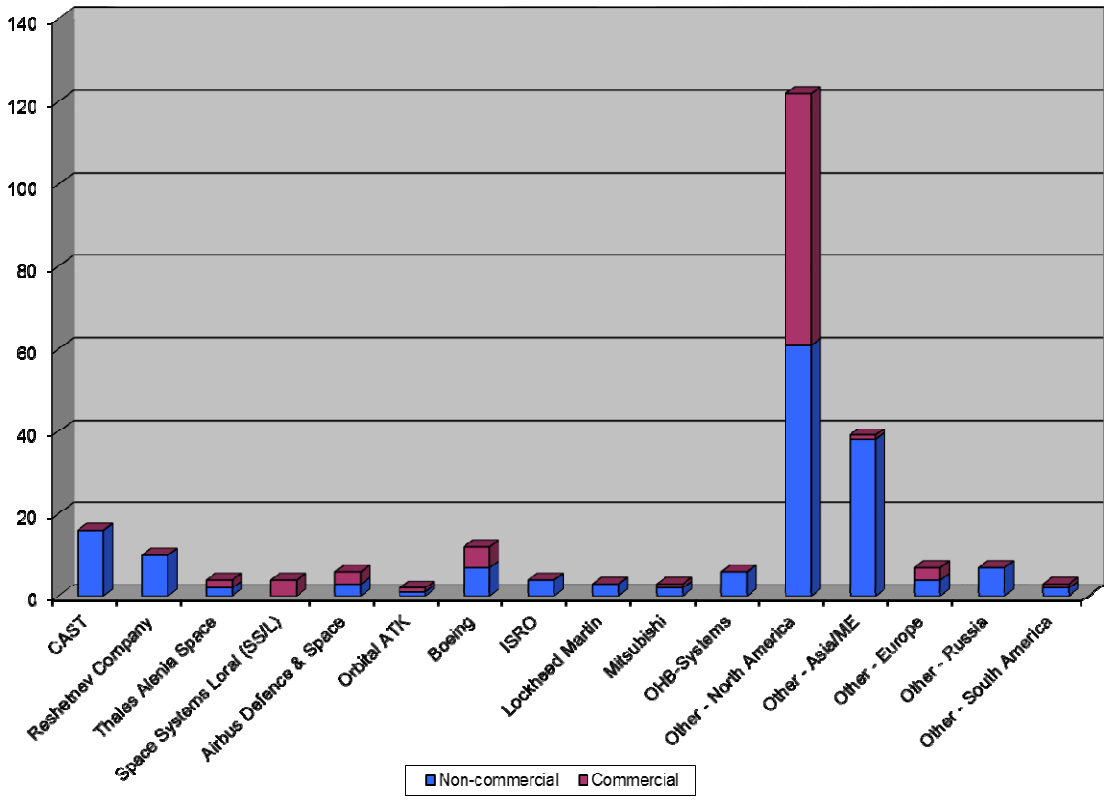


Figure 2.13: Satellites launched in 2015 by manufacturer and commercial status (Source: FAA)

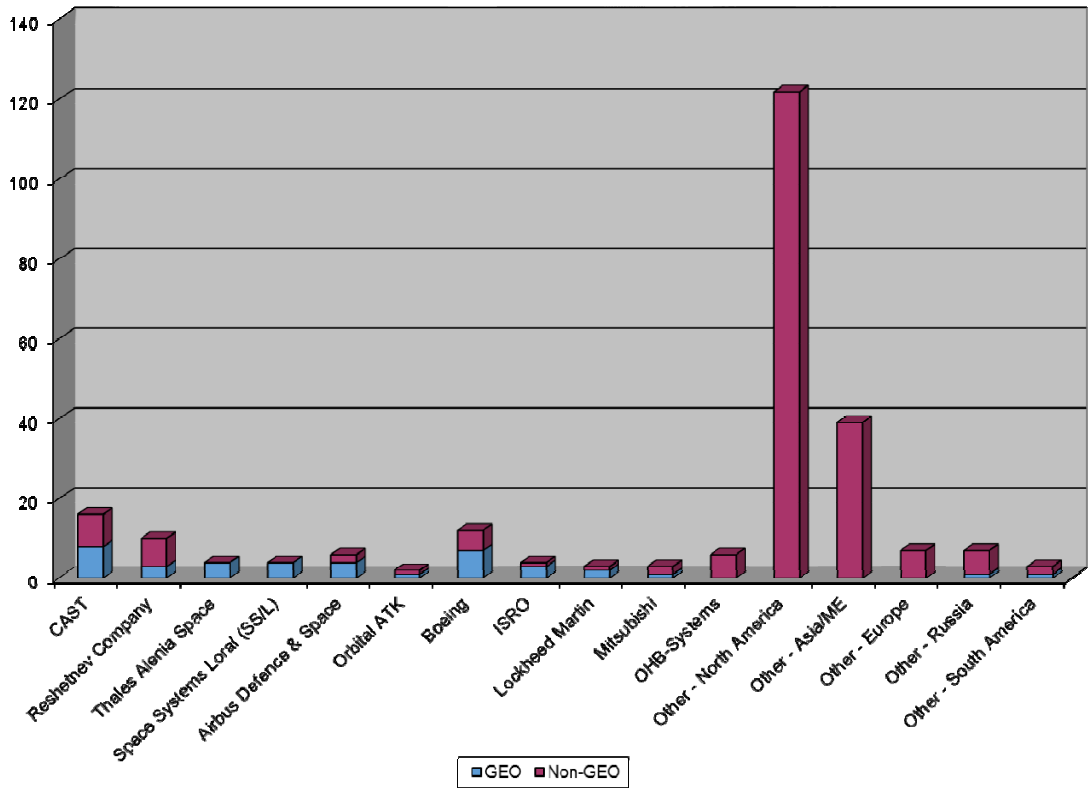


Figure 2.14: Satellites launched in 2015 by manufacturer and orbit type (Source: FAA)

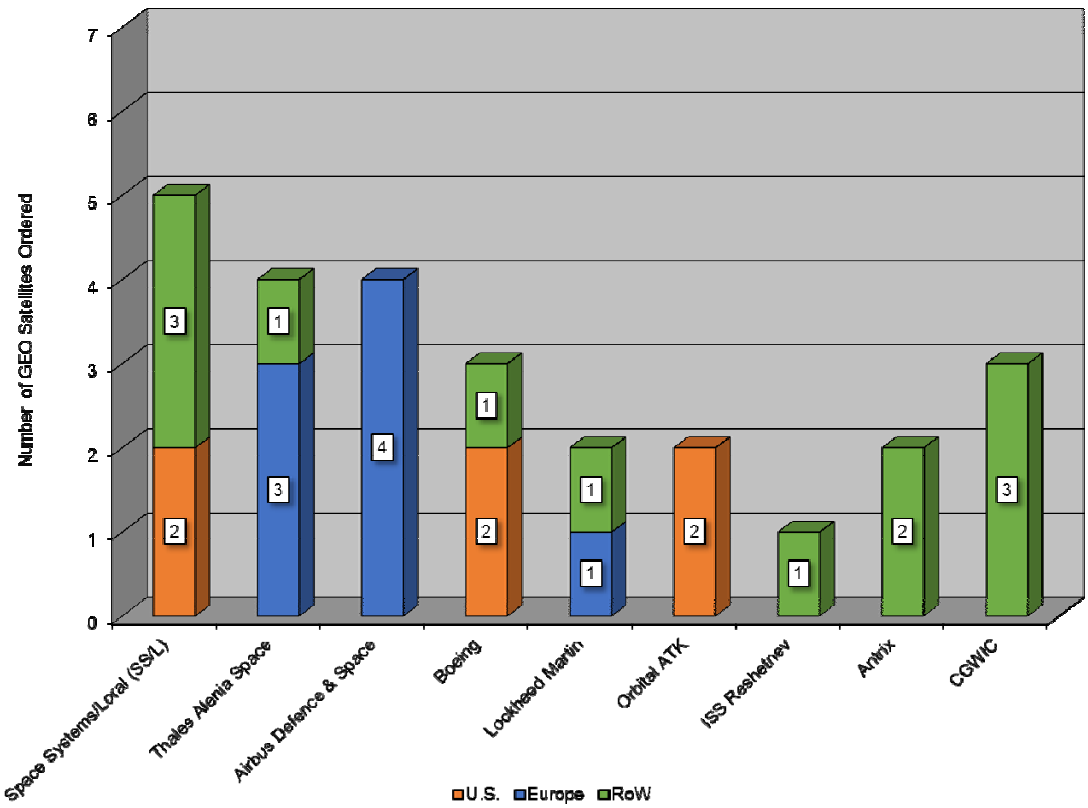


Figure 2.15: GEO satellite orders in 2015 by manufacturer

In 2015, Boeing took the top position among the commercial prime contractors with the launch of 5 of its commercial satellites. Canada's Space Systems Loral (SS/L) took the second position manufacturing 4 commercial satellites, while Airbus Defense & Space was third in terms of its 3 commercial satellites. Thales Alenia Space built 2 commercial satellites, while Mitsubishi, and Orbital ATK each developed 1 commercial satellite (Figure 2.13).[93]

In 2015, 15.7% of the 248 satellites launched were geostationary satellites (Figure 2.14). In this field, 35.9% of the 39 GEO satellites came from North America (including 7 by Boeing, 4 by SS/L, 2 by Lockheed Martin, and 1 by Orbital ATK). Europe provided 20.5% of the GEO satellites (4 by Airbus Defence & Space and 4 by Thales Alenia Space, built mainly for telecommunications purposes). China's CAST also provided 20.5% of the GEO satellites launched in 2015, launching a total of 8 satellites to GEO orbit following a hiatus in 2014. Russia's Reshetnev Company had a 7.7% share of GEO satellites launched into orbit, as did India's ISRO, each launching of 3 satellites. Japan's Mitsubishi had a 2.6% share, launching 1 satellite to GEO orbit, in addition to 1 satellite by Other – Russia, and 1 by Other – South America.[94]

Among the 209 non-GEO orbiting satellites, North America's share grew to 61.7% (5 by Boeing, 1 by Lockheed Martin, 1 by Orbital ATK, and another 122 – mostly cube satellites - from other parts of North America). Manufacturers in Asia held a 23.9% share with 50 non-GEO satellites (8 by China's CAST, 2 by Japan's Mitsubishi, 1 by India's ISRO, and another 39 developed by in Other – Asia/ME). Europe's share was 7.2% with 15 non-GEO satellites (6 by OHB Systems, 2 by Airbus Defence & Space, and the remainder from other European makers). Russia's share was 6.2% with 13 non-GEO satellites (7 by the Reshetnev Company, and the remaining by Other Russian manufacturers). The remaining 2 non-GEO satellites were developed in South America, and accounted for a 1.0% share.[95]

In 2015, North American prime spacecraft manufacturers had a combined lead in orders for commercial GEO communications satel-

[93] Ibid.

[94] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 40.

[95] Federal Aviation Administration. The Annual Compendium of Commercial Space Transportation: 2016. Washington DC: FAA, Jan. 2016: 65-69.

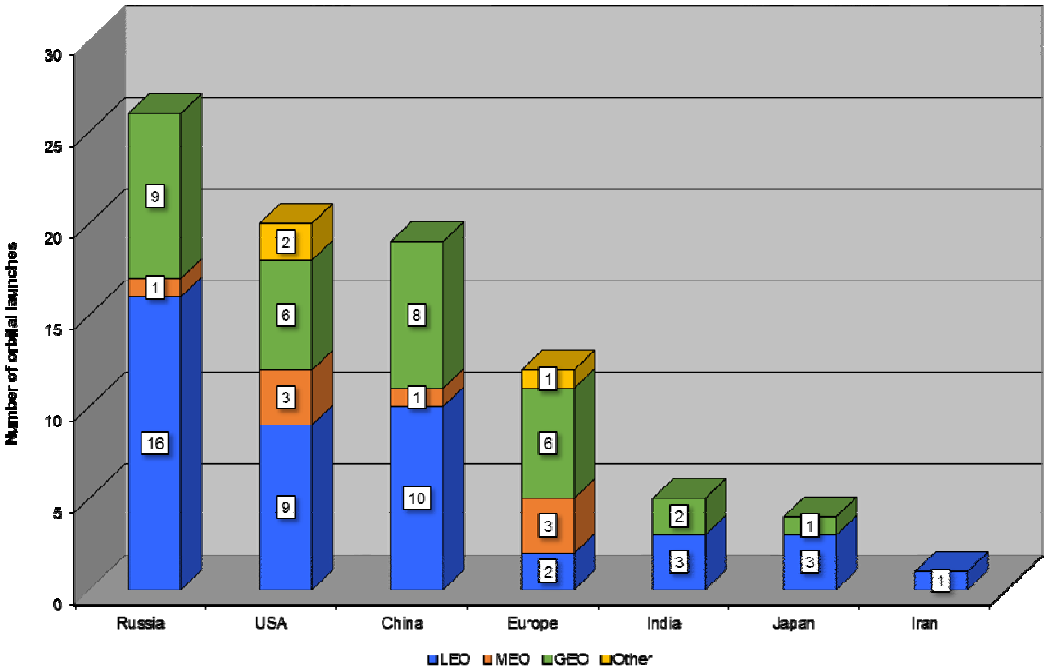


Figure 2.16: Total worldwide orbital launches per country/institution 2015 (Source: FAA)

lites, accounting for 46.1% of the 26 contracts awarded, whereas European contracts decreased to 30.8% of the available awards. SS/L won the most commercial orders, 5 contracts (including the Azerspace 2, BSat 4a, Telkom 4, Telstar 18V, and Telstar 19V). Europe's Airbus Defence & Space with 4 orders (Inmarsat-6 F1, Inmarsat-6 F2, SES 14, and Eutelsat Quantum), along with Thales Alenia Space, which also had 4 orders (Bangabandhu 1, Eutelsat African Broadband Satellite, Comsat-NG 1, and Comsat-NG 2), came next. U.S. prime contractors' Boeing had 3 contracts (ABS 8, SES 15, and Silkwave 1), while Lockheed Martin won 2 commercial contracts for the year (ArabSat 6A and HellasSat 4) along with Orbital ATK (SES 16/GovSat and an unknown satellite). China's CGWIC had an 11.5% share by winning 3 contracts (APStar 6C, ChinaSat 6C, and ChinaSat 18), while India's Antrix had a 7.7% share winning 2 contracts (GSat 17 and GSat 18). Lastly, Russia's ISS Reshetnev won a contract to build the Russian Yamal 601 communication satellite resulting in a 3.8% share.[96]

[96] "Recently awarded GEO-Sat Contracts." 6 May 2016. Gunter's Space Page 12 May 2016 <http://space.skyrocket.de/doc_sat/sat-contracts.htm>.

## 2.5 International Sectoral Comparison

In order to assess the scope and dynamism of the activities, strategies and plans of the main space-faring nations, key space activities, such as the ability to launch missions, and also the number and type of missions launched, must be considered.

### 2.5.1 Launch Sector

The possession of launch vehicles and spaceports is a central element in enabling independence in space activities. Moreover, the number of launches and the level of activity of the space bases give an indication of the dynamism of a country in the space sector.

In 2015, a total of 87 orbital launches was carried out by seven countries; down from 92 orbital launches in 2014 (Figure 2.16). The rank order among the top four launching states remained the same in 2015, wherein Russia led with 26 launches, followed by 20 launches by the U.S., 19 by China, and 12 by Europe. India conducted 5 launches, followed by Japan with 4, and 1 launch by Iran. Overall, the trend remained consistent with previous years, with the pace of respective launching states performing to their capacities.

The number of missions reduced to 265 in 2015, from 295 in 2014; still, that number

remains heavily skewed as microsatellite missions represented more than half (54.0%) of the number of satellites launched in 2015 (Figure 2.17). In 2015, a total of 143 microsatellites built mainly by governments, universities, and non-profits were launched into space, whereas 168 microsatellites were launched in 2014. The U.S., China, and Russia held the top three positions in terms of the number of missions launched, followed Europe which had 11 missions (or 24 when including missions by individual European countries). The U.S. conducted a total of 138 missions (*including nearly 104 microsatellite missions*, for a share of 52.1% of the total missions launched), followed by China with 45 (17.0%), Russia with 27 (10.2%), and Europe with a combined 24 missions (9.1%).

The increase in missions in recent years is partly due to the growth of microsatellite missions. If the total 143 microsatellites were removed from consideration, of the remaining 122 missions conducted the U.S. would have a 27.9% share, while Russia would have 20.5%, China would have 18.0%, Europe would have 16.4% and Japan's share would be 3.3%; combining to about 86.1% of the total non-microsatellite missions launched 2015.

Figure 2.18 presents the distribution of the total mass of payloads launched by launching state in 2015. In 2015, Russian launch systems lifted 130.7 tons of payload into orbit, of which 82.3% was for its domestic market; Russian launchers lifted all Russian payloads for the year. The U.S. launch systems placed 88.0 tons of payload into orbit; 96.6% of the mass was U.S. payloads. China lifted 51.5 tons of payload into orbit; 93.7% of the mass was for Chinese payloads, in addition to the mass of a telecom satellite for the Laos government. Europe placed 62.3 tons of payload into orbit, with only 46% of that mass coming from European flagship projects including Galileo and Copernicus, along with satellites for Eumetsat, France, Italy, Luxembourg, and Norway. Japan lifted 24.2 tons of payload into orbit, with 79.4% of the mass belonging

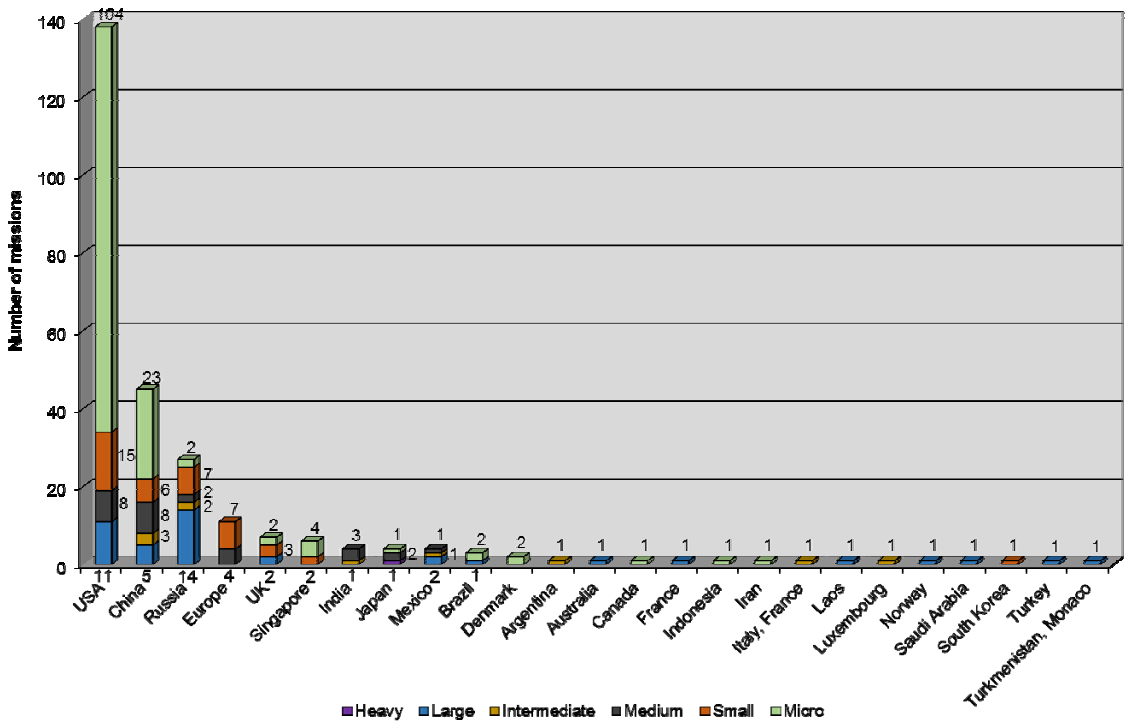


Figure 2.17: Number of missions launched into space by country/institution and payload size in 2015 (Source: FAA)

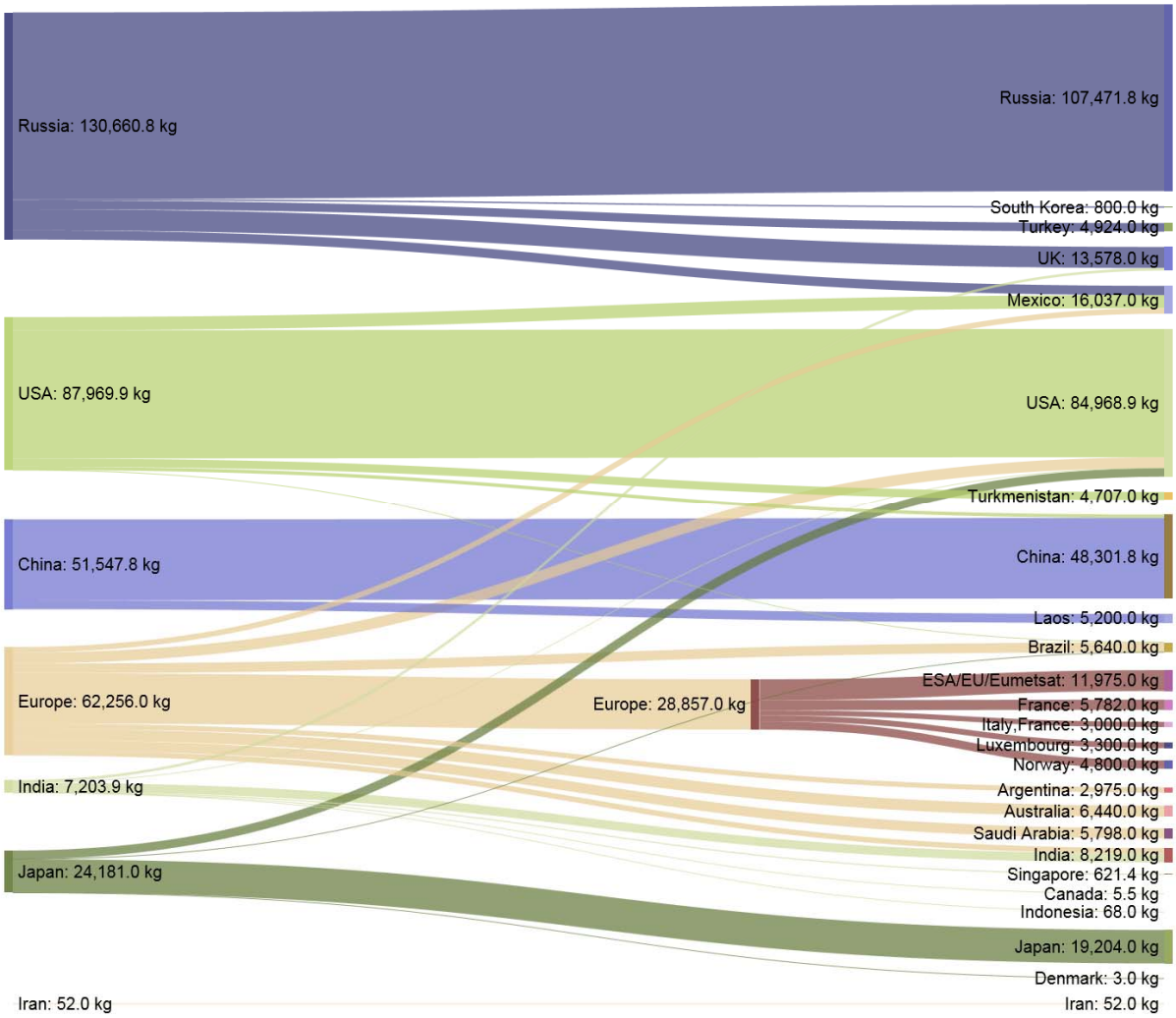


Figure 2.18: Distribution of total mass of payloads launched by launching state in 2015 (Source: Gunter's Space Page)

to Japanese payloads. India lifted 7.2 tons of payload into orbit, with 70.2% of the mass coming from Indian payloads – Europe's Ariane 5 ECA also launched the 3.2 ton GSAT 15 communications satellite for ISRO. And Iran used its Safir 2 launcher to lift its 52.0 kg Fajr microsat into orbit.[97]

| Country | Micro | Small | Medium | Inter-mediate | Large | Heavy |
|---|---|---|---|---|---|---|
| Russia | 2 | 8 | 2 | 2 | 18 | 0 |
| USA | 87 | 15 | 10 | 0 | 11 | 0 |
| China | 23 | 6 | 7 | 3 | 6 | 0 |
| Europe | 0 | 7 | 4 | 5 | 6 | 0 |
| India | 12 | 5 | 3 | 0 | 0 | 0 |
| Japan | 18 | 0 | 2 | 0 | 1 | 1 |
| Iran | 1 | 0 | 0 | 0 | 0 | 0 |
| **Total** | **143** | **41** | **28** | **10** | **42** | **1** |

Table 2.5: Distribution of the payloads launched in 2015 by Country (Source: FAA and Gunter's Space Page)

[97] Micro payloads have a mass of 91 kg or less, and are mainly science satellites, technological demonstrators or small communications satellites. Small payloads weigh between 92 and 907 kg and are very often Earth Observation satellites, similar to the Jason or the RapidEye series. Medium payloads weigh between 908 and 2,268 kg, and feature the most diverse set of satellites, including small satcoms in geostationary orbit, Earth Observation satellites, and most of the Russian military satellites from the Kosmos series. Intermediate payloads, weighing between 2,269 and 4,536 kg, comprise medium satcoms and big scientific satellites. Large payloads, between 4537 and 9,072 kg, refer to big satcoms, as well as to the Soyuz and Progress spacecraft flying to the ISS. Finally, Heavy payloads, exceeding 9,072 kg, are linked to ISS activity, such as the cargo spacecraft, ATV, HTV, etc. *See* Commercial Space Transportation: 2011 Year in Review, 32.

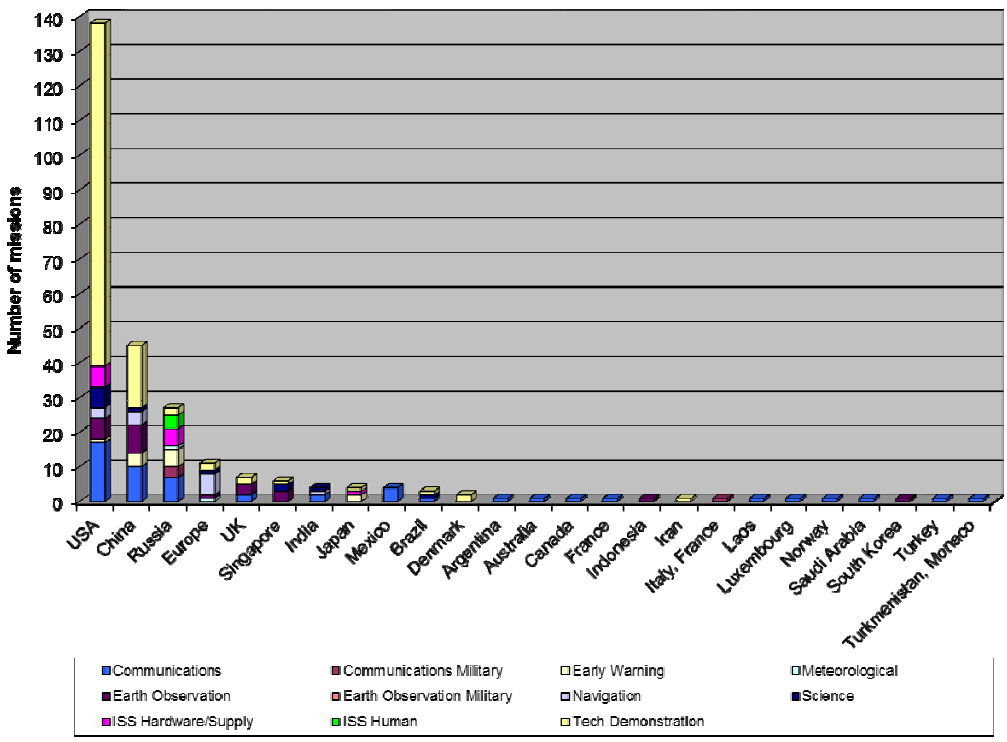


Figure 2.19: Types of missions launched into orbit in 2015 (Source: FAA)

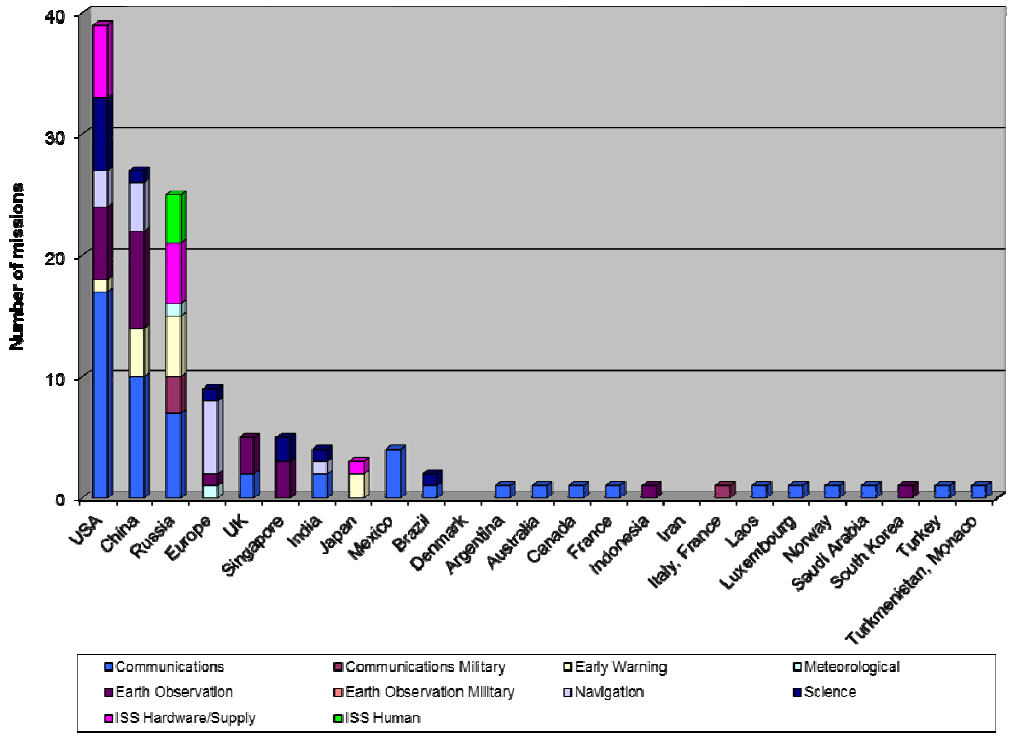


Figure 2.20: Types of missions launched into orbit in 2015, not including Tech Demonstrations (Source: FAA)

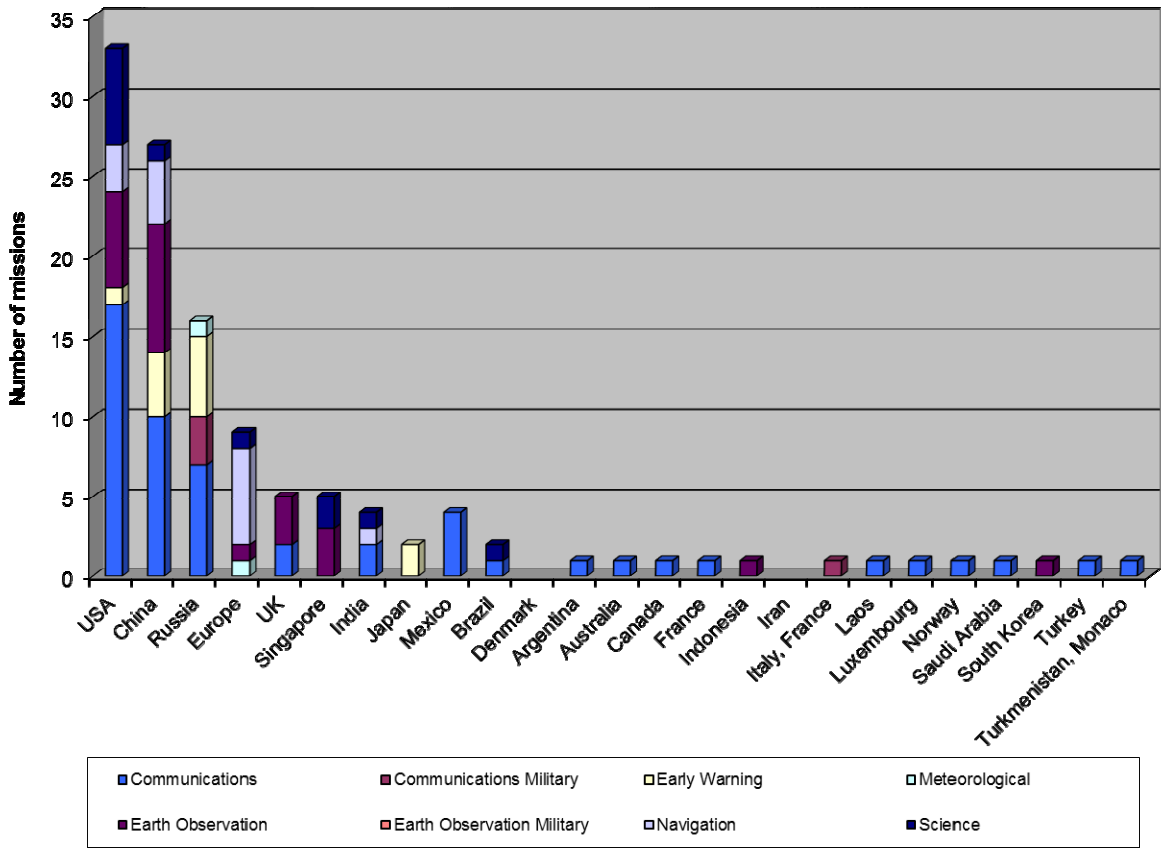


Figure 2.21: Types of missions launched into orbit in 2015,
not including Tech Demonstrations and crewed / cargo missions to the ISS (Source: FAA)

In 2015, most of the missions were classified as technology demonstrations, including 97 cubesats from the U.S. (i.e. 50 from Planet Labs), NASA's Ultrasat small satellite, and the U.S. Air Force's large X-37B spacecraft. Moreover, China's technology demonstrations included 16 cubesats and 2 small satellites, with some technology demonstration cubesats peppered in the missions of the other spacefaring countries (Figure 2.19). When removing the 129 technology demonstration missions from consideration, the remaining 136 missions covered nearly the entire spectrum of missions. The U.S. focus was also on communication satellites, with continued development in remote sensing, science, and ISS cargo resupply missions, and in navigation and early warning systems. China focused on communications and remote sensing activities, along with navigation and early warning satellites; moreover, China did not conduct missions involving its space station for a second year in 2015. Russia launched an assortment of civil and military communication satellites, in addition to 5 early warning systems; it also conducted 5 cargo resupply missions and 4 crewed missions to the ISS. Much of Europe's activity centred on launching its Galileo navigation satellites, along with the launch of the Copernicus Sentinel 2a remote sensing satellite, and Eumetsat's MSG 4 meteorological satellite (Figure 2.20 and 2.21).

Among the remaining 136 non-technology demonstration missions, civil communications had the highest share of activity, at about 39.0% in 2015, while Earth observation missions accounted for 16.9%, and navigation missions accounted for 10.3%. Next, early warning systems, science missions, and ISS cargo resupply missions each accounted for 8.8% shares. Crewed launches to the ISS and military communication satellite systems each had 2.9% shares, while meteorological systems maintained a 1.5% share.

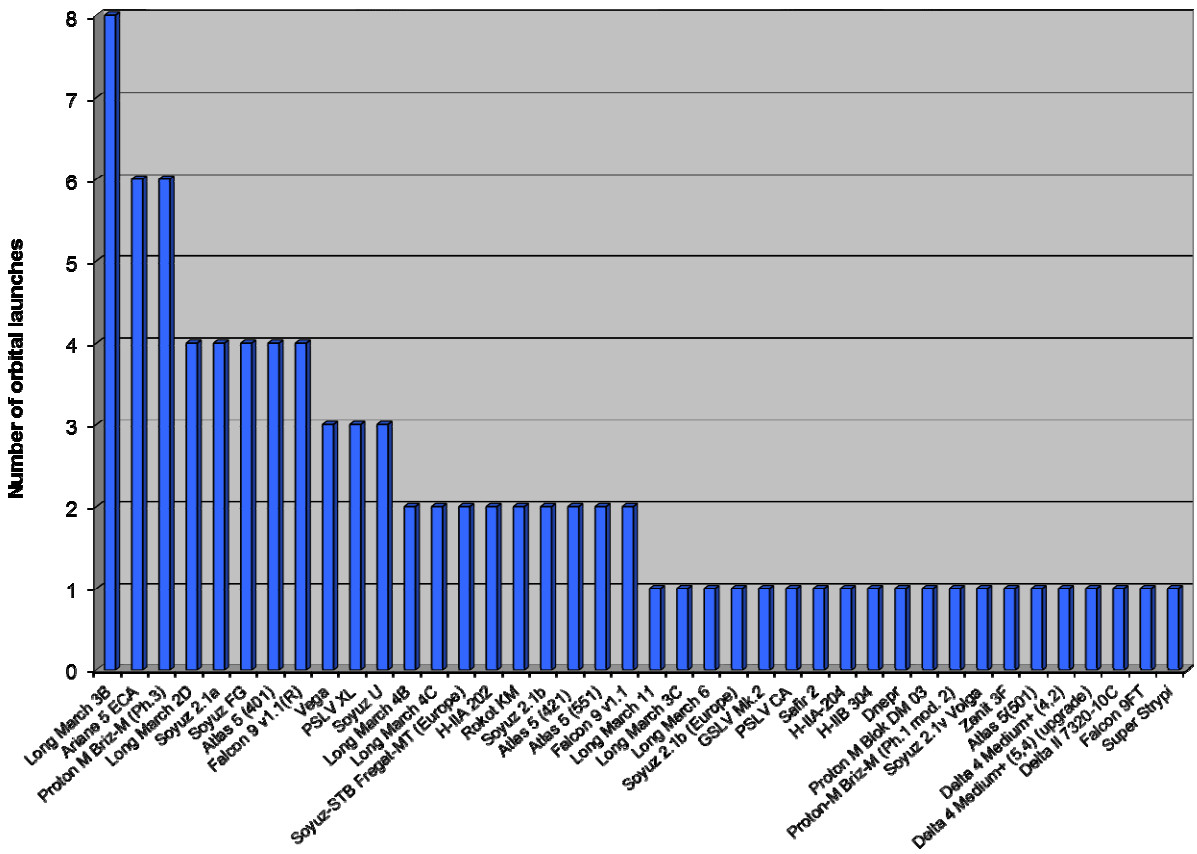


Figure 2.22: Worldwide orbital launches per launch system in 2015 (Source: FAA)

China's Long March 3B launch system was in the most use in 2015 (Figure 2.22) with 8 launches. Both Europe's Ariane 5 ECA and Russia's Proton M Briz-M (Ph.3) were the second-most used launch systems, each with 6 launches; five launch systems shared the third position, including China's Long March 2D, Russia's Soyuz 2.1a and Soyuz FG, and the U.S. Atlas 5 (401) and Falcon 9v1.1(R) – each with 4 launches. Europe's Vega launcher, along with India's PSLV XL and the Russian Soyuz U each had 3 launches, followed by nine launch systems each conducting 2 launches, and single launches by twenty other launch system configurations.

Russia's eleven launch configurations (mainly Soyuz and Proton M variants) amounted to 29.9% of the launches (26 launches). The U.S. also used eleven configurations (mainly variations of the Atlas V and commercial Falcon 9 launch systems) amounting to 23.0% of the launches (20 launches). On the other hand, China's seven launch configurations had a 21.8% share of the launches (19 launches), while Europe's four systems (i.e. Ariane 5 ECA, Vega, Soyuz STB Fregat-MT, and Soyuz 2.1b) accounted for 13.8% (12 launches). The Ariane 5 has the advantage of the ability to carry two payloads, which should be considered when assessing the European figure. India's three launch systems accounted for 5.7% of the launches (5 launches), while Japan's three launch systems accounted for 4.6% (4 launches). Lastly, Iran's single launch system accounted for 1.1% (1 launch).

The total number of active launch configurations (including their variations) increased to 40 in 2015 from 36 in 2014. Yet the year-to-year fluctuations may be less significant when considering that some launcher configurations have several variations that were not used in 2015.

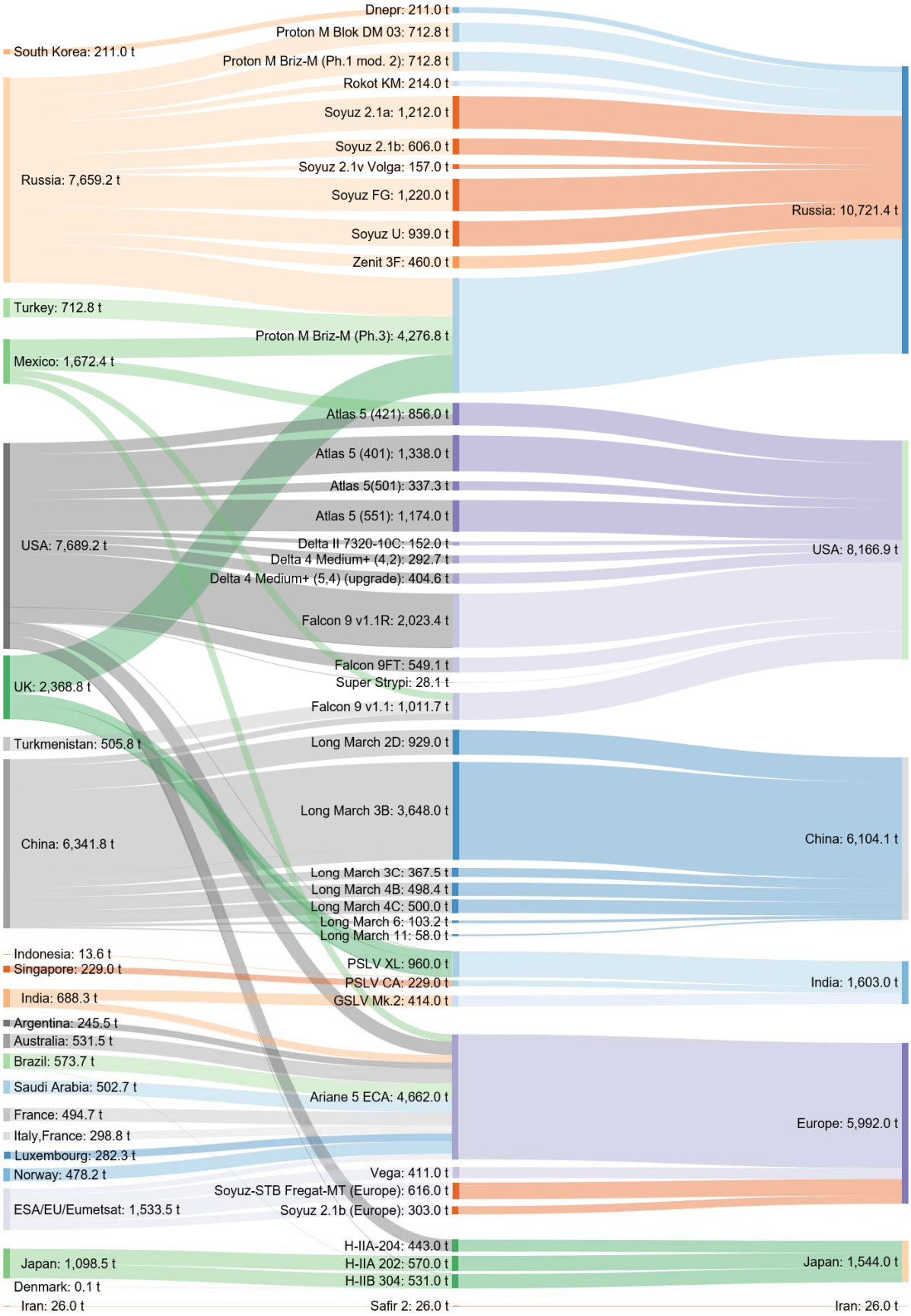


Figure 2.23: Distribution of total mass of launch systems launched by launching state in 2015 (Source: Gunter's Space Page and Spaceflight 101)

| Country | Launch System | Number of Launches | Mass of Launcher (metric ton) | Mass Sum (metric ton) |
|---|---|---|---|---|
| Russia | Dnepr | 1 | 211.0 | 211.0 |
| | Proton M Blok DM 03 | 1 | 712.8 | 712.8 |
| | Proton-M Briz-M (Ph.1 mod. 2) | 1 | 712.8 | 712.8 |
| | Proton M Briz-M (Ph.3) | 6 | 712.8 | 4276.8 |
| | Rokot KM | 2 | 107.0 | 214.0 |
| | Soyuz 2.1a | 4 | 303.0 | 1212.0 |
| | Soyuz 2.1b | 2 | 303.0 | 606.0 |
| | Soyuz 2.1v Volga | 1 | 157.0 | 157.0 |
| | Soyuz FG | 4 | 305.0 | 1220.0 |
| | Soyuz U | 3 | 313.0 | 939.0 |
| | Zenit 3F | 1 | 460.0 | 460.0 |
| USA | Atlas 5 (401) | 4 | 334.5 | 1338.0 |
| | Atlas 5 (421) | 2 | 428.0 | 856.0 |
| | Atlas 5(501) | 1 | 337.3 | 337.3 |
| | Atlas 5 (551) | 2 | 587.0 | 1174.0 |
| | Delta II 7320-10C | 1 | 152.0 | 152.0 |
| | Delta 4 Medium+ (4,2) | 1 | 292.7 | 292.7 |
| | Delta 4 Medium+ (5,4) (upgrade) | 1 | 404.6 | 404.6 |
| | Falcon 9 v1.1 | 2 | 505.8 | 1011.7 |
| | Falcon 9 v1.1(R) | 4 | 505.8 | 2023.4 |
| | Falcon 9FT | 1 | 549.1 | 549.1 |
| | Super Strypi | 1 | 28.1 | 28.1 |
| China | Long March 2D | 4 | 232.3 | 929.0 |
| | Long March 3B | 8 | 456.0 | 3648.0 |
| | Long March 3C | 1 | 367.5 | 367.5 |
| | Long March 4B | 2 | 249.2 | 498.4 |
| | Long March 4C | 2 | 250.0 | 500.0 |
| | Long March 6 | 1 | 103.2 | 103.2 |
| | Long March 11 | 1 | 58.0 | 58.0 |
| Europe | Ariane 5 ECA | 6 | 777.0 | 4662.0 |
| | Vega | 3 | 137.0 | 411.0 |
| | Soyuz-STB Fregat-MT (Europe) | 2 | 308.0 | 616.0 |
| | Soyuz 2.1b (Europe) | 1 | 303.0 | 303.0 |
| India | PSLV CA | 1 | 229.0 | 229.0 |
| | PSLV XL | 3 | 320.0 | 960.0 |
| | GSLV Mk.2 | 1 | 414.0 | 414.0 |
| Japan | H-IIA 202 | 2 | 285.0 | 570.0 |
| | H-IIA-204 | 1 | 443.0 | 443.0 |
| | H-IIB 304 | 1 | 531.0 | 531.0 |
| Iran | Safir 2 | 1 | 26.0 | 26.0 |

Table 2.6: Distribution of the mass of launch systems launched by launching state in 2015 (Source: Gunter's Space Page and Spaceflight 101)

Figure 2.23 presents the distribution of the total mass of launch systems launched by launching state in 2015. The demand for specific launch systems is seen on the left side of the figure, while countries that supplied the launchers are displayed on the right side. As seen in Figure 2.18, the majority of U.S., Russian, and Chinese launch systems when to cater to their respective institutional markets, whereas a substantial portion of Europe's launch systems where used by non-European actors.

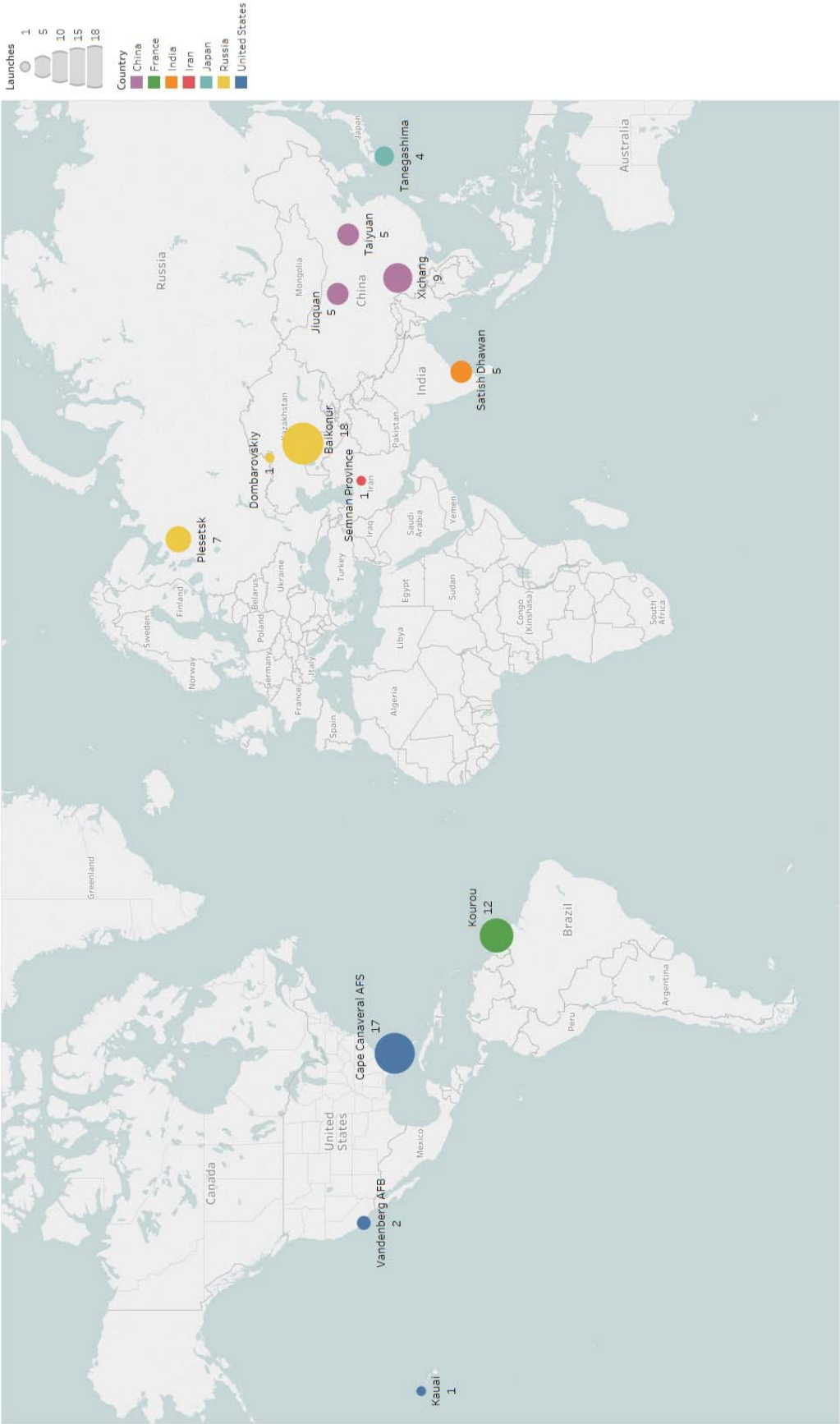


Figure 2.24: Worldwide orbital launches per launch site in 2015 (Source: FAA)

Space transportation infrastructure is another factor that helps assess space capacity, as spaceports are integral for independent access to space (Figures 2.24). The number of spaceports used by a country, as well as the frequency of launches conducted from them, are important indicators of the momentum of a country's space activities.

In 2015, the Baikonur spaceport in Kazakhstan (leased and operated by Russia) was the most active launch site with 18 launches (i.e. 20.7% of total launches). Cape Canaveral Air Force Station in the U.S. was the next most active launch site with 17 launches (19.5%). Europe's Kourou Spaceport in French Guiana was in third position with 12 launches (13.8%), while China's Xichang launch site came in fourth with 9 launches (10.3%), followed by Russia's Plesetsk site with 7 launches (8.0%).

Next, China's Jiuquan and Taiyuan launch sites, and India's Satish Dhawan Space Centre, each had 5 launches (5.7%). Japan's Tanegashima Space Center had 4 launches (4.6%), while the Vandenberg Air Force Base in the U.S. had 2 launches (2.3%). Lastly, Russia's Dombarovskiy launch site, the U.S. Pacific Missile Range Facility in Kauai, and Iran's satellite launch site in the Semnan Province each had 1 launch (1.1%).

While Europe is stable with the spaceport in Kourou, it runs the risk of being further outdistanced by the Russia, the U.S., and China, which benefit from the numerous launch sites available and increased activity. This risk is counterbalanced with the availability of the launcher Ariane 5 launcher family, in addition to the Vega launcher, and the Europeanized Soyuz 2 launcher which will operate from Kourou through 2019. In 2015, Russian sites hosted 29.9% of total launches followed by 23.0% in the U.S., 21.8% for the China, and 13.8% for Europe. The situation could change in 2016 with Russia`s development of its Vostochny Cosmodrome, and China's development of its Wenchang Satellite Launch Center.

| Country / Region | Spaceport | Micro | Small | Medium | Inter-mediate | Large | Heavy |
|---|---|---|---|---|---|---|---|
| Europe | Kourou, French Guiana | 0 | 7 | 4 | 5 | 6 | 0 |
| United States | Cape Canaveral AFS | 57 | 15 | 9 | 0 | 10 | 0 |
| | Vandenberg AFB | 17 | 0 | 1 | 0 | 1 | 0 |
| | Kauai | 13 | 0 | 0 | 0 | 0 | 0 |
| Russia | Baikonur (Kazakhstan) | 0 | 0 | 2 | 0 | 16 | 0 |
| | Plesetsk | 2 | 7 | 0 | 2 | 2 | 0 |
| | Dombarovskiy | 0 | 1 | 0 | 0 | 0 | 0 |
| China | Xichang | 0 | 1 | 2 | 1 | 6 | 0 |
| | Jiuquan | 4 | 4 | 2 | 1 | 0 | 0 |
| | Taiyuan | 19 | 1 | 3 | 1 | 0 | 0 |
| India | Satish Dhawan | 12 | 5 | 3 | 0 | 0 | 0 |
| Japan | Tanegashima | 18 | 0 | 2 | 0 | 1 | 1 |
| Iran | Semnan Province | 1 | 0 | 0 | 0 | 0 | 0 |

Table 2.7: Distribution of the payloads launched in 2015 by Launch site (Source: FAA and Gunter's Space Page)

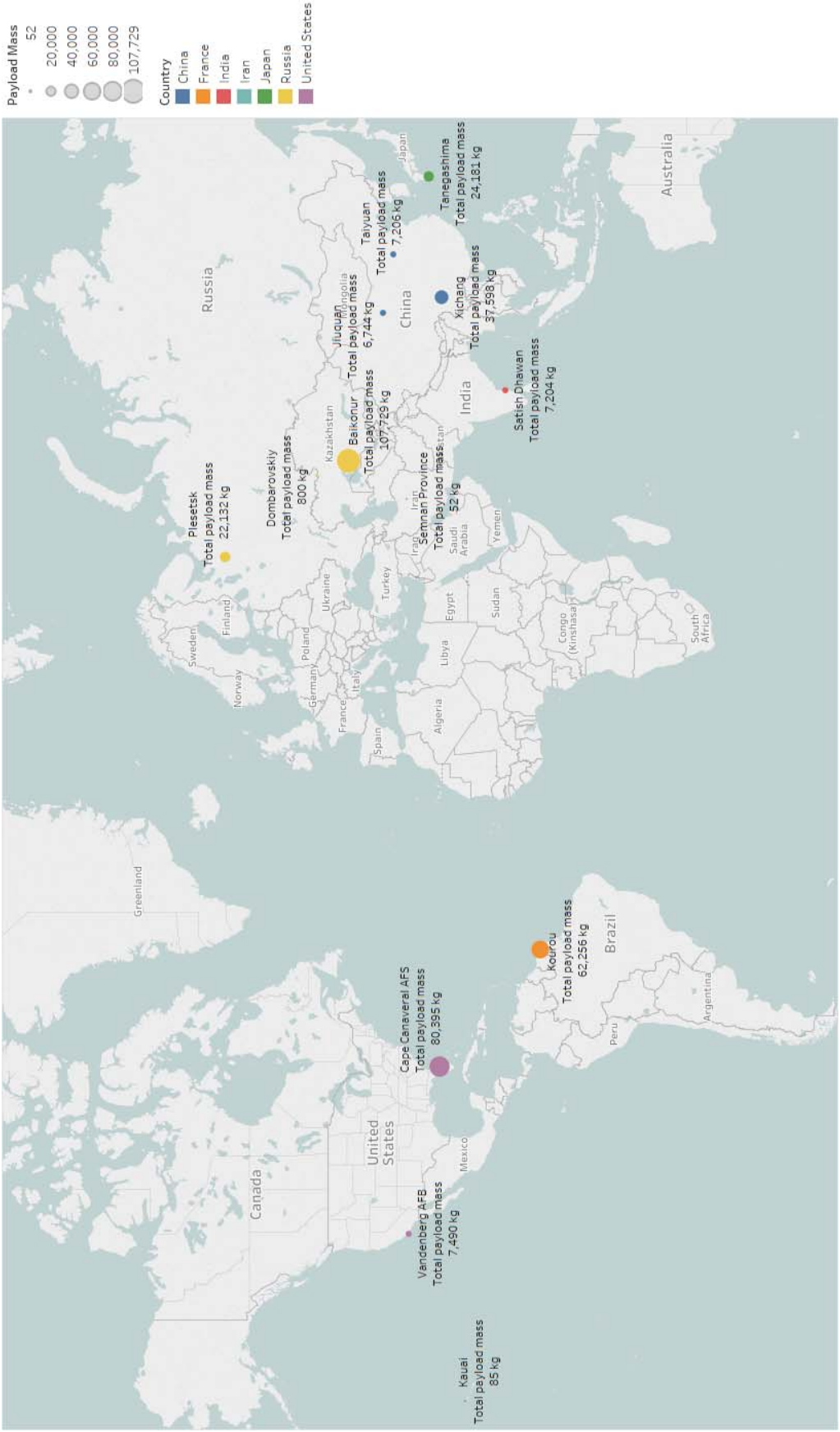


Figure 2.25: Total payload mass launched per launch site in 2015 (Source: FAA)

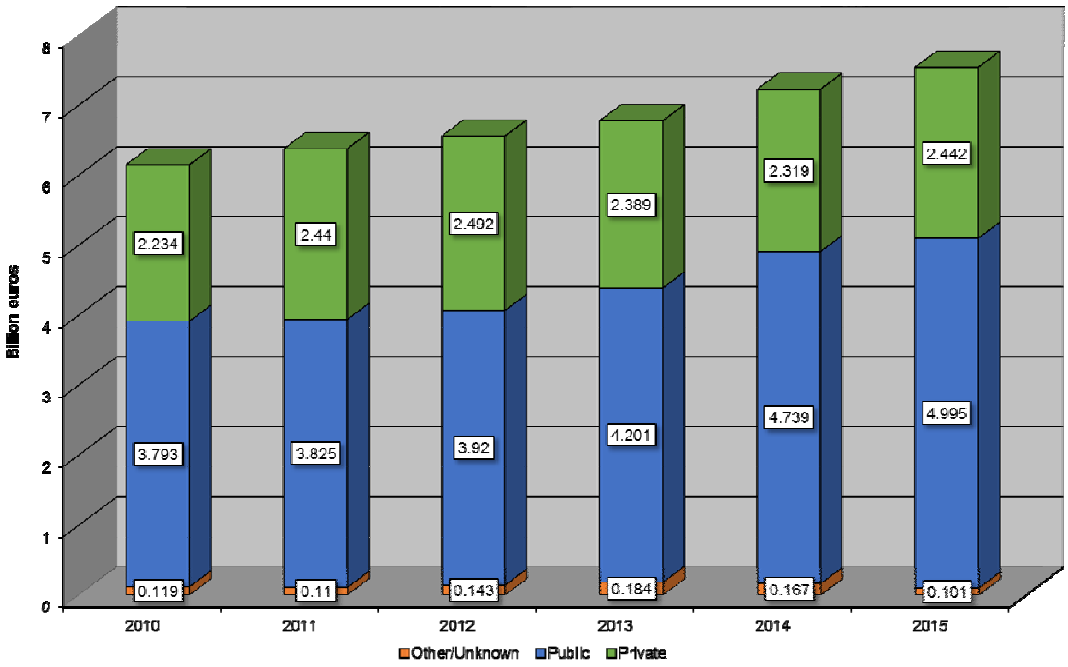


Figure 2.26: Estimated consolidated turnover of the European space sector in Euros
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## 2.6 State of the European Industry

The financial results of Europe's space manufacturing industry in 2015 provide insight into the European space industry's long-term developments and character, operating as both a strategic sector and infrastructure supplier. The trends reviewed in this section are mainly based on statistics generated by ASD-Eurospace.[98]

The European space industry continued to see a steady incremental increase in turnover in recent years. By 2015, it grew by 4.3% to €7.538 billion from €7.225 billion in 2014 (Figure 2.26). Yet, the number of commercial GEO communications satellite orders won by European prime contractors dropped slightly in 2015 to a combined share of 30.8% between European prime contractors Thales Alenia Space and Airbus Defence & Space (i.e. 4 orders each out of a total of 26 orders) from 33.3% of the 27 orders placed in 2014.[99]

Employment levels are another way to gauge the situation of the main companies in the space sector (Figure 2.27). Around 895 jobs were created in 2015, marking another boost compared to the smaller incremental growth before 2014.

In the European space sector, most funding goes toward institutional civil programmes rather than to institutional military programmes. Here, ESA's role has continued to increase, aided by the development of EU's two flagship space programmes, Copernicus and Galileo. In 2015, 74% of the final sales in Europe's space industry came from European customers, while 26% of final sales came from exports.[100] In the past five years, the share of revenue generated by exports has steadily increased, from 18.7% in 2011, 20.3% in 2012, 23.2% in 2013, and 24% in 2014. When counting only domestic sales to European customers, institutional programmes (both civil and military) were the main source of revenue reaching 75.0% in 2015, while sales to European commercial customers such as satellite or launch service operators (e.g. Eutelsat, Arianespace, etc.) generated 24.0%, and the remaining 1.0% was generated by other/unknown.[101] When looking at Figure 2.28, it appears that the turnover in launchers and parts has a growing share, likely attributable to development of the Ariane 6 launcher, while turnover in commercial satellites and parts looks to be decreasing relative to the other segments.

[98] ASD-Eurospace. "Facts & figures – The European Space Industry in 2015." 20th edition. June 2016.
[99] "Recently awarded GEO-Sat Contracts." 6 May 2016. Gunter's Space Page 12 May 2016 <http://space.skyrocket.de/doc_sat/sat-contracts.htm>.

[100] ASD-Eurospace. "Facts & figures – The European Space Industry in 2015." 20th edition. June 2016: 10.
[101] ASD-Eurospace. "Facts & figures – The European Space Industry in 2015." 20th edition. June 2016: 6.

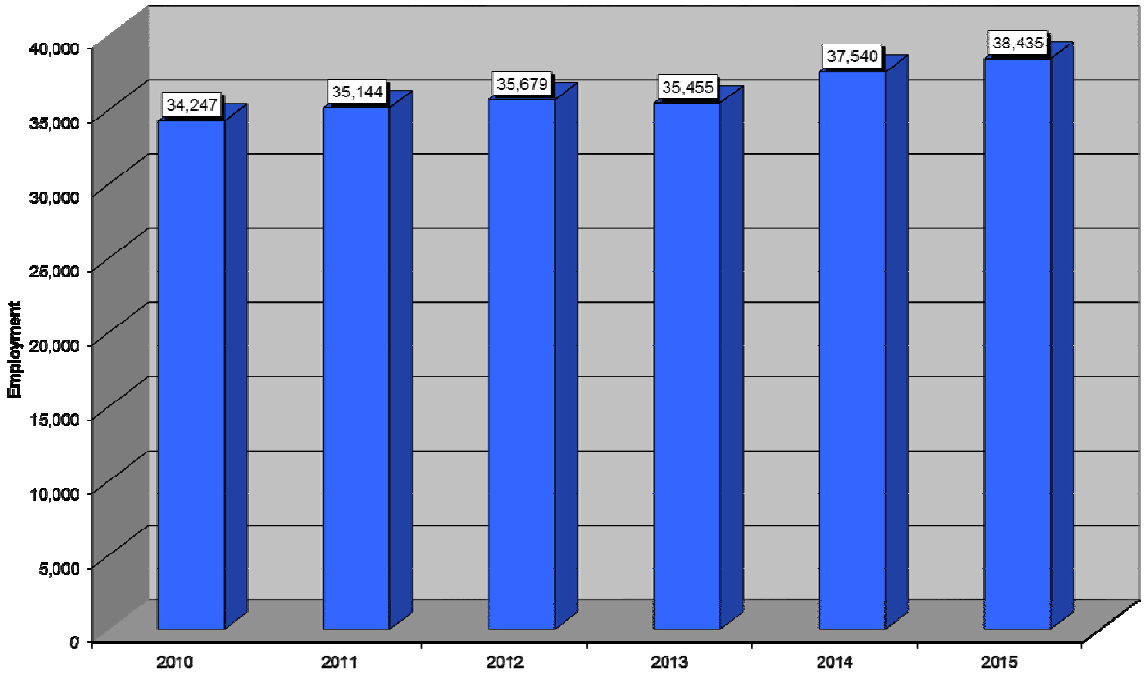


Figure 2.27: European space industry employment
(copyright by Eurospace – all rights reserved, used with permission, reproduction forbidden)

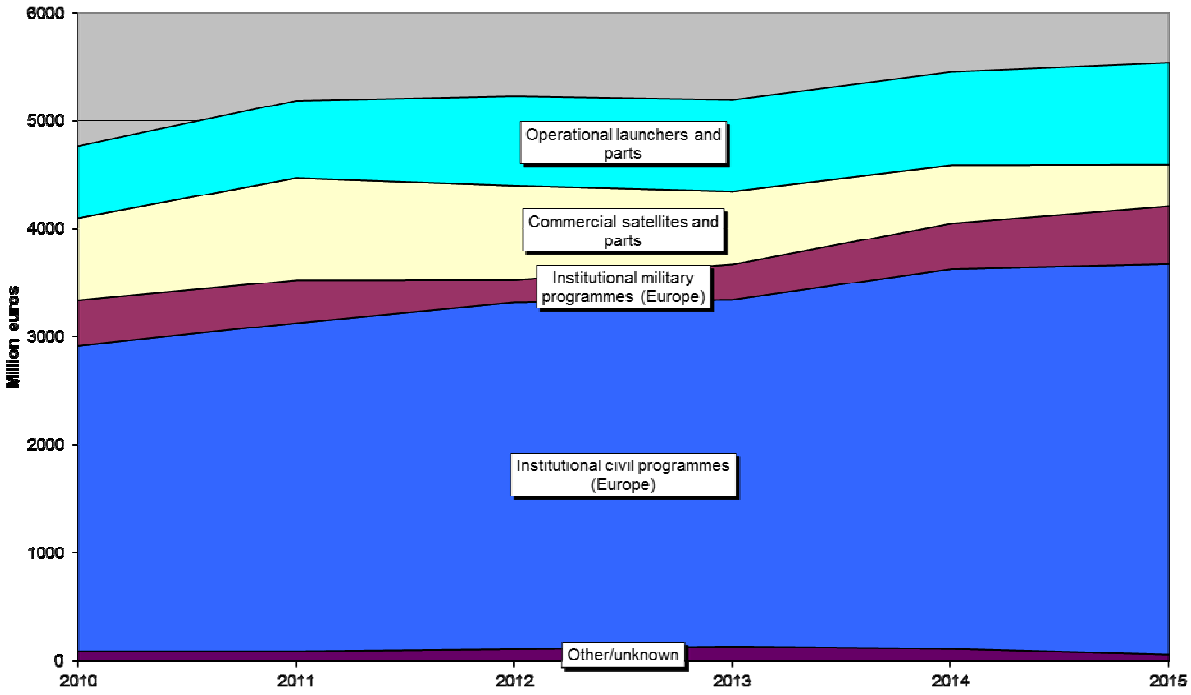


Figure 2.28: Estimated share of European space industry consolidated turnover per institutional customer
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When looking at the European space industry by sector (Figure 2.29), there was a 4.3% overall increase in turnover in 2015, and that increase had the greatest impact on support and test activities, which grew by 16.7% and launcher developments and production which grew by 10.5%. Satellite applications (e.g. navigation systems and telecommunications systems) saw a 3.4% increase in 2015, whereas scientific programmes dropped by 2.2%.

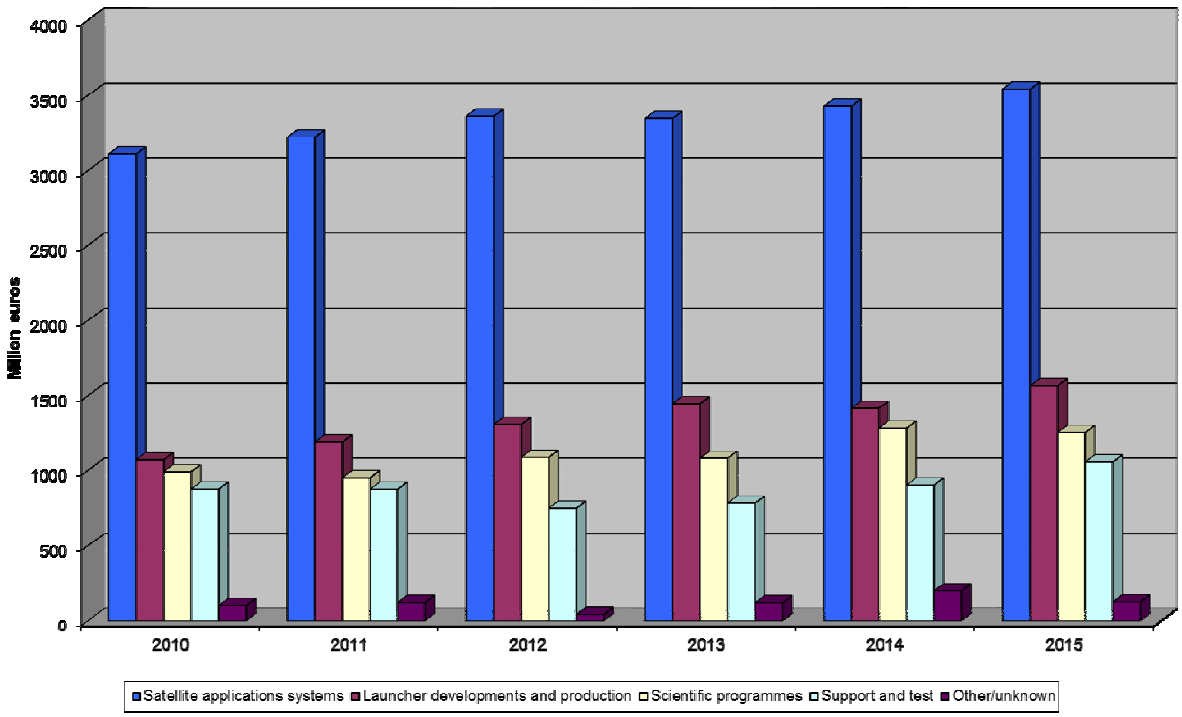


Figure 2.29: Estimated share of European space industry consolidated turnover per sector
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While Figure 2.29 displays the impact of the turnover per sector, and provides a historical timeline, it is possible to drill down further into each category to assess the impact of the increase in turnover. In 2015, while there was a 1.6% overall decrease in the turnover of European satellite applications, the effect varied among the three parts of the satellite applications sector (i.e., telecommunication, earth observation, and navigation/localisation systems). Turnover from telecommunications systems in the European sector was on the uptick, increasing by 2.6% to €749 million from €730 million in 2014. However, turnover from European navigation systems (e.g. Galileo) decreased by 5.2% to €400 million in 2015 from €422 million in 2014; and Earth observation systems (e.g. Copernicus) turnover decreased by 3.4%, earning €794 million from €822 million in 2014.[102]

In launcher development and production, it should be noted that European launcher developments are funded almost exclusively by ESA. In 2015, expenditure on launcher development increased to over €600 million, while operational launcher systems and parts turnover increased significantly to just under €1 billion in 2015.[103] Next, scientific programmes in turnover decreased by 3.9% in 2015, generating about €1.190 billion from 1.238 billion in 2014, mainly from decreased turnover in space exploration, human spaceflight and microgravity segments.[104]

[102] Ibid. at 16.
[103] Ibid. at 14.
[104] Ibid. at 16.

# 3. Space Industry Evolutions

This chapter focuses on major developments among companies within the space industry. The year-end results of major launch companies, satellite operators, and satellite prime contractors, and other competitors are provided, along with elaboration on notable achievements within the industry. Segments within each geographical region are also grouped to establish a basis for comparison.

## 3.1 Europe

At the end of 2015, Arianespace commercial launch company revenue was announced to be €1.4 billion from the €1.399 billion earned in 2014. And while operating profit was not disclosed for the year, it was expected to break even when counting €100 million in price support from ESA. Arianespace conducted 12 launches in 2015, including 6 Ariane 5 ECA launches, 3 Europeanized Soyuz launches, and 3 launches for the Vega launcher.[105] In 2015, the launch provider won 14 contracts to lift satellites in GEO orbit using the Ariane 5 ECA launcher, 12 of which were commercial awards; in comparison, SpaceX won 9 commercial geostationary launch awards, while International Launch Services (ILS) won a single commercial launch award.[106] Arianespace also booked its largest single launch contract on 25 June 2015, involving 21 Russian Soyuz rockets – some launching from Europe's spaceport in French Guiana – to lift OneWeb's 700 small satellite broadcasting constellation into LEO orbit in 32-36 satellite batches starting in 2017. The contract is valued at more than €1 billion, and is considered to be the largest commercial launch purchase in history, besting SpaceX's block contract with Iridium signed in 2010 valued at nearly $500 million.[107] Arianespace's total contract wins for 2015 amounted to €2.5 billion, with €875 million coming from Ariane 5 launch awards.[108]

Eutelsat earned a total revenue of €1.476 billion for the year-ending 30 June 2015, a 9.5% increase from the €1.348 billion earned in the previous year. Its EBITDA margin remained at 76.7% of revenue for the year, while its net profit grew by 17.2% amounting to €355.2 million as at 30 June 2015 from €303.2 million in the previous year.[109] The share of revenue generated from European regions continued to decrease in the reporting year, reaching 59.0% in 2015 from 64.0% as of 30 June 2014, while revenue from the Americas jumped to 20.8%, followed by the Middle East (12.1%), Africa (5.6%), and Asia (2.5%).[110] Eutelsat's revenue in the six months ending 31 December 2015 reached €774.4 million, up 7.1% from the €722.8 million earned in the previous year. Eutelsat ordered its first Eutelsat Quantum satellite from Airbus Defence and Space in July 2015, to be launched in 2019; another all-electric High Throughput Satellite was ordered from Thales Alenia Space in October 2015, also to be launched in 2019. And by the end of 2015, Eutelsat's order backlog had decreased to €5.8 billion from €6.2 billion as of mid-year.[111]

SES earned a total revenue of €2.014 billion in revenue for the year ending 31 December 2015, a 5.0% increase from €1.919 billion earned in the previous year. Its EBITDA for 2015 was €1.494 billion (74.2% of revenue), from €1.428 billion (74.4% of revenue) in 2014. Moreover, its backlog for the year grew

[105] De Selding, Peter B. "Arianespace Surpassed SpaceX in Commercial Launch Orders in 2015." 6 Jan. 2016. SpaceNews 17 June 2016 <http://spacenews.com/arianespace-surpassed-spacex-in-commercial-launch-orders-in-2015/>.

[106] De Selding, Peter B. "Three's Company – Commercial Launch Contracts." 18 Jan. 2016. SpaceNews Magazine 5 Sept. 2016 <http://www.spacenewsmag.com/feature/threes-company/>.

[107] Clark, Stephen. "OneWeb launch deal called largest commercial rocket buy in history." 1 July 2015. Spaceflight Now 17 June 2016 <https://spaceflightnow.com/2015/07/01/oneweb-launch-deal-called-largest-commercial-rocket-buy-in-history/>.

[108] De Selding, Peter B. "Arianespace Surpassed SpaceX in Commercial Launch Orders in 2015." 6 Jan. 2016. SpaceNews 17 June 2016 <http://spacenews.com/arianespace-surpassed-spacex-in-commercial-launch-orders-in-2015/>.

[109] "Full Year 2014-2015 Results." 30 July 2015. Eutelsat 9 June 2016 <http://news.eutelsat.com/pressreleases/full-year-2014-15-results-1197412>.

[110] Reference Document 2014-2015. 22 Oct. 2015. Eutelsat 10 June 2016: 140 <http://www.eutelsat.com/files/contributed/investors/pdf/AGM2015/ETL-DDR%202014-15-UK-web.pdf>.

[111] Press Release. "Eutelsat Communications First Half 2015-2016 Results." 17 Feb. 2016. Eutelsat 10 June 2016 <http://news.eutelsat.com/pressreleases/eutelsat-communications-first-half-2015-2016-results-1318802>.

to €7.4 billion in 2015 from €7.3 billion in 2014. SES plans to launch 7 new satellites between the end of 2015 through 2017, including SES-9 which will add 180 incremental wide beam transponders and 36 GHz of HTS capacity.[112]

Intelsat's total revenue for 2015 was $2.352 billion, a 4.8% decrease from the $2.472 billion earned in the previous year. Its adjusted EBITDA for 2015 was $1.854 billion (78.8% of revenue), while its adjusted EBITDA in 2014 was $1.854 billion (79.2% of revenue). Its backlog for 2015 was about four times its annual revenue for the year at $9.4 billion. The operator planned to launch its first Intelsat Epic next generation high throughput satellite, Intelsat 29e, into orbit near the beginning of 2016; other satellites it plans to launch in that year include its Intelsat 31, Intelsat 36, and Intelsat 33e.[113]

Hispasat earned a total revenue of €219.6 million for 2015, an increase of 8.66% from the €202.1 million earned in 2014. Its EBITDA remained above 80% in 2015, growing by 1.4 points to 81.5%, while its net profit grew by 37.3% reaching €62.6 million in 2015 from €45.6 million in 2014. Hispasat's recent entrance into Morocco provided access to a new market and additional income. The revenue coming from space capacity rentals also grew by 9.7%, reaching €216.4 million from €197.2 million in 2014; this year 65.4% of the revenue came from clients in the Americas, while 34.6% came from leasing space capacity to clients in Europe and North Africa.[114]

Telenor Satellite Broadcasting of Norway reported a 1.3% decrease in revenue for the year ending 31 December 2015, with the decline attributable to its divestment of its subsidiary Conax, which had been deconsolidated in the first quarter of 2014. The Oslo-based satellite fleet operator reported revenue of 6.076 billion kroner (€635.04 million) in 2015, from 6.155 billion kroner (€679.50 million) in 2014. That revenue included Nordic DTH subscribers and households in SMATV networks, revenues from satellite services, revenues from terrestrial radio and TV transmission and sale of encryption and conditional access services for TV distribution. The launch of its new satellite, Thor 7, on 27 April 2015 was the main reason for the increase in the company's capital expenditure for 2015.[115]

Inmarsat's total revenue decreased by 0.9% for the year ending 31 December 2015, generating $1.274 billion (€1.17 billion) from $1.286 billion (€1.058 billion) in 2014. Its EBITDA grew by 3.6% to $726.0 million (€664.41 million) from $701.0 million (€576.66 million) in 2014, while its margin increased to 57.0% from 54.5% in 2014. Around 93.0% of that revenue was generated from its Mobile Satellite Services (MSS) including Maritime, Government, Enterprise, Aviation, and other, amounting to $1.186 billion (€1.09 billion); the remaining 7.0% came from the LightSquared Cooperation Agreement which earned $88.1 million (€80.63 million) in 2015. Its total revenue also included wholesale MSS revenues of $832.8 million (€762.15 million), which increased by 5.2% from $791.4 million (€651.02 million) in 2014, wherein higher wholesale MSS revenue in Maritime and Aviation helped to offset its continued decline in government wholesale business.[116]

The Airbus Group's Airbus Defence and Space (Airbus D&S) division reported a 0.4% increase in revenue for 2015, reaching €13.080 billion from €13.025 billion in 2014. The Airbus D&S Space Systems business line accounted for 29% of that revenue, or around €3.79 billion. And the division's overall order intake increased by 18.1%, reaching €14.440 billion from €12.225 billion in 2014, while its backlog lowered by 0.5% to €42.861 billion from €43.075 billion in 2014. Airbus D&S booked orders for five telecommunications satellites in 2015, along with a contract for 900 small satellites to be built for OneWeb. Its ESA orders included a contract to build the Juice Orbiter, and a service module for the manned U.S. Orion space capsule. Airbus D&S also signed the first Quantum satellite contract with Eutelsat and ESA, which will be the first satellite capable of adapting its coverage, bandwidth, power and frequency, and its orbital position according to changing customer requirements.[117] On 21 December

[112] "SES Annual report 2015 – New foundations." 7 Apr. 2016. SES 7 Sept. 2016 <http://www.ses.com/22199159/annual-report-15-en.pdf>.
[113] "Intelsat Announces Preliminary Fourth Quarter and Full Year 2015 Results." 22 Feb. 2016. BusinessWire 7 Sept. 2016 <http://www.businesswire.com/news/home/20160222005419/en/Intelsat-Announces-Preliminary-Fourth-Quarter-Full-Year>.
[114] "HISPASAT increases total revenue by 8.7% in 2015." 15 Feb. 2016. Hispasat 13 June 2016 <http://www.hispasat.com/en/press-room/press-releases-2016/pagina-3/204/hispasat-increases-total-revenue--by-87-in-2015>.
[115] Annual Report 2015. Telenor Group 18 Apr. 2016: 88 <https://www.telenor.com/wp-content/uploads/2015/09/Godkjent-Annual-Report-2015_7y8erjhregj745.pdf>.
[116] "Global Reach Global Impact | Inmarsat PLC Annual Report and Accounts 2015." 6 Apr. 2016. Inmarsat 13 June 2016 <http://www.inmarsat.com/wp-content/uploads/2016/04/Inmarsat_AR15_Bookmarked.pdf>.
[117] "Flying ahead | Annual Report 2015." 26 Apr. 2016. Airbus Group 17 June 2016: 24-28

2015, the Airbus Group signed a share-purchase agreement to sell its Vizada commercial mobile satellite division back to the company's previous owner Apax Partners, with the deal set to close in early 2016 subject to regulatory approvals.[118]

The first priority of the newly established Airbus Safran Launchers (ASL) in developing the Ariane 6 launcher is to reduce the cost of launching a heavy telecomm satellite to geostationary transfer orbit by 50% in comparison to the Ariane 5.[119] In addition to its modernized and simpler design, and the reshaped role of industry, expenditures on the Ariane 6 will be reduced by integrating the launcher horizontally; a notable departure from the vertical integration of previous Ariane launchers.[120] Capable of lifting two telecom satellites with a combined mass of 9,500 kg to geostationary transfer orbit at a total cost of around €90 million, the 64 configuration of the Ariane 6 with four boosters will be sold for €96.34 million per launch (or €48.17 million per customer).[121] The 62 configuration of the Ariane 6 with two boosters for small satellites will cost around €75 million.[122]

By 10 July 2015, the UK-based Surrey Satellite Technology Ltd. (SSTL) had delivered the DMC3 satellite constellation into orbit for its China-based customer Twenty-First Century Aerospace Technology Co. (21AT). SSTL was able to bypass U.S. ITAR export restrictions and deliver its three-satellite Earth observation constellation into orbit by launching the satellites aboard India's lower-cost PSLV launcher. SSTL, an arm-length subsidiary of Airbus D&S, entered into the contract with its anchor and sole customer 21AT (China's first non-government owned Earth observation imagery provider) in 2011, after receiving export consent by the governments of both the UK and China. The three small satellites were lifted into orbit on a single PSLV launcher that carried two additional payloads, which enabled 21AT's constellation to enter into full service soon afterward. By launching the three satellites on a single low cost PSLV launcher, SSTL's business model allowed it to charge a substantially lower price for the constellation than would normally be the case. Its contract with 21AT is valued at £110 million (€149.23 million). SSTL used 21AT's purchase of all of the capacity of the DCM3 system for 7 years to pay for the system's construction, launch and insurance.[123] The system is spaced at 120 degrees apart at 647km LEO orbit, and each satellite is capable of pointing up to 45 degrees nadir, allowing the system to revisit any point on Earth every 24 hours. The system relies on xenon-electric propulsion to allow for around a 10-year operating life. Under SSTL's contract with 21AT, 21AT may send image requests to the satellites directly when targets are on China's mainland, but its requests for targets outside of China would be subject to a right of review.[124]

SSTL hopes that the 21AT contract will attract other companies or nations to purchase an additional fourth DMC3 satellite, which would help to increase revisit rates and provide an in-orbit backup for the system, in addition to increasing its capacity.[125] The offer of immediate access to the full system is meant to be an additional lure for potential customers. Other competitors, including Airbus D&S, Deimos Imaging of Spain, and ImageSat of Israel are using the same business strategy. Meanwhile, another competitive challenge threatening to undo both SSTL and 21AT's business comes from China's decision to develop its own domestically-built constellation of 16 by the end of 2016, and 60 by 2020 which will offer a 30 minute revisit capability across the globe; that constellation would increase to 138 satellites with a 10 minute revisit capability by 2030.[126]

<http://annualreport.airbusgroup.com/api/airbus_ar_2015.pdf>.

[118] Jasper, Christopher. "Airbus Agrees to Sell Commercial Satcoms Business Back to Apax." 21 Dec. 2015. Bloomberg 17 June 2016 <http://www.bloomberg.com/news/articles/2015-12-21/airbus-agrees-to-sell-commercial-satcoms-business-back-to-apax>.

[119] De Selding, Peter B. "ESA Approval Paves Way for Ariane 6, Vega-Contracts." 17 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/esa-approval-paves-way-for-ariane-6-vega-contracts/>.

[120] De Selding, Peter B. "ESA Inks $3.8 Billion in Contracts for Ariane 6, Vega-C and Spaceport Upgrades." 12 Aug. 2015. SpaceNews 5 Jan. 2016 <http://spacenews.com/esa-inks-3-8-billion-in-contracts-for-ariane-6-vega-c-and-spaceport-upgrades/>.

[121] De Selding, Peter B. "With Revenue Looking Up, Arianespace Seeks To Bring Ariane 5 Costs Down." 21 Oct. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/with-revenue-looking-up-arianespace-seeks-to-bring-ariane-5-costs-down/>.

[122] Gallois, Dominique. "Ariane 6, un chantier européen pour rester dans la course spatiale." 1 Dec. 2014. Le Monde 9 Mar. 2016 <http://www.lemonde.fr/economie/article/2014/12/01/les-europeens-s-appretent-a-mettre-ariane-6-en-chantier_4532259_3234.html>.

[123] De Selding, Peter B. "SSTL Using Immediate Access as a Lure To Sell a 4th DMC-3." 16 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/sstl-using-immediate-access-as-a-lure-to-sell-a-4th-dmc-3/>.

[124] Ibid.

[125] De Selding, Peter B. "India's PSLV Lofts UK-built Earth-observation Satellites Leased by Chinese Firm." 13 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/indias-pslv-lofts-uk-built-earth-observation-satellites-leased-by-chinese-firm/>.

[126] De Selding, Peter B. "China Launches High-resolution Commercial Imaging Satellite." 7 Oct. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/china-launches-high-resolution-commercial-imaging-satellite/>.

The Thales Group's Aerospace segment generated around €2.045 billion in sales in 2015 from €1.955 billion in 2014; the segment includes its Avionics business and revenue from its Space Global Business Unit e.g. Thales Alenia Space and Telespazio under its Space Alliance strategic partnership with Finmeccanica. In 2015, Thales Alenia Space entered into the C/D phase of the Neosat programme with ESA, and signed a contract with Eutelsat for a telecommunications satellite that will be the first commercial use of the all-electric Spacebus NEO satellite platform. Thales Alenia Space also signed contracts to build the Bangabandhu telecom satellite for Bangladesh, and to provide a payload for Argentina's ARSAT-3 satellite. Additionally, Thales Alenia Space has signed a contract to build 8 additional satellites for the O3b Network, and it continues to work with LEOSAT on the feasibility and definition of its 80-120 broadband Internet satellite constellation. Some of Thales Alenia Space's institutional contracts in 2015 include its 65% partnership agreement for the Comsat NG French military satellite communications programme, and its contract with ESA and the European Union to build the C and D models of the Sentinel 1 environmental monitoring satellite under the Copernicus programme.[127]

OHB AG of Germany increased its total revenue to €730.38 million for the fiscal year ending 31 December 2015; a 5.5% decrease from the €772.95 million earned in 2014. Its EBITDA reached €52.13 million in 2015, decreasing by 2.4% from €53.42 million in 2014.[128] In February 2015, OHB System completed the integration of its first GEOCOM satellite for the commercial telecommunications satellite operator Hispasat, while OHB Sweden and ÅAC Microtec received a contract from the Swedish National Space Board (SNSB) for the development of a highly capable "InnoSat" small satellite platform and for is first use on the Mesospheric Airglow/Aerosol Tomography and Spectroscopy (MATS) advanced science mission. The OHB-developed and built Galileo FOC satellites numbers 3 and 4 were successfully launched into orbit on a Europeanized Soyuz launcher on 28 March 2015, followed by the launch of numbers 5 and 6 on 11 September 2015, and the launch of numbers 8 and 9 on 17 December 2015. OHB System was also awarded a contract for the expansion of the German federal armed forces' large satellite ground station on 10 November 2015; and on 22 December 2015, OHB's strategic subsidiary Orbcomm launched its second mission of eleven OG2 satellites into orbit on a Falcon 9 launcher.[129] By the end of 2015, OHB's staff numbered 2,056, a reduction of 50 personnel which was relatively stable by comparison to its previous reduction of 326 employees in 2014 due to the deconsolidation of its subsidiary Aerotech Peissenberg GmbH & Co. About 65.5% of those employees worked in OHB's Space Systems business unit, while the remainder worked mainly in other Aerospace and Industrial Products. Moreover, 79.3% of OHB's employees were based in companies in Germany, while 15.1% were in other parts of Europe, and the remaining 5.6% worked in the rest of the world.[130]

RUAG Space revenue decreased by 3.7%, earning CHF 310 million (€286.27 million) for the fiscal year ending 31 December 2015, from CHF 322 million (€267.68 million) in 2014. Its EBITDA was CHF 45 million (€41.56 million) in 2015, an increase of 4.7% from the CHF 43 million (€35.75 million) it had earned in the previous year.[131] Based in Switzerland, Sweden, Austria, and Finland, RUAG Space had 1,204 employees in 2015, an increase of 41 staff from the previous year.[132] RUAG completed its acquisition of the space unit of Finnish company Patria on 7 May 2015. First announced on 17 December 2014, Patria Space's business operations and assets, along with its 29 employees were transferred to the newly founded company RUAG Space Finland.[133] Patria's space business has been active in various ESA satellite programmes including Sentinel-2, Earthcare and Swarm and the Gaia space telescope, with key product areas in spacecraft control electronics, electrical power subsystems, electronic units, and related test equipment. RUAG also had cause to celebrate its successful launch of its 250th fairing on 22 June 2015, which encapsulated Europe's Sentinel-

[127] "Registration Document 2015 | Annual Financial Report." 22 Feb. 2016. Thales 17 June 2016: 116 <https://www.thalesgroup.com/sites/default/files/asset/document/2015_registration_document.pdf>.
[128] Annual Report 2015. 16 Mar. 2016. OHB 24 Apr. 2016: 41-43 <http://www.ohb.de/tl_files/ohb/pdf/finanzberichte_hauptversammlung/2015/ohb_gb_2015_e.pdf>.
[129] Ibid.
[130] Annual Report 2015. 16 Mar. 2016. OHB 24 Apr. 2016: 61 <http://www.ohb.de/tl_files/ohb/pdf/finanzberichte_hauptversammlung/2015/ohb_gb_2015_e.pdf>.
[131] RUAG Annual Report 2015. 17 Mar. 2016. RUAG 24 Apr. 2016: 25 <https://www.ruag.com/fileadmin/ruag/group/Annual_Report/2015/GB/RUAG_GB_2015_72dpi_E.pdf>.
[132] Ibid. at 18.
[133] Media release. "RUAG completes acquisition of Patria's space business." 12 May 2015. RUAG 6 July 2016 <http://www.ruag.com/space/media/media-releases/news/ruag-completes-acquisition-of-patrias-space-business/dea359f87ec7580485cade82cfb694d1/>.

2a environmental satellite while transporting it into orbit.[134]

## 3.2 United States

Boeing's Network & Space Systems segment under its Defence, Space & Security division reported a 3.1% decrease in revenue, earning $7.751 billion for the year ending 31 December 2015 from $8.003 billion 2014, due to lower satellite volume in its fourth quarter. However its operating earnings increased by 4.0% in 2015, reaching $726 million from $698 million in 2014. Moreover, its backlog at the end of 2015 was $7.4 billion, from $8.9 billion in 2014.[135]

Lockheed Martin's Space Systems segment revenue for in 2015 decreased by 1.1% to $9.105 billion from $9.202 billion in adjusted revenue earned in 2014. Its operating earnings also decreased by 1.4%, to $1.171 billion from $1.187 billion in 2014. During the fourth quarter of 2015, Lockheed Martin realigned certain programs among its business segments in connection with a strategic review of its government IT and technical services businesses, which included transferring space services programs from its Information Systems & Global Solutions (IS&GS) business segment to its Space Systems business segment.[136]

With the lifting of the U.S. ban on the Russian-built RD-180 engine that had been enacted in the NDAA National Defense Authorization Act for 2015 (NDAA-15), the United Launch Alliance (ULA) ordered 20 more RD-180 engines, in addition to the 29 RD-180 engines it had ordered before Russia's annexation of Crimea from Ukraine.[137] ULA that has had the U.S. government launch services market to itself since its formation in 2006 but now faces increasing competition from SpaceX. Since ULA uses RD-180 engines for the first stage of its Atlas 5 launcher, the restriction limited its use before ULA's follow-on Vulcan launcher - powered by Blue Origin's BE-4 engine - is ready in 2020. While ULA needed access to at least 13 more RD-180 engines in order to remain competitive with SpaceX.[138]

Orbital ATK's revenue for the year ending 31 December 2015 increased by 52.2%, earning $1.137 billion from the combined revenue of $747 million earned in 2014 – i.e. adjusted as of the 9 February 2015 merger of Orbital Sciences Corporation (Orbital) and Alliant Techsystems Inc. (ATK) that took place on 1 January 2014. Its operating earnings increased by 7.8%, reaching $87.3 million from the adjusted $81.0 million in 2014. The company's backlog was $8.1 billion at the end of 2015.[139]

DigitalGlobe, the commercial high-resolution Earth observation satellite imagery provider, reported a 7.3% revenue increase for 2015, earning $702.4 million from $654.6 million in 2014. Its adjusted EBITDA grew by 24.3%, reaching $355.7 million, while its net income was $23.3 million for 2015. During 2015, DigitalGlobe announced an agreement with KACST and TAQNIA Space to develop and launch 6 or more sub-metre satellites, with DigitalGlobe providing ground infrastructure, operations expertise, production capabilities, and global sales and distribution capabilities, while KACST and TAQNIA Space will fully fund and build the satellites. DigitalGlobe also announced several early contractual agreements for direct access EO capacity from international defence and intelligence customers for its WorldView-4 that was slated to launch in September 2016.[140]

On 23 November 2015, Blue Origin conducted the first successful test flight of its reusable New Shepard suborbital launcher, which conducted a powered vertical landing, while its unoccupied crew capsule parachuted to a landing after separating at its peak.[141] Addi-

[134] Media release. "Riding high: RUAG's 250th fairing launch." 19 June 2015. RUAG 6 July 2016 <http://www.ruag.com/space/media/media-releases/news/riding-high-ruag-s-250th-fairing-launch/064689ee1cecd0fcf08b4652ada0799d/>.

[135] "Boeing Reports Fourth-Quarter Results and Provides 2016 Guidance." 27 Jan. 2016. Boeing 7 July 2016 <http://investors.boeing.com/investors/investor-news/press-release-details/2016/Boeing-Reports-Fourth-Quarter-Results-and-Provides-2016-Guidance/default.aspx>.

[136] "Lockheed Martin Reports Fourth Quarter and Full Year 2015 Results." 26 Jan. 2016. Lockheed Martin 7 July 2016 <http://www.lockheedmartin.com/us/news/press-releases/2016/january/012516-lm-q4-fy2015-earnings.html>.

[137] Shalal, Andrea. "ULA Orders 20 More RD-180 Rocket Engines." 23 Dec. 2015. SpaceNews 14 Jan. 2016 <http://spacenews.com/ula-orders-20-more-rd-180-rocket-engines/>.

[138] Ferster, Warren. "Defense Bill Curbs ULA Use of Russian Engines but Draws Veto Threat." 30 Sept. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/defense-bill-limits-ula-to-9-more-russian-built-engines/>.

[139] "Orbital ATK Announces Fourth Quarter and Full Year 2015 Financial Results." 29 Feb. 2016. Business Wire 7 July 2016 <http://www.businesswire.com/news/home/20160229007038/en/Orbital-ATK-Announces-Fourth-Quarter-Full-Year>.

[140] "DigitalGlobe Reports Full Year and Fourth Quarter 2015 Results." 25 Feb. 2016. RSS Feeds 7 July 2016 <http://investor.digitalglobe.com/phoenix.zhtml?c=70788&p=RssLanding&cat=news&id=2143469

[141] Foust, Jeff. "Blue Origin Flies — and Lands — New Shepard Suborbital Spacecraft." 24 Nov. 2015. SpaceNews 7 Dec. 2015 <http://spacenews.com/blue-origin-successfully-flies-new-shepard-suborbital-vehicle/>.

tional test launches are planned for 2016, followed by manned tests, and possible commercial service soon afterward.

Soon after Blue Origin's historical first, on 21 December 2015 SpaceX conducted the first successful landing of the first stage of its two-stage Falcon 9 launcher. Unlike Blue Origin's suborbital test, the Falcon 9 mission - which also delivered 11 commercial Orbcomm OG2 satellites into orbit – travelled at speeds reaching Mach 10, and involved a series of three "boostback burns," to return the first stage to its landing pad in Cape Canaveral, Florida.[142] Despite the 'black swan' reusable launcher event, an initial assessment by European rival Arianespace in October 2015 highlighted that the cost in energy of returning the stage, the launcher's refurbishment, and the fact that reuse means a smaller production run and thus higher per-unit costs would require SpaceX to keep a launch rhythm of 30 times per year to justify the work.[143] Moreover, the Falcon 9's marketability and its refurbishment reliability are other concerns, especially for a customer that must balance the unknown risk of launching a satellite on a Falcon 9 that has been reused several times over, rather than being the launcher's first payload.[144] As both SpaceX and Blue Origin are privately funded, their financial details of are not publicly available.

And while ISS operations have been extended to 2024, the station's utilisation beyond 2024 remains open[145], with some ISS advocates anticipating it will continue at least until 2028 with the potential to transition into a commercial station.[146] On 11 April 2016, at the 32nd Annual Space Symposium held in Colorado, USA, United Launch Alliance (ULA) and Bigelow Aerospace announced a partnership agreement to launch two of Bigelow's inflatable B330 space habitats into low Earth orbit on two Atlas V launchers between late-2019 and 2020. The announcement came shortly after Bigelow's BEAM module was launched aboard the SpaceX Dragon CRS-8 mission to the ISS on 8 April 2016; the BEAM module will be attached to the ISS for a two-year experimental demonstration.[147] NanoRacks has also facilitated the use of the ISS for businesses for over five years, brokering the launch to the station and the release of payloads into LEO orbit. And the recently formed Axiom Space LLC, led by former NASA ISS manager, Michael Suffredini, plans to eventually develop its own commercial space station.[148]

## 3.3 Russia

At the beginning of 2015, signs already indicated that the new Vostochny Cosmodrome would miss its aim of being ready before the end of the year, as construction was behind schedule by up to three months, and the 6,000 workers at the site were less than half of what was needed. Despite a cash infusion of an additional 50 billion roubles ($1.3 billion) to finish construction on time[149], the year saw similar delays, as more than 100 workers went on strike in March and April 2015 to protest unpaid wages, while a second manager was fired at the end of March 2015 because of delays and corruption scandals.[150] Ultimately, construction of the spaceport continued into 2016. Yet the importance of the Vostochny Cosmodrome for Russia should be stressed, as it will give Russia an alternative launch port to the Baikonur Cosmodrome that has been leased from Kazakhstan since the Soviet Union's collapse in 1991.[151]

[142] Wall, Mike. "Wow! SpaceX Lands Orbital Rocket Successfully in Historic First." 21 Dec. 2015. Space.com 7 July 2016 <http://www.space.com/31420-spacex-rocket-landing-success.html>.
[143] De Selding, Peter B. "With Revenue Looking Up, Arianespace Seeks To Bring Ariane 5 Costs Down." 21 Oct. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/with-revenue-looking-up-arianespace-seeks-to-bring-ariane-5-costs-down/>.
[144] De Selding, Peter B. "With Eye on SpaceX, CNES Begins Work on Reusable Rocket Stage." 5 Jan. 2015. SpaceNews 30 Dec. 2015 <http://spacenews.com/with-eye-on-spacex-cnes-begins-work-on-reusable-rocket-stage/>.
[145] Messier, Douglas. "Private Space Stations Could Be a Reality by 2025." 25 Aug. 2015. Space.com 25 Oct. 2016 <http://www.space.com/30359-private-space-stations-reality-2025.html>.
[146] Smith, Marcia S. "Panel: Seamless Transition to Commercial LEO Space Station Needed." 22 Sept. 2015. SpacePolicyOnline.com 25 Oct. 2016 <http://www.spacepolicyonline.com/news/panel-seamless-transition-to-commercial-leo-space-station-needed>.
[147] Gebhardt, Chris. "ULA and Bigelow announce partnership for first commercial space stations." 11 Apr. 2016. NASAspaceflight.com 25 Oct. 2016 <https://www.nasaspaceflight.com/2016/04/ula-bigelow-partnership-first-commercial-space-stations/>.
[148] Foust, Jeff. "Former NASA ISS manager planning commercial space station venture." 23 June 2016. SpaceNews 25 Oct. 2016 <http://spacenews.com/former-nasa-iss-manger-planning-commercial-space-station-venture/>.
[149] Bodner, Matthew. "Cash Infusion Reaffirms Putin's Commitment to New Launch Complex." 3 Sept. 2014. SpaceNews 16 July 2015 <http://spacenews.com/41747cash-infusion-reaffirms-putins-commitment-to-new-launch-complex/>.
[150] Foust, Jeff. "Russia Fires Launch Site Construction Manager Again." 30 Mar. 2015. SpaceNews 1 Jan. 2016 <http://spacenews.com/russia-fires-launch-site-construction-manager-again/>.
[151] Soldatkin, Vladimir. "Putin orders building hastened at new Russian spaceport." 27 Aug. 2014. Reuters 16 July 2015 <http://www.reuters.com/article/2014/09/02/us-russia-space-idUSKBN0GX1AV20140902>.

## 3.4 Japan

Mitsubishi Electric Co. (Melco) of Japan develops satellites within its Information and Communication Systems (ICS) business segment; however, as this segment does not separate satellite-related revenue from its telecommunication, information systems, and electronic systems business, it should only be seen as generating a small portion of the total revenue earned by this segment. In the year ending 31 March 2015, the ICS segment generated 11.2% of Melco's total sales. The ICS segment increased net sales by 2.1%, reaching ¥559.5 billion in 2015, from ¥548.2 billion in 2014. Operating income had a substantial increase in 2015, reaching ¥18.9 billion, following continued growth in recent years, due primarily to an increase in sales.[152] The revenue generated for the fiscal year grew mainly from sales due to progress in orders already received for projects in the defence systems business, which offset decreases in revenue from telecommunications equipment business, information systems and services business, and electronic systems business, which experienced respective decreases in demand for communications infrastructure products, in system integration business, and in orders due to decreases in large-scale projects in the defence system businesses.[153]

NEC Corporation of Japan is entering into satellite integration, building on its wealth of experience in developing communication subsystems in the last four decades, within its Public Business segment, which includes satellite-related revenue within its other Major Products and Services, such as systems integration, maintenance and support, outsourcing/cloud services, and system equipment, Hence, its satellite-related business should only be seen as generating a small portion of the total revenue earned by this segment.[154] In the year ending 31 March 2015, NEC's Public Business segment generated 28% of its total sales. The segment increased net sales by 11.3%, reaching ¥821.9 billion in 2015, from ¥738.4 billion in 2014. Operating income increased by 1.6%, reaching ¥62.0 billion, from ¥58.6 billion in 2014.[155] The Japanese government launched its Advanced Satellite with New System Architecture for Observation (ASNARO-1) on 6 November 2014. The ASNARO-1 is the first of a new generation of low-cost Earth observation satellite platforms built by NEC Corp. Rather than develop a more powerful bus for Western customers, its focus is on emerging Asian and South American countries that do not yet require powerful bus systems. NEC plans to offer its low cost satellites in package deals that include communications, ground support and, in the case of Earth observation satellites, geospatial information products and services to enable full use of the systems.[156]

## 3.5 China

AsiaSat of Hong Kong had a 4.0% decrease in revenue in 2015, earning HK$1.311 billion from HK$1.365 billion in 2014. Its operating profit decreased by 16.2%, reaching HK$608.7 million from HK$726.3 million.[157] AsiaSat underwent a comprehensive rebranding exercise following the Carlyle Group's acquisition of General Electric Company's 50% voting interest and 49.5% economic stake in AsiaSat's majority shareholder Bowenvale Ltd. at the beginning of 2015; Bowenvale Ltd., a joint venture with China's government-backed CITIC Group, has about a 74% stake in AsiaSat.[158] AsiaSat successfully regained access to the video market in China, and expected to generate additional revenues from a new AsiaSat 6 customer from January 2016. And lastly, the construction of AsiaSat 4's replacement, AsiaSat 9, remained on track for completion in late 2016 or early 2017.[159]

[152] "2015 Annual Report | For the year ended March 31, 2015." 15 July 2015. Mitsubishi Electric 13 June 2016: 10 <http://www.mitsubishielectric.com/company/ir/library/annual_report/pdf/ar2015.pdf>.

[153] "Investor Relations – Results by Business Segment." 3 July 2015. Mitsubishi Electric 13 June 2016 <http://www.mitsubishielectric.com/company/ir/highlights/segment/index.html>.

[154] "Annual Report 2015 – Year ended March 31, 2015." 22 June 2015. NEC 9 July 2016 <http://www.nec.com/en/global/ir/pdf/annual/2015/ar2015-e.pdf>.

[155] "Annual Report 2015 (Financials) – Year ended March 31, 2015." 28 Aug. 2015. NEC 9 July 2016 <http://www.nec.com/en/global/ir/pdf/annual/2015/ar2015_fin.pdf>.

[156] Kallender-Umezu, Paul. "Japan's NEC Looks To Expand Commercial Market Footprint." 24 Nov. 2014. SpaceNews 11 Feb. 2015 <http://spacenews.com/42644japans-nec-looks-to-expand-commercial-market-footprint/>.

[157] "Teamwork, together we reach new heights - 2015 Annual Report." 16 Mar. 2016. AsiaSat 13 June 2016: 63 <http://103.15.135.80/sites/default/files/E1135_AR_0421_0854.pdf>.

[158] Fellman, Joshua. "Carlyle Fund to Buy GE's Stake in AsiaSat, Make Buyout Offer." 24 Dec. 2014. Bloomberg 13 June 2016 <http://www.bloomberg.com/news/articles/2014-12-23/carlyle-fund-to-buy-ge-s-stake-in-asiasat-and-make-buyout-offer>.

[159] Media Release. "AsiaSat Reports 2015 Annual Results." 16 Mar. 2016. AsiaSat 13 June 2016 <http://103.15.135.80/sites/default/files/2015%20AsiaSat%20Annual%20Results_English_final_0.pdf>.

Three DFH-4 telecommunication satellites were launched into orbit in 2015, including TJS-1 on 12 September, Apstar-9 on 16 October, and LaoSat-1 on 20 November. While the first two satellites are operated by Chinese customers, LaoSat-1 was sold by CASC's China Great Wall Industry Corporation (CGWIC) commercial arm to Laos in a contract signed in March 2010.[160] Of the 15 DFH-4 commercial satellites that have been launched since the platform's development in 2006, CGWIC has sold 8 to international customers; it plans 12 more DFH-4 spacecraft in the coming years.

## 3.6 India

ISRO's Antrix commercial arm reported a 17.0% increase in revenue earning 1,860.71 crore Rupees for the year ending 31 March 2015 from 1,590.52 crore Rupees in 2014. Its profit increased by 2.5%, reaching 205.50 crore Rupees from 200.56 crore Rupees in 2014. During the year, Antrix signed eight PSLV launch services agreements to carry 16 international customer satellites as co-passengers; the company has a total of 33 satellite launch agreements.[161]

## 3.7 Rest of the World

Canada's Space Systems/Loral (SS/L), a subsidiary of MDA Corp. based in the U.S., once again won the most commercial satellite contracts in 2015, outbidding the usual top prime contractors for 5 of the roughly 26 orders that were open for competitive bidding. Europe's Thales Alenia Space and Airbus Defense & Space each had 4 orders, while Boeing had 3, and Lockheed Martin and Orbital ATK each won 2 orders. China's CGWIC commercial arm won 3 commercial orders, while India's Antrix commercial arm won 2, and Russia's ISS Reshetnev won 1.[162] The revenue earned by SS/L's parent company, MDA Corp., for the fiscal year-ended 31 December 2015 increased by 0.9% to C$2.117 billion, from C$2.099 billion in 2014.[163]

Com Dev International is Canada's second largest space company after MDA Corp, providing space hardware subsystems and components. At the beginning of 2015, fewer tax incentives, a drought of U.S. institutional orders caused by stresses in the U.S. space budget in 2014, and a loosening of U.S. ITAR restrictions on how satellite components are treated, pushed Com Dev to close its facilities in California, and bid on U.S. military contracts while working in lower-cost Canada.[164] At that time Com Dev still hoped to acquire a U.S. company that did not rely on government orders. Com Dev's focus broadened to tap the UK's high-growth space market, with its purchase of MESL Holdings and MESL Microwave of Scotland. The purchase was valued at C$23 million. Com Dev hoped its MESL acquisitions would generate an additional C$10 million for the 2015 year. Yet on 5 November 2015, Com Dev International announced its acquisition by Canadian company Honeywell and the spinout of Com Dev's exactEarth subsidiary. Honeywell's acquisition of Com Dev is valued at approximately C$455 million.[165] In the year prior to its acquisition, Com Dev had reported total revenue of C$208.2 million for the fiscal year-ended 31 October 2014, down 3.4% from C$215.5 million in 2013.[166]

Com Dev's subsidiary exactEarth Ltd. provides maritime traffic information to coastal authorities from the signals that they transmit to exactEarth's LEO constellation. In the nine-months ended 31 July 2015, exactEarth earned C$19.1 million, up 68% from the nine months ended 1 August 2014. Its EBITDA over that same period reached C$3.6 million by 31 July 2015, from C$1.2 million in the nine months ended 1 August 2014.[167] Prior to

[160] "LaoSat 1." 17 Apr. 2016. Gunter's Space Page 7 Sept. 2016 <http://space.skyrocket.de/doc_sdat/laosat-1.htm>.
[161] "Annual Report 2014-15." 30 Nov. 2015. Antrix 9 July 2016 <http://www.antrix.gov.in/sites/default/files/article-attachments/ANNUAL%20REPORT%202014%20-2015%28ENGLISH%29.pdf>.
[162] "Recently awarded GEO-Sat Contracts." 6 May 2016. Gunter's Space Page 12 May 2016 <http://space.skyrocket.de/doc_sat/sat-contracts.htm>.
[163] "MDA reports fourth quarter and full year 2015 results." 24 Feb. 2016. MDA Corp. 7 July 2016 <http://mdacorporation.com/news/pr/pr2016022401.html>.
[164] De Selding, Peter B. "Com Dev Closing California Plant But Expects To Find Another U.S. Foothold." 16 Jan. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/com-dev-closing-california-plant-but-expects-to-find-another-u-s-foothold/>.
[165] "COM DEV announces acquisition by Honeywell and spinout of exactEarth." 6 Nov. 2015. Com Dev International 16 June 2016 <https://www.comdev.ca/images/financial-reports/CDV_Honeywell_release_2015-11-05.pdf>.
[166] "COM DEV Announces Fourth Quarter and Year-End Fiscal 2014 Results." 15 Jan. 2015. COM DEV International 10 Feb. 2015 <http://www.comdev.ca/images/financial-reports/CDV_Q4_14_Financial_Release2.pdf>.
[167] "COM DEV announces acquisition by Honeywell and spinout of exactEarth." 6 Nov. 2015. Com Dev International 16 June 2016 <https://www.comdev.ca/images/financial-reports/CDV_Honeywell_release_2015-11-05.pdf>.

its spinoff from Com Dev following the parent company's acquisition by Honeywell on 5 November 2015, on 9 June 2015, exactEarth and Harris Corp. of the U.S. announced a strategic partnership, wherein Harris Corp will mount exactEarth developed payloads on 58 next-generation Iridium mobile communication satellites. Under the arrangement, Harris Corp. will gain immediate access to exactEarth's constellation of 8 small LEO Automatic Identification Satellites (AIS). Under the new partnership, exactEarth expects to increase its AIS constellation to 11 satellites by 2017, in addition to increasing sales to U.S. government customers.[168] While Harris Corp. will assume the cost of integrating exactEarth technology in its Iridium Next payloads, exactEarth has agreed to pay $10 million in commitment fees through to June 2016.[169] Under exactEarth's partnership with Harris Corp., exactEarth will pay Harris Corp. $3 million per year after the full deployment of Harris' payloads hosted on 72 Iridium satellites. Those Iridium satellites were to begin to launch starting in early 2016, wherein during this initial period, Harris will pay exactEarth 15% of its institutional revenues until it reaches $339,000 in revenue or by March 2016; from there, its payment to exactEarth increases to 50% of government revenue up to a ceiling of $40 million. After reaching that ceiling, exactEarth will then receive 33% of the generated revenues.[170] By 13 July 2015, the ownership configuration of exactEarth had exhibited signs of change, as its parent Com Dev and minority owner Hisdesat (73% Com Dev, 27% Hisdesat) announced their decision to make available 40-45% of their ownership in exactEarth in an initial stock offering expected to generate C$88 million.[171]

Thailand's Thaicom satellite operator earned 12.453 billion baht for the year ended 31 December 2015, an increase of 4.7% over its restated revenue of 11.893 billion baht earned in 2014. Its profits from its operations continued to grow, this time by 52.2%, to 2.305 billion baht in 2015, from 1.514 billion baht in 2014.[172] Its satellite and related services amounted to 73.8% of the revenue generated in 2015, an incremental increase from the 71.4% share in 2014, and 69.6% share in 2013. Its sales and services revenue by geographic area came from Thailand (63.2%), Australia (10.2%), Japan (5.2%), Myanmar (5.0%), India (4.4%), China (2.6%), and Others (9.4%).[173] Among the significant developments for Thaicom over 2015, on 17 August 2015, the company and Thailand's Ministry of Defence signed a memorandum of understanding for collaboration in satellite communications and the possibility of co-developing a satellite project between the two parties. Other developments near the end of the year, included the Thaicom 7 satellite reaching a 100% booking of transponders on 19 November 2015, followed by the company recognising the 454 million baht impairment loss on investment on one of its Australian broadband satellite service providers.[174]

On 16 April 2015, NewSat Ltd. of Australia filed for bankruptcy protection with the U.S. Bankruptcy Court of Delaware (applying Australian administration proceedings).[175] The start-up satellite fleet operator, which reported a 17% drop in revenue for the six months ending 31 December 2014, totalling 13.7 million Australian dollars, and a net loss of 39.7 million Australian dollars[176], had been in financial constraints in recent years after defaulting on around $300.5 million in loans from the U.S. Export-Import (Ex-Im) Bank, and a $115 million loan guarantee provided by France's Coface to launch its Jabiru-1 satellite aboard an Ariane 5 launcher.[177] NewSat's lenders had grown unwilling to supply additional funds for the development of the Jabiru-1 after it missed a 30 November 2014 deadline to raise an additional $40 million in cash or equity.[178] By that time,

[168] De Selding, Peter B. "Harris, exactEarth To Place AIS Gear on Iridium Craft." 9 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/harris-exactearth-to-place-ais-gear-on-iridium-craft/>.
[169] De Selding, Peter B. "Harris, exactEarth Aim To Ride Iridium Next to Growth in AIS." 15 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/harris-exactearth-aim-to-ride-iridium-next-to-growth-in-ais/>.
[170] De Selding, Peter B. "Harris, exactEarth Aim To Ride Iridium Next to Growth in AIS." 15 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/harris-exactearth-aim-to-ride-iridium-next-to-growth-in-ais/>.
[171] De Selding, Peter B. "exactEarth's IPO Plans Coming into Focus." 17 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/exactearths-ipo-plans-coming-into-focus/>.

[172] "The Next Phase 2016 – Annual Report 2015." 3 Mar. 2016. Thaicom Public Company Limited 15 June 2016: 155° E, 156° W <http://thcom.listedcompany.com/ar.html>.
[173] Ibid. at 061° E.
[174] Ibid. at 051° E - 053° E.
[175] De Selding, Peter B. "NewSat Seeks Bankruptcy Protection." 17 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/newsat-seeks-bankruptcy-protection/>.
[176] De Selding, Peter B. "NewSat's Losses Deepen as Creditors Circle." 27 Feb. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/newsats-losses-deepen-as-creditors-circle/>.
[177] De Selding, Peter B. "NewSat Seeks Bankruptcy Protection." 17 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/newsat-seeks-bankruptcy-protection/>.
[178] De Selding, Peter B. "Jabiru-1 Launch Slips Further as NewSat, Creditors Haggle over New Financing." 9 Feb. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/jabiru-1-launch-slips-further-as-newsat-creditors-haggle-over-new-financing/>.

NewSat had used mainly Ex-Im Bank funds to invest $193 million in Jabiru-1, while around $78 million was still needed to complete the satellite.[179] A bankruptcy filing appeared unavoidable as NewSat was beset by breach of contract notices from its two principal suppliers (i.e. for the non-payment of $21 million to Lockheed Martin and $42.4 million to Arianespace) early in 2015, and refusals by its lenders Coface and Ex-Im Bank to approve loan waivers that would have permitted funding to resume.[180]

On 22 May 2015, the bankruptcy court ruled that the contract between NewSat and Lockheed Martin was no longer in force because NewSat, Ex-Im Bank and Lockheed Martin had failed to resolve their difference by a mutually agreed upon deadline. As NewSat was unable to pay past-due bills to Lockheed Martin, Lockheed was granted permission to take possession of the mostly completed Jibaru-1.[181] However, the cancellation of the contract potentially left the Ex-Im Bank with a loss of over $100 million, as Ex-Im Bank's security claim was placed on NewSat that no longer had a claim over the Jabiru-1.[182] On 29 May 2015, the court ordered a standstill agreement between NewSat and Arianespace, allowing Arianespace to stop further work on the contract while NewSat was given until 1 August 2015 to finalize the sale of its slot on the Ariane 5 launcher to satellite fleet operator Measat of Malaysia.[183]

[179] De Selding, Peter B. "Aug. 1 Deadline Set for Selling NewSat's Ariane 5 Launch Slot to Measat." 29 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/aug-1-deadline-set-for-selling-newsats-ariane-5-launch-slot-to-measat/>.

[180] C.f. De Selding, Peter B. "NewSat in Credit Bind after Coface Rebuffs Waiver Request." 8 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/coface-refusal-puts-newsat-in-tight-spot-with-creditors/>; and De Selding, Peter B. "Ex-Im Hasn't Given Up on Recovering $100 Million NewSat Loss." 9 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/ex-im-hasnt-given-up-on-recovering-100-million-newsat-launch/>.

[181] SpaceNews Editor. "Editorial | NewSat's Failure and the Ex-Im Bank." 15 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/editorial-newsats-failure-and-the-ex-im-bank/>.

[182] De Selding, Peter B. "Aug. 1 Deadline Set for Selling NewSat's Ariane 5 Launch Slot to Measat." 29 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/aug-1-deadline-set-for-selling-newsats-ariane-5-launch-slot-to-measat/>.

[183] De Selding, Peter B. "Aug. 1 Deadline Set for Selling NewSat's Ariane 5 Launch Slot to Measat." 29 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/aug-1-deadline-set-for-selling-newsats-ariane-5-launch-slot-to-measat/>.

# 4. European Institutional Market

This chapter analyses institutional space spending in Europe along distinct internal categories. The contributions are explained and contrasted with each other, displaying significant ratios and proportions regarding European space activities, and establishing a basis for comparison with space actors outside Europe.

## 4.1 Civilian Space Expenditure

National space budgets in Europe usually encompass both European and national components. The former normally consist of contributions to the European Space Agency (ESA) and EUMETSAT, and are regarded as civilian for the purposes of this report, as both organisations are broadly labelled as civilian despite the presence of dual-use products and services. While direct Member State contributions to the European Union do not officially have a space related designation, even prior to the Lisbon Treaty, EU funds have been increasingly used to finance space activities, including the two EU flagship programmes Galileo and Copernicus. In this section they are only visible through the ESA budget or are wrapped into the budgets of other actors.

While some European countries are engaged in multinational cooperation through participation in ESA, they may also have bilateral agreements on space activities between them. Through this cooperation, certain security related space projects are funded simultaneously by European institutions (notably the European Commission and the European Defence Agency) and by other sources.

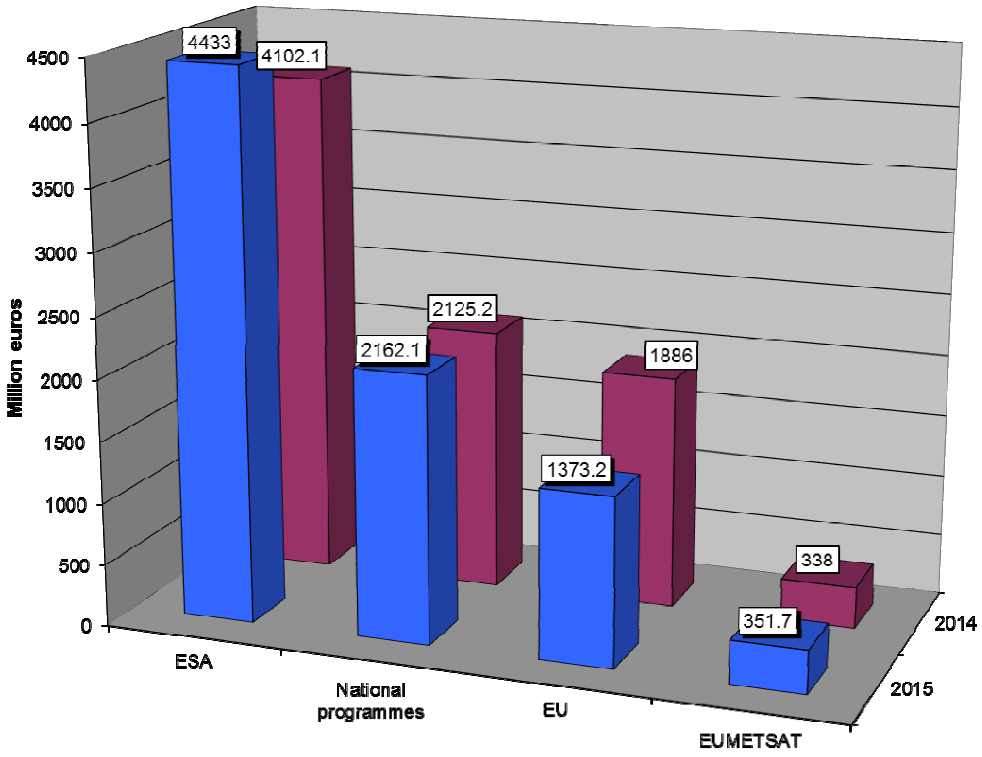


Figure 4.1: Estimated European civil public expenditures in 2015.

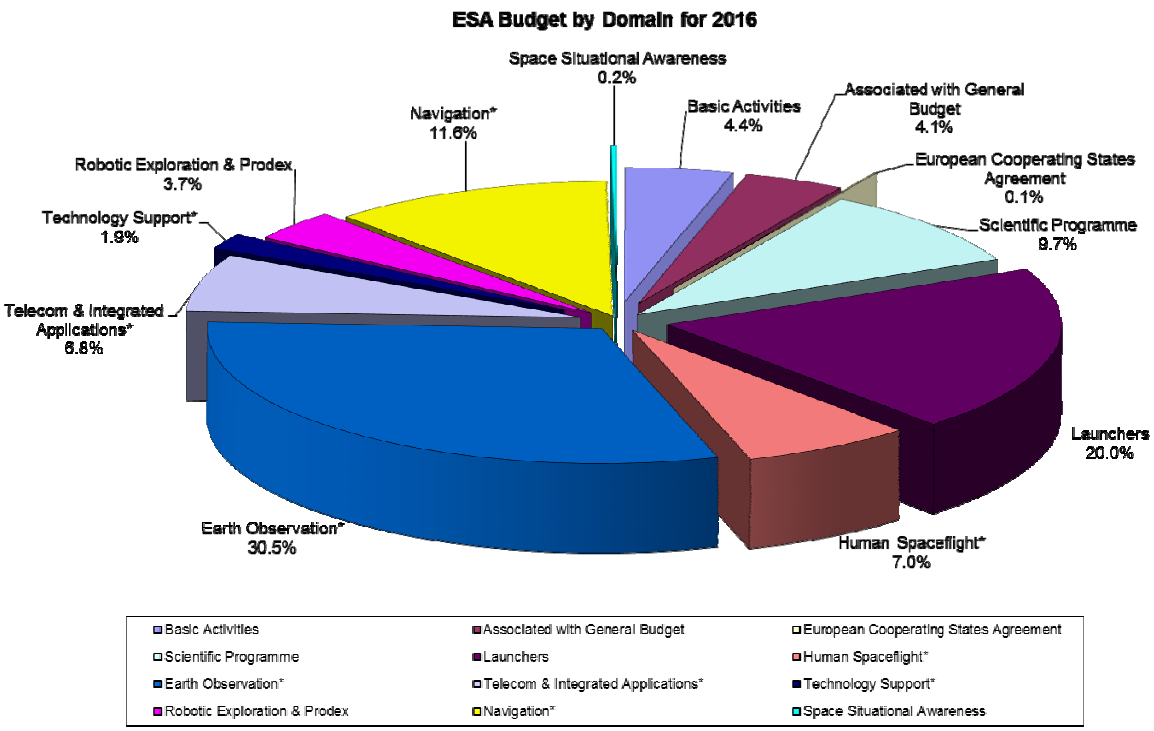


Figure 4.2: ESA Programmatic Budget Allocations for 2016 (Source: ESA)

Not all European states invest in military and intelligence gathering space activities; and in any event, most institutional spending is directed toward civilian activity. The total sum of European institutional spending on space lowered by 1.6% in 2015, to reach €8.320 billion from €8.451 billion in 2014; yet this reduction may be due to the use of Eurospace figures as an authority in lieu of Euroconsult figures, which do not account for expenditures in services. In 2015, ESA expenditures increased by €330.9 million to be €4.433 billion, while national civil programme expenditures increased by a combined total of €36.9 million to be €2.162 billion. Expenditures by the EU is estimated to have decreased by €512.8 million to €1.373 billion, while Eumetsat expenditure increased by a combined €13.7 million to €351.7 million. According to Eurospace, the share between civilian and military funding can be roughly estimated to be around 91.9% civilian and 8.1% military. However, Europe's security-related space activities in both its share-size and amounts invested are still a fraction of what was spent by the U.S. In 2015, European expenditure on defence space programmes was about €675.2 million, whereas U.S. expenditure in security-related space activities was $23.572 billion.[184]

[184] "Missile Defense Agency Fiscal Year (FY) 2016 Budget Estimates | Overview." 26 Jan. 2015 MDA 10 July 2016 <http://mda.mil/global/documents/pdf/budgetfy16.pdf>.

## 4.2 European Space Agency (ESA)

The European Space Agency's budget increased by 18.49% in 2016 to €5.253 billion from €4.433 billion in 2015. The biggest budget allocation increase went to launcher development which grew by 73.0%, reaching €1.051 billion or one-fifth of ESA's spending. Funding for Earth observation increased by 27.8%, reaching €1.604 billion (a 30.5% share of ESA's budget), while spending on Navigation decreased by 8.3% to reach €609.5 million (11.6%). Funding for Space Science was remained unchanged at €507.9 million (9.7%), while human spaceflight decreased by 1.7% at €365.1 million (7.0%). Next, Telecom & Integrated Applications increased by16.2% at €359.3 million (6.8%), while Robotic Exploration & Prodex also had an increase of 23.8% reaching €192.8 million (3.7%). Funding for Space Situational Awareness decreased by 7.2% reaching €12.9 million (0.2%), while the remaining 8.6% of funding was allocated to ESA's basic activities, activities associated with the General budget, and the European Cooperating States Agreement.[185]

[185] "ESA Budget 2015 by Domain. 15 Jan. 2015. ESA 11 Sept. 2015 <http://www.esa.int/spaceinimages/Images/2015/01/ESA_Budget_2015_by_domain>.

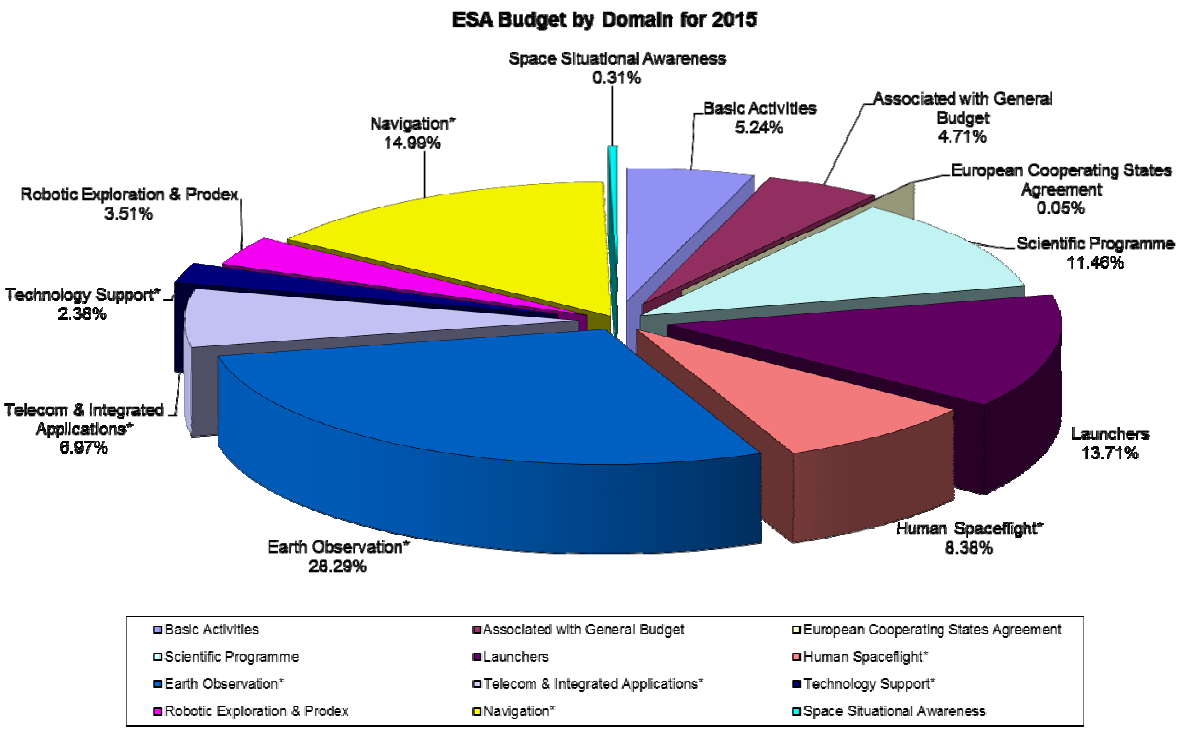


Figure 4.3: ESA Programmatic Budget Allocations for 2015 (Source: ESA)

In 2015, ESA`s budget increased by 8.1% to €4.433 billion, with the biggest relative change occurring in the allocation to Space Situational awareness, which increased by 52.7% to €13.9 million; yet that amount represented 0.3% of the total budget for 2015. Earth observation received the second highest relative increase in funding at 36.9%, reaching €1.254 billion; its budget share of 28.3% nearly doubled all other ESA activities for the year. Meanwhile, Navigation increased by 5.4% to €664.5 million (15.0%); increases in Earth observation and navigation came mainly from EU investment in its Copernicus and Galileo flagship programmes. Robotic Exploration & Prodex also increased by 15.5% to €155.8 million (3.5%), however aside from marginal increases for Scientific Programme, Basic Activities, and Human Spaceflight, all other programmes saw reductions in funding.[186]

While the life of the ISS has been formally extended to 2024, ESA has stopped the production of its Automated Transfer Vehicles (ATVs) which covered ESA's 8.3% share of the ISS's annual operating costs until 2017. ESA's final ATV mission, ATV-5 George Lemaître, ended on 15 February 2015, following its separation from the ISS a day earlier.[187]

ESA will use the knowledge gained from the ATV programme to build its European Service Module for NASA's Orion spacecraft that will fly astronauts to the Moon and beyond; its dues for the utilization of the ISS for the period 2018-2020 is estimated at a total of €455 million.

The development of ESA's Public Private Partnership (PPP) with Airbus Defence & Space to develop the European Data Relay System (EDRS) system progressed further in 2015. The EDRS system, planned to have at least three satellites geostationary orbit, will relay data from satellites in non-geostationary orbit to ground stations, to dramatically decrease latency time in signal transmission and provide near-real-time services on a global scale. The first EDRS node (EDRS-A) was launched on 22 June 2015 as a hosted payload aboard the Sentinel 1a satellite. Eutelsat's commercial telecom satellite, Eutelsat-9B was launched on 30 January 2016, carrying an EDRS laser communications terminal.[188] And OHB AG of Bremen is building the third EDRS-C satellite for the Airbus-managed system, which is expected to

[186] "ESA Budget 2015 by Domain. 15 Jan. 2015. ESA 11 Sept. 2015 <http://www.esa.int/spaceinimages/Images/2015/01/ESA_Budget_2015_by_domain>.

[187] "Last ATV reentry leaves legacy for future space exploration." 15 Feb. 2015. ESA 30 May 2016 <http://m.esa.int/Our_Activities/Human_Spaceflight/ATV/Last_ATV_reentry_leaves_legacy_for_future_space_exploration>.

[188] De Selding, Peter B. "ILS Proton successfully launches Eutelsat 9B telecom/data-relay satellite." 30 Jan. 2016. SpaceNews 21 Oct. 2016 <http://spacenews.com/ils-proton-successfully-launches-eutelsat-9b-telecomdata-relay-satellite/>.

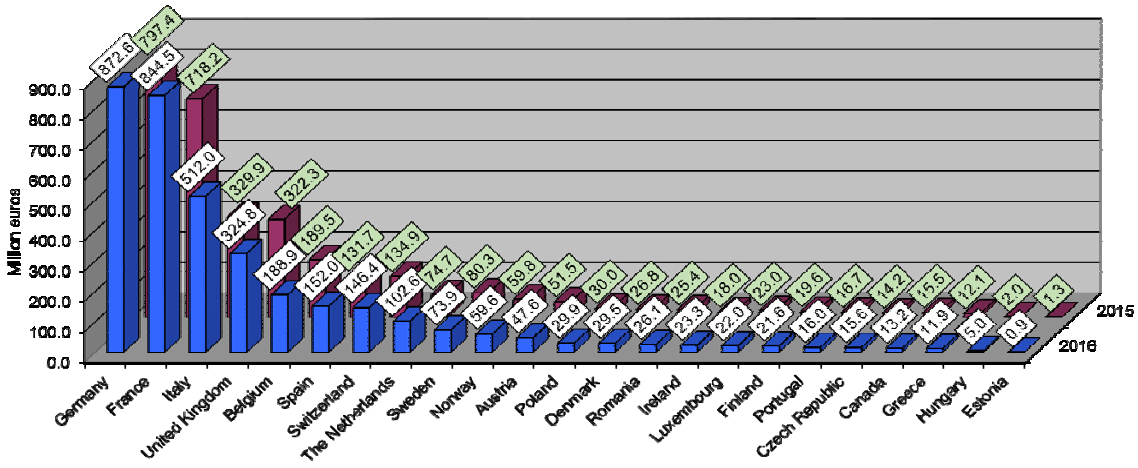


Figure 4.4: Member States' Contributions to ESA's Budget from 2015 to 2016 (Source: ESA)

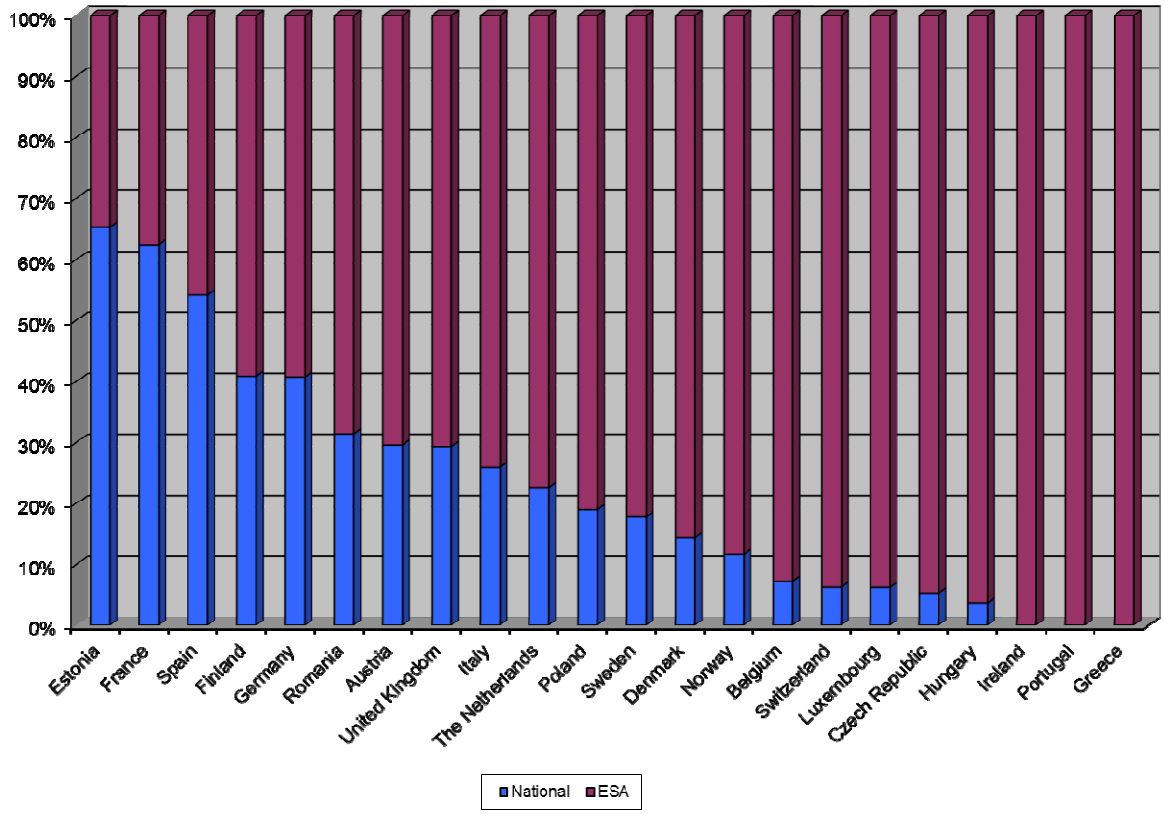


Figure 4.5: Estimated Shares of European National Institutional Investment in Civilian Space of ESA Members in 2016 (Source: ESA, European Space Technology Master Plan 12th Edition, The European Space Directory 2015)

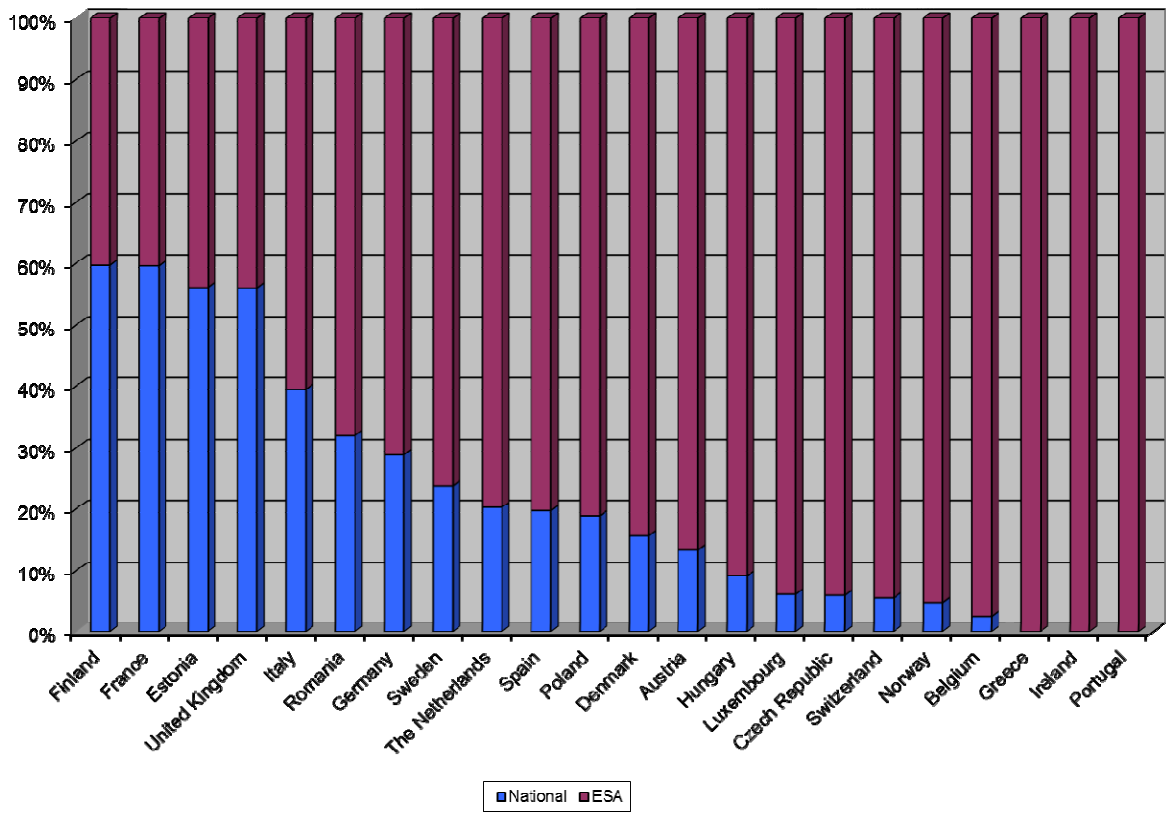


Figure 4.6: Estimated Shares of European National Institutional Investment in Civilian Space of ESA Members in 2015 (Source: ESA, Euroconsult, The European Space Directory 2015)

be launched in 2017. Moreover, a laser terminal will be launched later as a hosted payload aboard another telecommunications satellite. Another PPP exists between ESA and another OHB System AG industrial team for the development of the SmallGEO platform, intended as a general-purpose small geostationary satellite to buttress European industry's position in the commercial telecom market. The first SmallGEO, albeit delayed from its initial launch schedule, will be ready for delivery by October 2016, after completing mechanical testing and thermal-vacuum chamber tests.[189]

## 4.3 EUMETSAT

Eumetsat brought its two new programmes, EPS-Second Generation (EPS-SG) and Jason-Continuity of Service (Jason-CS) into force in 2015. The intergovernmental organisation launched its last Meteosat Second Generation satellite, MSG-4, on 15 July 2015; therein, after completing commissioning in December, the spacecraft was renamed Meteosat-11 and stored in orbit for a 2.5 year duration.[190] Eumetsat also successfully launched its Jason-3 satellite on 17 January 2016, while ESA launched the Sentinel-3A on 16 February 2016. Eumetsat has also begun to develop its 10-year strategy "Challenge 2025" to reach an optimum realisation of the portfolio of programmes acquired in recent years, and address its future role in Copernicus and the "big data" challenge. And Eumetsat began discussions with Serbia, the last remaining EUMETSAT Cooperating State, on accession as a full Member State in 2017, following the expiry of its Cooperating State Agreement.[191]

The vast majority of Eumetsat's budget comes from contributions from its Member States and Cooperating States. Member contributions are calculated on the basis of their Gross National Income (GNI). In 2015, the percentage distribution of contributions were

[189] De Selding, Peter B. "OHB readies SmallGEO platform, Galileo bid and role in Airbus Safran-dominated Arianespace." 21 Mar. 2016. SpaceNews 21 Oct. 2016 <http://spacenews.com/ohb-readies-first-smallgeo-platform-galileo-bid-and-role-in-airbus-safran-dominated-arianespace/>.

[190] "EUMETSAT has successfully completed the commissioning of its MSG-4 satellite, and renamed it Meteosat-11." 16 Dec. 2015. Eumetsat 24 Oct. 2016 <http://www.eumetsat.int/website/home/News/DAT_2880495.html?lang=EN&pState=1>.

[191] See Eumetsat Annual Report 2015. 30 June 2016. Eumetsat 21 Oct. 2016: 2-5 <http://www.eumetsat.int/website/home/AboutUs/Publications/AnnualReport/index.html>.

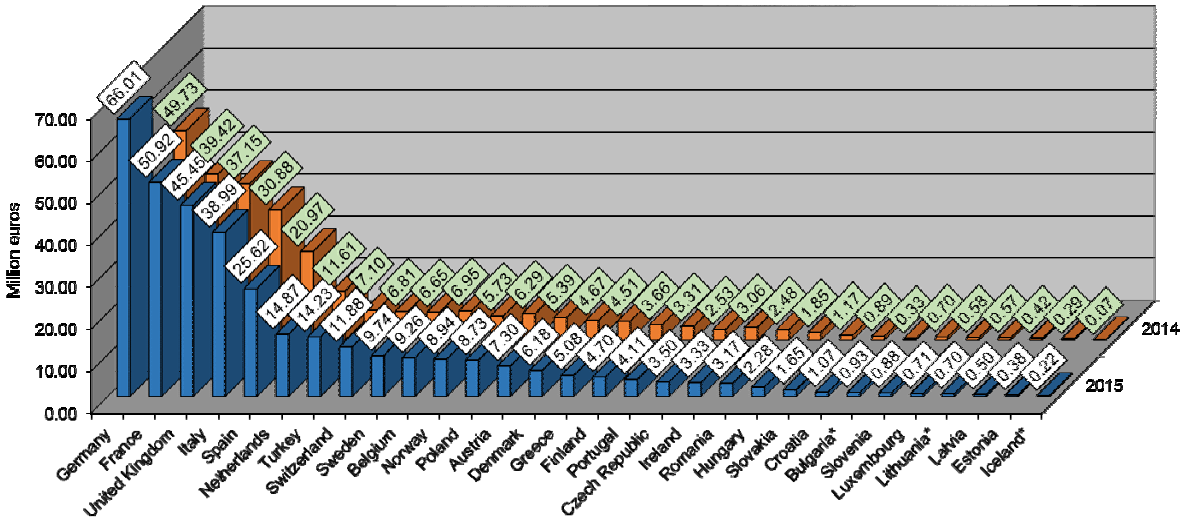


Figure 4.7: Member states' contributions to Eumetsat in 2015 and 2014 (Source: EUMETSAT)

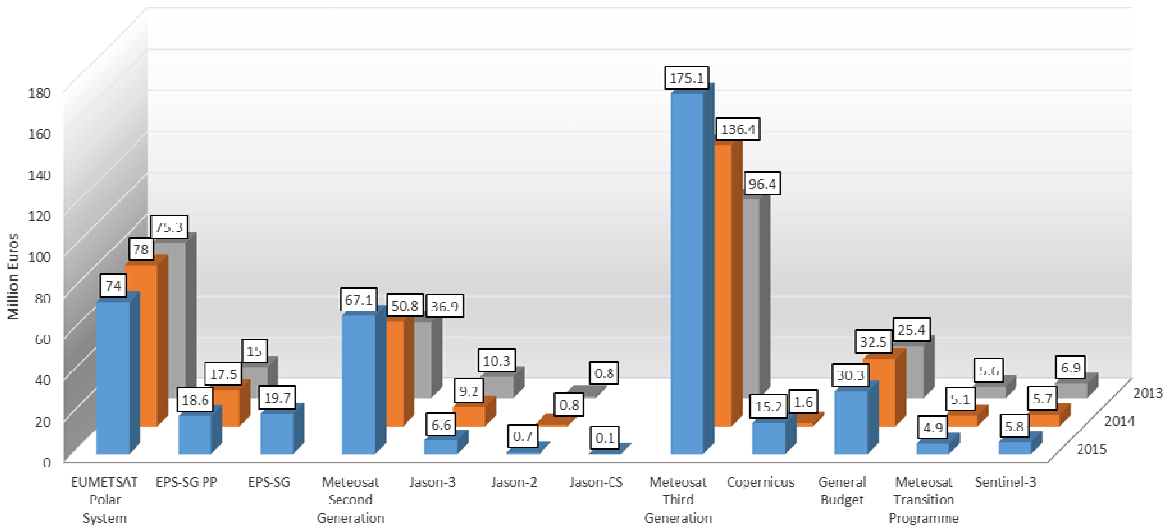


Figure 4.8: Major Programmatic Allocations of Eumetsat 2015-2013

similar to 2014, aside from four position changes by Belgium, Poland, Czech Republic, and Bulgaria (Figure 4.7). In 2015, Eumetsat contributions increased from all Member States with a median increase of 28.8%. Germany remains the largest contributor with an 18.79% share contribution in 2015, from 18.71% in 2014. France followed next with a diminished share contribution of 14.50% in 2014 down from 14.83% in 2014. And the United Kingdom's share was 12.94% in 2015, down from 13.98% in 2014; similarly, Italy's share lowered to 11.10% in 2015 from 11.62% in 2014. Spain and the Netherlands rounded out the major contributors at about 7.29% and 4.23% in 2015, respectively. In 2015, these six states accounted for about 68.85% of the total allocation. The contributions from the remaining Member States ranged from 4.05% to 0.06%.[192]

In 2015, Eumetsat's total expenditure increased by 23.8% to €418.1 million from €337.6 million in 2014, as the intergovernmental organisation sought to play a more defined role in the EU's Copernicus flagship programme, and to ensure continuity of services throughout the next decade. In 2015, funding for the Meteosat Third Generation Programme increased by 28.4% to €175.1 million, while the Meteosat Second Generation also increased by 32.1% to €67.1 mil-

[192] See Eumetsat Annual Report 2015. 30 June 2016. Eumetsat 21 Oct. 2016: 65 <http://www.eumetsat.int/website/home/AboutUs/Publications/AnnualReport/index.html>.

lion, and funding for the Meteosat Transition Programme decreased by 3.9% to €4.9 million. The Eumetsat Polar System decreased by 5.1% to €74 million, while the EPS Second Generation Preparatory Programme increased by 6.3% to €18.6 million, and new funding of €19.7 million went to the EPS Second Generation mission in 2015. Next, funding for Jason-3 decreased by 28.3% to €6.6 million, while funding for Jason-2 decreased by 12.5% to €700,000, and new funding of €100,000 went to initial studies for the Jason-CS/Sentinel-6 cooperative mission in 2015. And Eumetsat funding toward diversification activities related to Copernicus increased substantially in 2015, reaching €15.2 million from €1.6 million; and funding for the Copernicus Sentinel-3 satellite increased by 1.8% to €5.8 million. The general budget also decreased by 6.8% to reach €30.3 million.[193]

## 4.4 National Agencies

In 2015, the hierarchy of European national civilian space programmes (not including contributions to ESA) changed somewhat compared to 2014, although that is likely due to the use of Eurospace estimates as an authority, which do not account for expenditures in services, in lieu of Euroconsult figures. France remained in the first position in national space expenditure, more than doubling the UK as the second position holder. Germany and Italy came in third and fourth position, with a combined share of around 92.7% of the total expenditure on European national civilian programmes.

### 4.4.1 France

Prior to Airbus Safran Launcher's (ASL) formal bid on 7 May 2015 to ESA for the production of the Ariane 6 launcher, questions remained over the division of responsibilities between industry and government. The 2014 ESA Ministerial Council meeting left open issues such as whether ASL would be required to invest upwards of €400 million of its own capital in the Ariane 6 launcher programme, and whether an additional €200 million would be temporarily removed by ESA from the project that was initially valued at €3.215 billion.[194]

An ESA concern was that if ASL were forced to pay the €400 million, it might spread that cost over future commercial launches. The effect on Ariane 6's competitiveness might come into question, especially following SpaceX's streak in the commercial market, and Japan considering lowering its launcher cost by 50% to win additional commercial business. Moreover, the move could dampen the effect of the favourable exchange rate that is currently developing, allowing Europe's launcher to compete with U.S. launchers at near par-value currencies.[195]

Separately, ASL raised its desire for a complete paradigm shift in governance before it would consider investing its own resources into the new launcher. That is, in order for the Ariane 6 to become more competitive, ASL wanted oversight over the design, production, commercialization and operations of the launcher. A second issue that threatened to stall negotiations was the ownership of Arianespace, in which ASL sought to increase its 39% stake in the launch company to include the near 34.7% stake held by the French government through CNES, resulting in the removal of CNES's minority blocking power in launcher development.[196]

The French government agreed to sell its stake in Arianespace to ASL by the end of 2015, but reserved informal oversight over the company, which will remain intact at its Evry headquarters, and will utilize the Ariane 6 launch platform CNES is building in French Guiana.[197] Following negotiations between ESA and ASL, it was agreed that ASL would contribute €400 million to the Ariane 6 development contract, while €200 million will be cut out partly by shaving the cost of certain buildings and facilities that will integrate the launcher horizontally, and an additional €200 million will be removed as unnecessary expenditures. ESA signed the Ariane 6 development contract with ASL on 12 August 2015. The contract, now valued at around €2.4 billion, will cover development of the launcher from 2015 to its inaugural flight in 2020.

A related industry concern that remains to be resolved is whether the ASL launch contractor configuration will be neutral among European

[193] Ibid. at 64.
[194] De Selding, Peter B. "ESA, Industry at Odds over Ariane 6 Funding Responsibilities." 3 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/esa-industry-at-odds-over-ariane-6-funding-responsibilities/>.
[195] De Selding, Peter B. "Arianespace Assures French Parliament it Can Outcompete SpaceX." 13 May 2015. SpaceNews 5 Jan. 2016 <http://spacenews.com/arianespace-assures-french-parliament-it-can-outcompete-spacex/>.
[196] De Selding, Peter B. "New Airbus-Safran Venture Eyes Full Control of Arianespace." 8 Jan. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/new-airbus-safran-venture-eyes-full-control-of-arianespace/>.
[197] De Selding, Peter B. "France Giving up Arianespace Ownership, but not Oversight." 19 June 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/france-giving-up-arianespace-ownership-but-not-oversight/>.

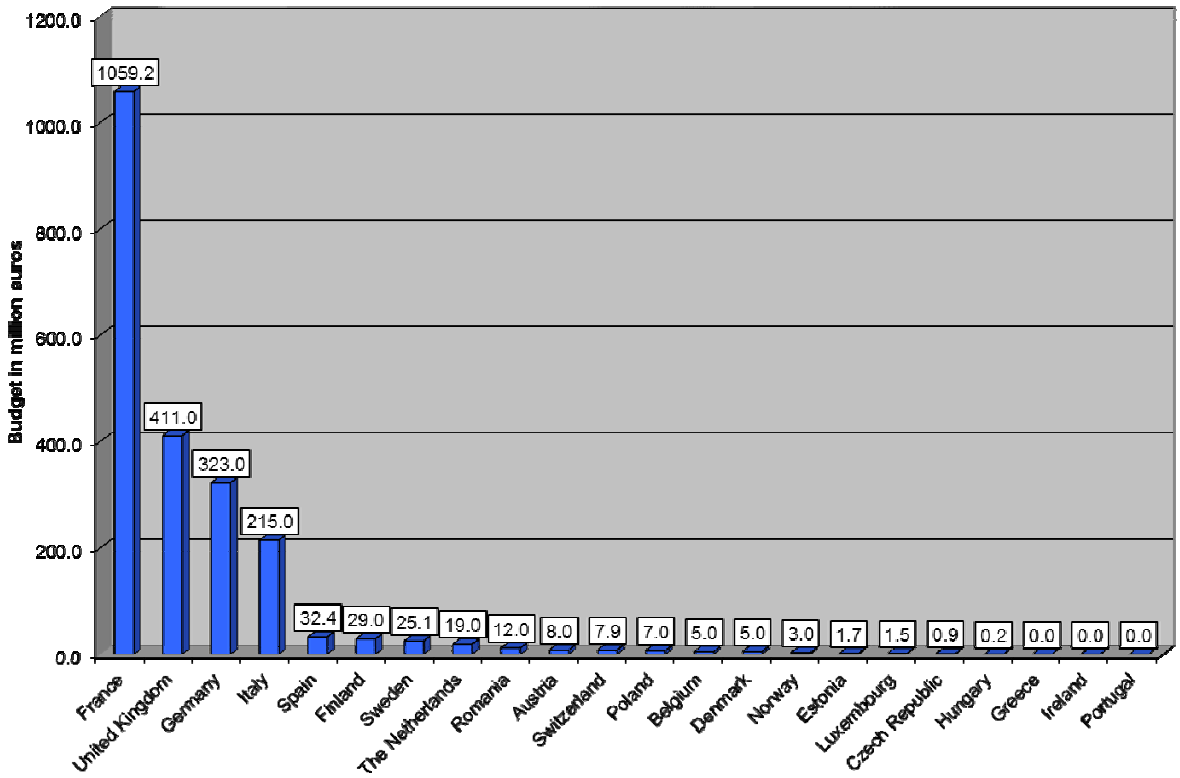


Figure 4.9: National civilian programmes 2015 in million euros (Source: Eurospace, and Space Directory 2016)

satellite manufacturers. While Airbus D&S is a 50% shareholder in ASL, it also directly competes with Thales Alenia Space and smaller prime contractor OHB, in manufacturing commercial satellites. Hence, a valid concern among European competitors is the possibility that an Airbus-controlled Ariane 6 might form a preference for its satellites through commercial or design biases.

Lastly, on 12 August 2015, ESA and CNES signed a contract to develop the Ariane 6 launch pad and horizontal launcher integration facilities in Europe's Guiana Space Centre in French Guiana. Valued at €600 million, construction of the new launch installation will need to be completed before the intended demonstration launch of the Ariane 6 in 2020. French industry can expect to receive 52% of the value of the contract in proportion to its government's investment in the ESA Ariane 6 launcher programme. Likewise, Germany's industry will receive a 23% share of the contract, while the remaining 25% will be spread among Italy, and other Ariane 6 participating member states under ESA's geographic return policy.[198]

### 4.4.2 Germany

On 18 June 2015, the German Aerospace Centre (DLR) elected Pascale Ehrenfreund as the new Chair of the DLR Executive Board, replacing Jan Woerner who began his new role as ESA's Director General on 1 July 2015.[199] Pascale Ehrenfreund, who is the DLR's first female Chair, began her role on 17 August 2015. Pascale was born in Vienna, Austria, where she obtained degrees in Astronomy and Biology at the University of Vienna, in addition to her doctorate and various other degrees. Prior to her appointment at the DLR, Pascale was a Professor of Space Policy and International Affairs at the Elliott School of International Affairs, George Washington University, and Lead Investigator at the NASA Astrobiology Institute, in addition to accepting the honorary position of President of the Austrian Science Fund (FWF) in 2013, and being a visiting researcher at the European Space Policy Institute.[200]

[198] De Selding, Peter B. "ESA Inks $3.8 Billion in Contracts for Ariane 6, Vega-C and Spaceport Upgrades." 12 Aug. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/esa-inks-3-8-billion-in-contracts-for-ariane-6-vega-c-and-spaceport-upgrades/>.

[199] "First woman to head a major German research facility." 18 June 2015. DLR 29 June 2016 <http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-13955/#/gallery/19767>.

[200] "Pascale Ehrenfreund - Chair of the DLR Executive Board." 7 Oct. 2015. DLR 29 June 2016 <http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10329/510_read-14467>.

The ESA and DLR decision makers decided to move the Rosetta spacecraft to a safe distance from the comet 67P/Churyumov-Gerasimenko in mid-2015 during its closest approach to the Sun. As communications with the Philae lander were unlikely to be re-established, the space agencies' chose to study the composition of the comet's tail, requiring its orbit to be adjusted to about 1,000 km from the comet's nucleus.[201] Rosetta's mission has been extended into September 2016, where the spacecraft will then be guided to alight on the comet's surface to finish its mission.[202]

### 4.4.3 Italy

As Europe's launch sector begins its substantial reorganisation to make it more competitive in the global market, the launch rate of the Vega launcher, developed by Italian prime contractor Avio SpA, is expected to increase. An increased demand and favourable EU/U.S. exchange rates have helped grow the Vega's backlog to 11 launches for a total of 13 satellites as of June 2015, meanwhile the demand for Vega has also allowed Arianespace to increase its launch price. Whereas in 2013, Vega's backlog of 4 satellite launches was valued at €130 million, or €32.5 million per launch, the value of this new backlog has grown to €400 million, or €36.4 million per launch.[203] The Vega launcher's P-120 first stage will also serve as the strap-on booster for 62 and 64 variants of the Ariane 6 launcher.[204]

Despite committing to funding nearly 50% of the next generation Vega launcher at the 2014 Ministerial Council meeting, the Italian government was also able to allocate €30 million per year from 2015 to 2018, to put forward a second generation Cosmo-SkyMed military and civilian radar Earth observation programme. Cosmo-SkyMed is part of a bilateral agreement with the French Defence Ministry, wherein Italy contributes radar data to France, while France provides Italy with products from its optical reconnaissance satellites. Valued at €500 million, Italy's contract with the Italian Space Agency (ASI) and Thales Alenia Space will be for two next generation satellites, and is expected to employ a total of nearly 400 engineers and technicians at Thales Alenia Space's facilities in Rome, L'Aquila, and Turi, Italy. The new generation will be launched into orbit between 2017 and 2018.[205]

## 4.5 European Union (EU)

The EU Copernicus flagship programme has entered its operational phase, following the successful launches of its Sentinel-1B satellite on 22 April 2016, its Sentinel-2A on 22 June 2015, and Sentinel-1A on 3 April 2014. While funding for the programme had been uncertain during the Commission's development of the seven-year Multiannual Financial Framework (MFF) for 2014 - 2020, the European Commission managed to keep the Copernicus programme within the MFF budget, albeit with a €2 billion reduction, thus amounting to €3.8 billion (in 2011 prices).[206] In coordinating the evolution of the Copernicus Space Component, ESA has prepared a long-term plan for the content and associated funding needs, covering the operation of the Sentinels up to 2020, and the procurement of recurrent Sentinel satellites and instruments and access to data available from contributing missions up to 2028.[207]

By the end of 2015, the EU Galileo flagship GNSS programme had managed to recover from the rough start it experienced in 2014, where one of the four in-orbit validation (IOV) satellites launched in 2014 suffered irreparable power degradation from an unknown anomaly, while two satellites were placed in a bad orbit by a Soyuz Fregat upper stage. An additional 6 Galileo navigation satellites were successfully placed into medium Earth orbit in 2015, enabling the European Commission to debut initial Galileo services (i.e. open service, SAR, and PRS) with the

[201] Crew, Bec. "Our last chance to contact the Philae comet lander probably failed." 13 Jan. 2016. Science alert 20 May 2016 <http://www.sciencealert.com/our-last-chance-to-contact-the-philae-comet-lander-probably-failed>.
[202] De Selding, Peter B. "ESA Managers Face Choice on Rosetta Priorities." 13 Aug. 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/esa-managers-face-choice-on-rosetta-priorities/>.
[203] De Selding, Peter B. "Vega Launches Sentinel-2A Observation Satellite." 23 June 2015. SpaceNews 5 Jan. 2016 <http://spacenews.com/vega-launches-sentinel-2a-observation-satellite/>.
[204] De Selding, Peter B. "ESA Inks $3.8 Billion in Contracts for Ariane 6, Vega-C and Spaceport Upgrades." 12 Aug. 2015. SpaceNews 5 Jan. 2016 <http://spacenews.com/esa-inks-3-8-billion-in-contracts-for-ariane-6-vega-c-and-spaceport-upgrades/>.
[205] De Selding, Peter B. "Italian Commitment to Next-gen Radar Satellites in Time to Avert Gap." 21 Jan. 2015. SpaceNews 8 Jan. 2016 <http://spacenews.com/italian-commitment-to-next-gen-radar-satellites-in-time-to-avert-gap/>.
[206] "For Europe's Embattled GMES, Good and Bad News." 7 Dec. 2012. SpaceNews 25 Apr. 2014 <http://spacenews.com/article/civil-space/32717for-europe%E2%80%99s-embattled-gmes-good-and-bad-news>.
[207] "Green Light for GMES Copernicus." 4 July 2013. ESA 28 Apr. 2014 <http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Green_light_for_GMES_Copernicus>.

remaining nine fully operational satellites by late 2016. The EU Galileo flagship GNSS programme's 7-year budget of €6.3 billion (at 2011 prices) was approved by the European Parliament on 22 November 2013.[208] Switzerland joined the EU's Galileo programme at the beginning of 2014, following an agreement that requires Switzerland to make catch-up payments to the EU totalling €80.05 million, for the period 2008 to 2013, along with annual fees of €27 million in return for access to Galileo's restricted Public Regulated Service (PRS) signals. At the end of 2015, the EU was still sorting out access to the PRS signals its 28 member states, in addition to still considering whether to make PRS signals available to Norway and the United States.

Funding for Horizon 2020, the EU's Research and Innovation programme that includes a large variety of space research efforts, is estimated to be €1.4 billion over the 7-year period, i.e. €200 million per year.[209] However, the actual amount allocated to space research under Horizon 2020 fell short of that estimate for 2015 and for 2016. Under the Horizon 2020 Work Programme 2014-2015, the 2015 space research budget was €181.9 million.[210] Meanwhile, within the Horizon 2020 Work Programme of 2016-2017, the 2016 space research budget lowered to €167.1 million.[211]

[208] "Galileo Funding: A 'Small' Difference of €700 Million." 22 Nov. 2013. The European Sting 25 Apr. 2014 <http://europeansting.com/2013/11/22/galileo-funding-a-small-difference-of-e700-million/>.

[209] "Space Programs Facing Cuts in Seven-year EU Budget." 1 Feb. 2013. SpaceNews 25 Apr. 2014 <http://spacenews.com/article/space-programs-facing-cuts-in-seven-year-eu-budget>.

[210] Commission of the European Communities. Horizon 2020 – Work Programme 2014-2015. Annex 8. European Commission Decision C(2013)XXX of 10 December 2013. Brussels: European Union <http://ec.europa.eu/enterprise/policies/space/files/research/horizon-2020/h2020-leit-space-work-programme-2014-2015_en.pdf>.

[211] Commission of the European Communities. Horizon 2020 – Work Programme 2016-2017. 5 iii. Leadership in Enabling and Industrial Technologies – Space European Commission Decision C(2016)4614 of 25 July 2016. Brussels: European Union <http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-leit-space_en.pdf>.

# 5. The Defence Perspective

This chapter considers key developments in the field of military space activities. These developments include military space government programmes and related spending, industrial achievements in military space technologies, and the evolution of space security doctrines of all the major space-faring nations. Given the confidential nature of military space spending, calculating the exact volume and nature of these activities is difficult as the analysis is based only on open sources. Consequently, the facts and figures presented must be considered as incomplete in assessing the full range of military space programmes and should be treated accordingly. For these reasons, the following figures are conservative estimates and it is very likely that actual military space budgets far exceed the amounts that are reported. This is particularly the case with Russian and Chinese programmes that are often classified. With these factors in mind, readers can take from this chapter a relative assessment of global military space activities as per key space faring states, along with an overall estimate of the general trends in this field.

## 5.1 Trends in Military Expenditure

The Space Report 2016 listed space-related military spending in 2015 as having reached $34.151 billion, decreasing by 3.3% from $35.325 billion due more to unfavourable dollar exchange rates rather than decreased national spending.[212] As is typical with the nature of dual-use technology in space activity, there is a risk that certain military activities have been already included in larger budgets, which can result in double counting. Moreover, while missions, often listed as civil programmes, may also serve dual-purpose military objectives, their expenditure is not included in this section.

According to The Space Report 2016, the U.S. generated about 69.0% ($23.572 billion) of global military space spending in 2015, a notable increase from the 63.6% share estimated for 2014. Non-U.S. global military spending decreased to 31.0% ($10.579 billion) from 36.4% in 2014.[213] However, due to fluctuating exchange rates, variations in purchasing power, and different employment costs, a direct comparison of the budgets of these countries in fixed dollar values does not present a clear picture of their relative space defence efforts.

## 5.2 Europe

According to estimates by Eurospace, total funding for European military space programmes was about $753.051 million (€675.2 million) in 2015. France had the highest military budget at $362.696 million (€325.2 million), while the United Kingdom budgeted $317.860 million (€285.0 million), with Germany at $55.765 million (€50.0 million), and Italy at $16.730 million (€15.0 million). Yet, there is a discrepancy between estimates provided in the previous 2014 reporting period and the current figures, due once again to currency exchange rates, but also to the use of Eurospace figures as an authority in lieu of Euroconsult figures. It should also be noted that Eurospace figures do not account for expenditures in services.

Financial problems prevented Italy from participating in France's latest Comsat NG dedicated military communications system. Nevertheless, as the two countries previously collaborated in other milsat space programmes such as Cosmo-SkyMed and the Sicral 2 UHF and SH-band satellite, their collaboration sets an example that the other three closely allied European countries owning military satellite systems, i.e. Britain, Germany, and Spain, may benefit from adoption. The five countries have often indicated a desire to do so, however coordinating cooperative opportunities has proven difficult. In addition to financial constraints, as in the case of Italy, another barrier to collaboration was the desire to use existing capacity before investing in new capacity. Coordinating investment on a shared milsat programme will be a challenge, as the different stage life cycles of the military systems in orbit mean that countries may be unwilling to procure

[212] The Space Report 2016. Colorado Springs: The Space Foundation, 2014: 38.

[213] Ibid.

additional capacity while their own systems are expected to operate for several more years. Yet collaborating on a shared milsat programme should lower costs by an estimated €2 billion according to the European Defence Agency (EDA), and will substantially save costs over the long term while still making a bounty of capacity available.[214] Collaboration may also help to quell the unequal approach by the EC to milsatcom procurement of services from operators.

In a move to bolster its military communications space infrastructure and provide encrypted jam-resistant capacity to NATO-allied governments, Airbus D&S has moved its Skynet 5A military X- and UHF-band satellite to the Asia-Pacific region (covering 178 degrees West to 165 degrees East). The move will provide near-global telecommunications coverage for military users including the UK government, Skynet's anchor customer, along with NATO and individual NATO governments, which lease capacity from the system. [215] While Airbus D&S owns the Skynet satellite system, it has been in a £3.6 billion (€4.62 billion) contract with the British Defence Ministry since 2003. The current system management contract will end by August 2022, at which point the four Skynet 5 satellites and the four older Skynet 4 satellites will revert to British military control. The British government is now considering whether to continue the contract with Airbus or enter into a similar contract with another company. It is also considering the advantages of purchasing two satellites of its own, one in 2019 and another in the following year or two, and simply extending the life of the Skynet 5 system under British military control into the 2020s.[216]

## 5.3 The United States

The U.S. Department of Defense (DoD) space budget slightly increased by 4.8% in 2015, to $23.572 billion from $22.483 billion in 2014, while the budget for the U.S. Missile Defense Agency (U.S. MDA) continued to decrease in 2015, reducing by another 1.9% to around $7.46 billion in 2015 from $7.6 billion in 2014; however, it requested $8.127 billion in FY 2016 to improve and expand the development of its defences.[217] Near mid-2015, members of the U.S. Congress' House Armed Services Committee showed renewed interest in a 2009 concept to put several miniaturized kill vehicles on an interceptor missile to overcome the U.S. missile defense system's inability to reliably distinguish between missile warheads and relatively low-tech decoys. The U.S. MDA would make the multi-object kill vehicle (MOKV) a long-term technology, which would come after the completion of its redesigned kill vehicle (RKV) expected to be ready around 2020.[218] In August, Boeing, Lockheed Martin, and Raytheon each won study contracts worth approximately $9.7 million to develop MOKV concepts that are expected to be completed by May 2016. The three companies will also develop specific subsystems for the RKV, to modularize and simplify the interceptor's production; the RKV's design review is expected at the beginning of 2016, while bidding for the production contract is expected in 2018.[219]

Following the 31 March 2015 launch of Russia's Cosmos 2504 spacecraft; its resulting manoeuvres, including at least one case where the upper stage of its launcher appeared to be nudged to a higher orbit, motivated the U.S. to early deployment of its once-classified Geosynchronous Space Situational Awareness Program (GSSAP) satellites.[220] Two GSSAP satellites, which had been in checkout procedures and operational testing since their launch in July 2014, were taken out of test mode twice by 16 September 2015 to make observations of specific objects in geosynchronous orbit. The satellites performed as expected, with initial operational capability for the satellites expected in the following weeks. Another 2 GSSAP satellites could launch in 2016. Since the GSSAP programme's declassification in Feb-

[214] SpaceNews. "Editorial | Despite Compelling Logic, Cost Sharing Remains Elusive for European Milspace." 20 Jan. 2015. SpaceNews 8 Jan. 2016 <http://spacenews.com/cost-sharing-elusive-for-european-milspace/>.

[215] De Selding, Peter B. "Britain's Skynet 5A Reassigned to Asia-Pacific." 16 Mar. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/britains-skynet-5a-reassigned-to-asia-pacific/>.

[216] De Selding, Peter B. "Britain Backpedals on Privatized Milcom Satellites." 5 Nov. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/britain-backpedals-on-privatized-milcom-satellites/>.

[217] C.f. "Missile Defense Agency Fiscal Year (FY) 2015 Budget Estimates | Overview." 20 Feb. 2014. MDA 10 July 2016 <http://www.mda.mil/global/documents/pdf/budget_overview.pdf>.
"Missile Defense Agency Fiscal Year (FY) 2016 Budget Estimates | Overview." 26 Jan. 2015 MDA 10 July 2016 <http://mda.mil/global/documents/pdf/budgetfy16.pdf>.

[218] Gruss, Mike. "House Bill Would Revive Dormant Missile Defense Kill Vehicle Project." 11 May 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/house-bill-would-revive-dormant-missile-defense-kill-vehicle-project/>.

[219] Gruss, Mike. "MDA Pursues Kill Vehicles with Cost-cutting Mandate." 24 Aug. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/mda-pursues-kill-vehicles-with-cost-cutting-mandate/>.

[220] Gruss, Mike. "Maneuvering Russian Satellite Has Everyone's Attention." 17 July 2015. SpaceNews 20 Mar. 2016 <http://spacenews.com/maneuvering-russian-satellite-has-everyones-attention/>.

ruary 2014, U.S. defence officials have acknowledged that the satellites will perform their own rendezvous and proximity manoeuvres to allow close-up looks at spacecraft in GEO orbits.[221]

## 5.4 Russia

On 3 August 2015, the Russian government merged its Air Force and its recently-formed Aerospace Defence Forces (VKO) under one unified command structure, representing an evolution in Russian military thinking from an era where its air and space forces existed as separate branches with little overlap in command authority to one where air and space will be treated more as a seamless theatre of war.[222] By 17 November 2015, Russia seemed to have taken a page from the U.S. playbook during the Gulf War, as it involved 10 imagery and electronic warfare reconnaissance satellites, including civilian-use spacecraft, to provide support for its operation against ISIS forces in Syria. Russia's Aerospace Defence Force's strikes in Syria intensified after 31 October 2015, following the ISIS downing of a Russian aircraft that killed 224 people.[223]

Russia launched a second mysterious and potentially threatening space object known as Cosmos 2504 on 31 March 2015 - less than a year after the launch of the 2014-28E spacecraft which began exhibiting unusual behaviour in November 2014 that might be consistent with – but not indicative of – anti-satellite weapons tested by the Soviet Union during the Cold War.[224] By early July 2015, Cosmos 2504 had made at least 11 close approaches to the upper stage that had launched it into orbit, which led to the early deployment of two U.S. GSSAP satellites to observe the activity.[225] Russia's Olimp K satellite (alternatively known as Luch), operated by Russia's Aerospace Defence Forces (ADF), which launched on 27 September 2014, also raised some concerns when it parked into a GEO orbit between two of Intelsat's commercial GEOCOM satellites, Intelsat 7 and Intelsat 901, converging at a distance of 10 km from both spacecraft over a period of 5 months, before relocating near the Intelsat 905 satellite in September 2015. While on-orbit inspection technology is not unusual, the close proximity of the lurking satellite has raised concerns from Intelsat, and likely the U.S. government, as Intelsat has no way of knowing which way to manoeuvre its own satellite to maintain a safe distance without information about Olimp K's planned manoeuvres.[226]

## 5.5 Japan

Concern over China's 2007 direct-ascent anti-satellite weapon test, and subsequent experiments focusing on jamming and laser-blinding satellites, is said to have motivated Japan's shift toward placing security at the forefront of its national space policy.[227] Concern also exists over North Korea which has continued development of long-range ballistic missiles, one of which provocatively overflew Japan dropping its first stage very near Japanese territory in a test conducted in 1998.[228] Japan continued increasing its ties with the U.S. throughout 2015. For instance, in April 2015 the two countries updated their joint defence guidelines for the promotion of "seamless" cooperation, while also calling for an increase in Japan's use of space in support of the U.S.-Japan Security Alliance. And by July 2015, Japan had ended its ban on collective self-defence, allowing it to more readily come to the aid of U.S. in the event of a conflict in East Asian waters.[229]

By 8 December 2015, the U.S. Missile Defense Agency and Japan's Ministry of Defence had conducted a second live-fire test of the new Standard Missile-3 (SM-3) Block IIA mis-

[221] Gruss, Mike. "Space Surveillance Sats Pressed into Early Service." 18 Sept. 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/space-surveillance-sats-pressed-into-early-service/>.
[222] Bodner, Matthew. "Russian Military Merges Air Force and Space Command." 3 Aug. 2015. The Moscow Times 10 July 2016 <http://www.themoscowtimes.com/business/article/russian-military-merges-air-force-and-space-command/526672.html>.
[223] "Russia involves 10 reconnaissance satellites in Syria operation — General Staff." 17 Nov. 2015. TASS 20 Mar. 2016 <http://tass.ru/en/science/837273>.
[224] Ferster, Warren. "General: Russian, Chinese Launches Demonstrate Growing Space Threat." 15 Apr. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/u-s-general-says-russian-chinese-launches-demonstrate-growing-space-threat/>.
[225] Gruss, Mike. "Maneuvering Russian Satellite Has Everyone's Attention." 17 July 2015. SpaceNews 20 Mar. 2016 <http://spacenews.com/maneuvering-russian-satellite-has-everyones-attention/>.
[226] Gruss, Mike. "Russian Luch Satellite Relocates — Next to Another Intelsat Craft." 16 Oct. 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/russian-luch-satellite-relocates-next-to-another-intelsat-craft/>.
[227] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[228] Rose, Frank A. "Commentary | Strategic Stability in U.S.-China Relations." 29 Jan. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/commentary-strategic-stability-in-u-s-china-relations/>.
[229] Kallender-Umezu, Paul. "What's Behind Japan's Sudden Thirst for More Spy Satellites." 13 Nov. 2015. SpaceNews 7 Jan. 2016 <http://spacenews.com/whats-behind-japan-sudden-thirst-for-more-spy-satellites/>.

sile under the Aegis Ballistic Missile Defense program. The test evaluated the missile's performance based on telemetry and other data from the test, and validated the new sensor seeker developed for the redesigned kill vehicle. Its first test took place on 6 June 2015.[230] According to the U.S. Missile Defense Agency, the U.S. has spent $2 billion on the SM-3 IIA programme, along with a contribution of around $1 billion from Japan. In the coming years, the new missile will be deployed on U.S. Aegis destroyers and Japan's Kongo ships.[231]

Spending in defence areas continued to drive increased spending through 2015, amounting to ¥324.5 billion (€2.51 billion) for the fiscal year 2015 (beginning on 1 April 2015 and ending 30 March 2016).[232] About 61% of Japan's Cabinet Office budget of ¥22.3 billion (€172.41 million) has been earmarked for the expansion of the QZSS regional navigation system to an enhanced seven satellite constellation.[233] JAXA also received funding to begin the new development of a laser-optical data relay satellite, an advanced Earth observation satellite carrying a ballistic missile early warning sensor as a hosted payload for Japan's Ministry of Defence, and a new line of multipurpose small satellites capable of rapid production and deployment for a range of missions.[234]

## 5.6 China

China's space defence spending almost doubled between the years 2009 and 2014, growing from an estimated $977 million to $1.91 billion respectively.[235] Yet, a similar observation can be made about its civil space spending, which is estimated to have grown from $1.28 billion to $2.66 billion over that same period.[236] China's overall defence budget was expected to reach about $145 billion in 2015, while one U.S. DoD estimate suggested that its actual defence spending in 2015 could be greater than $175 billion.[237]

China's military space capability has long attracted heightened speculation, as China's space sector has long been intimately connected to the People's Liberation Army (PLA). Yet, China's recent Middle and Long Term Development Plan for State Civil Space Infrastructure (2015-2025) suggests a potential departure from that union, appearing more focussed on enhancing its space capabilities for domestic purposes – particularly in establishing its state civil space infrastructure system, and enhancing its competitiveness.[238]

Nonetheless, some concerns remain about China's military space capabilities following the publication of the U.S. DoD's annual report to Congress on China's military and security developments, and China's publication of its white paper on military strategy shortly afterward. The U.S. Pentagon published its 'Military and Security Developments Involving the People's Republic of China 2015' on 8 May 2015.[239] Among other observations of the development of China's space and counter-space capabilities, including directed-energy weapons and satellite jammers, the report described a launch event conducted on 23 July 2014 that had a similar profile to its January 2007 ASAT test which intercepted a no-longer functioning Chinese weather satellite and created a myriad of space debris. While the 2014 launch did not result in the destruction of a satellite or creation of space debris, it does follow on the heels of another disturbing launch that was conducted on 13 May 2013. The ballistic trajectory of that earlier launch had its apex at an altitude above 30,000 km, i.e. near GEO orbit where numerous communication and Earth observation satellites are stationed; yet the rocket

[230] "US, Japan Test Advanced SM-3 Missile for Aegis System - US Navy." 10 Dec. 2015. Sputnik News 21 Jan. 2016 <http://sputniknews.com/military/20151210/1031509097/us-japan-aegis.html>.
[231] Shalal, Andrea. "U.S.-Japan funded Raytheon SM-3 missile aces second test: Pentagon." 8 Dec. 2015. Reuters 21 Jan. 2016 <http://www.reuters.com/article/us-usa-japan-missile-defense-idUSKBN0TR2V320151209>.
[232] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[233] Rajagopalan, Rajeswari Pillai. "Op-ed | Japan's Space Policy Shift Reflects New Asian Realities." 23 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/op-ed-japans-space-policy-shift-reflects-new-asian-realities/>.
[234] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[235] Profiles of Government Space Programs. Paris: Euroconsult, 2015: 16.
[236] Profiles of Government Space Programs. Paris: Euroconsult, 2015: 14.
[237] Fisher, Richard D. Jr. "China's Rising Defense Budgets Stoke Regional Concerns." 8 Jan. 2015. Aviation Week & Space Technology 12 June 2015 <http://aviationweek.com/defense/china-s-rising-defense-budgets-stoke-regional-concerns>.
[238] Google Translated.
"关于印发国家民用空间基础设施中长期发展规划(2015-2025年)的通知." 26 Oct. 2015. National Development and Reform Commission 2 Feb. 2016 <http://www.sdpc.gov.cn/zcfb/zcfbghwb/201510/t20151029_756376.html>.
[239] "Office of the Secretary of Defense. "Annual Report to Congress - Military and Security Developments Involving the People's Republic of China 2015." 8 May 2015. Defense.gov 2 Feb 2016 <http://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf>.

was not on the appropriate trajectory to place objects in orbit and no new satellites were released.[240]

In rebuttal, China's Ministry of National Defence (MOD) released a white paper on China's Military Strategy on 26 May 2015.[241] In the narrative of its national security situation, an initial concern points to the provocative actions of the U.S. and other offshore neighbours, which in China's view have illegally reinforced their military presence on its reefs and islands in the South China Sea, in addition to maintaining constant close-in air and sea surveillance and reconnaissance against China.[242] In response to that perceived encroachment, the white paper outlines China's strategic guideline of active defence, along with modernizing its military to adapt to new changes in its maritime security environment.[243] And in terms of military space and counter-space activities, aside from a paragraph indicating that China will strengthen its capabilities for strategic deterrence and nuclear counterattack, and medium- and long-range precision strikes, it later goes on to say that "China will keep abreast of the dynamics of outer space, deal with security threats and challenges in that domain, and secure its space assets to serve its national economic and social development, and maintain outer space security".[244]

## 5.7 India

India is developing its own space military programme; however, the majority of the activities of the Indian Space Research Organization (ISRO) still focus on civil applications.

On 22 November 2015, India's Defence Research Development Organization (DRDO) conducted a validation test of its Advanced Air Defence (AAD) missile. Having undergone trials since 2007, this latest test focussed on the kill effect of the AAD in flight mode by analysing data from multiple tracking sources. The AAD, along with the Prithvi Air Defense (PAD) missile, which had its first test launch on 27 April 2014, are both part of the first phase of India's Ballistic Missile Defence (BMD) Initiative. While the AAD system is optimised for surface-to-air strikes against aircraft and UAVs, the PAD provides exoatmospheric defence; however, a full-scale BMD system would incorporate technology from both the PAD and AAD systems.[245]

India's PAD can also be seen as a further step toward developing its own anti-satellite capabilities. In this pursuit, the DRDO is looking at the feasibility of developing such an anti-satellite vehicle by integrating its Angi-3 missile with its PAD. If it succeeds, the anti-satellite missile would have an effective range of about 1400-1500 km, and would advance India's missile capabilities to be on a par with U.S. and China.[246]

[240] "Office of the Secretary of Defense. "Annual Report to Congress - Military and Security Developments Involving the People's Republic of China 2015." 8 May 2015. Defense.gov 2 Feb 2016: 14 <http://www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf>.

[241] Minnick, Wendell. "White Paper Outlines China's Ambitions." 27 May 2015. Defense News 22 Jan. 2016 <http://www.defensenews.com/story/defense/policy-budget/warfare/2015/05/26/china-us-pentagon-taiwan-report-south-east-sea-islands-reefs-s400-su35-missiles-satellite-space-deterrence/27957131/>; *see also* "China's Military Strategy." 26 May 2015. Ministry of National Defense – The People's Republic of China 3 Feb. 2016 <http://eng.mod.gov.cn/Database/WhitePapers/index.htm>.

[242] "I. National Security Situation." 26 May 2015 Ministry of National Defense – The People's Republic of China 3 Feb. 2016 <http://eng.mod.gov.cn/Database/WhitePapers/2015-05/26/content_4586688.htm>.

[243] "III. Strategic Guideline of Active Defense." 26 May 2015 Ministry of National Defense – The People's Republic of China 3 Feb. 2016 <http://eng.mod.gov.cn/Database/WhitePapers/2015-05/26/content_4586711.htm>.

[244] "IV. Building and Development of China's Armed Forces." 26 May 2015 Ministry of National Defense – The People's Republic of China 3 Feb. 2016 <http://eng.mod.gov.cn/Database/WhitePapers/2015-05/26/content_4586713.htm>.

[245] Panda, Ankit. "India Tests Supersonic Advanced Air Defense Missile." 23 Nov. 2015. The Diplomat 10 July 2016 <http://thediplomat.com/2015/11/india-tests-supersonic-advanced-air-defense-missile/>.

[246] "India Contemplates Anti-Satellite Vehicle Integration with Agni-III Ballistic Missile." 15 Oct. 2013. Missile Threat 12 May 2014 <http://missilethreat.com/india-contemplates-anti-satellite-vehicle-integration-with-agni-iii-ballistic-missile/>.

# 6. Space Policies and Strategies around the World

The following chapter presents an overview and analysis of the space policies of all major space-faring countries. Attention is particularly given to high-level policy developments and general trends that reveal the different actors' strategic rationales. Military space and defence related policies were considered in more detail in Chapter Five.

## 6.1 European Union

In regard to the EU's Copernicus programme, the status of the €500 million European Data Relay Satellite (EDRS) programme continued to be in doubt at the beginning of 2015 because of ongoing concerns about its business prospects. The programme was initiated in November 2008 as a PPP between ESA and Airbus Defence & Space to create a global optical satellite data relay service for civil and military users. The delay in development stemmed both from ESA taking longer than expected to validate EDRS technology and sign a broad Copernicus agreement with the EU, and by the initial resistance from the European Commission to commit to a Service Level Agreement (SLA) that was negotiated between ESA and Airbus D&S and presented to the Commission shortly before the contract's 22 December 2014 deadline.[247] Expected to be included within the EU's Copernicus arrangement with ESA, the SLA assumed that the European Commission would be EDRS's anchor customer, providing €20 million per year for five years. However, as at 28 January 2015 the Commission seemed willing to provide closer to €12 million per year for five years for the service. By 20 February 2015, the European Commission, ESA and Airbus D&S reached an agreement on the funding and management of the EDRS programme. While the specific commitments of the agreement were not made public, the European Commission had agreed to spend a little less than €100 million for the 2015-2020 period, with funds going toward the development of EDRS ground infrastructure and for data service. Moreover, the EDRS agreement included the formation of a joint ESA-EU-Airbus steering committee to provide all parties with more oversight over the EDRS programme.[248]

With the SLA finally secured, Airbus D&S will invest €130 million of its own money into the EDRS programme. With the European Commission now vested as EDRS's anchor customer, Airbus would then commercialize the service to civil and military users worldwide. Here, the U.S. DoD seems likely to be a prospective customer, especially following the signing of a U.S. and EU cooperation arrangement on Copernicus Earth observation data on 19 October 2015, and following U.S. and German negotiations on allocating satellite spectrum for UAVs crossing over the Atlantic that were in discussion at the ITU's WRC-15 meeting held in Geneva, Switzerland from 2 to 27 November 2015.[249]

On 16 June 2015, during the Paris Air Show, France, Germany, Italy, Spain and Britain agreed to make available their existing optical and radar tracking telescopes for use in the European Union's Space Surveillance and Tracking Framework. The EU initially approved the Framework programme in 2014, and has budgeted €70 million between 2015 and 2020. The EU programme extends beyond activities conducted by ESA in space tracking, which mainly focus on near Earth objects and space weather, to also include a military element. Moreover, part of the EU's aim is to reduce dependence on the U.S. Space Surveillance Network in tracking orbital objects to monitor and protect its two space flagship programmes Galileo and Copernicus. The five nation consortium supplying the assets on behalf of the EU will also create a Security Committee to determine who will have access to space surveillance

[247] De Selding, Peter B. "Data-relay Project Exemplifies Uneasy Relationship Between European Commission and ESA." 30 Jan. 2015. SpaceNews 8 Jan. 2016 <http://spacenews.com/data-relay-project-exemplifies-uneasy-relationship-between-european-commission-and-esa/>.

[248] "European Data Relay System confirms services for Copernicus in cooperation with the European Commission." 25 Feb. 2015. ESA 28 Jan. 2016 <http://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/European_Data_Relay_System_confirms_services_for_Copernicus_in_cooperation_with_the_European_Commission>.

[249] "Deal on using satellites for global flight-tracking in sight: US." 9 DefenceTalk.com 10 Jan. 2016 <http://www.defencetalk.com/deal-on-using-satellites-for-global-flight-tracking-in-sight-us-65777/>.

data together with the EU Satellite Centre (EUSC). The division of the €70 million among the consortium partners still needs to be determined.[250]

## 6.2 European Space Agency

ESA's budget increased by 8% in 2015, reaching €4.433 billion from €4.102 billion in 2014. Direct funding from ESA member states decreased by 2.9% to €3.241 billion, while funding from the EU and Eumetsat grew by 56.2% to €1.191 billion for the year.[251] While much attention leading up to 2015 was on ESA's long-term launch vehicle programme, funding for launchers changed only marginally for 2015 - intended for the upkeep of the Ariane 5 launcher and the current Vega launcher. Funding for the new Ariane 6 launcher and an upgraded Vega launcher is expected to increase in the coming years. In contrast, funding for Earth observation increased by 28.3% to €1254.3 billion, while Navigation had a 15.0% increase to €664.5 million with much of that funding coming from the EU's Copernicus and Galileo Flagship programmes. Moreover, in December 2014, the European Commission agreed to procure six new replacement satellites for the Copernicus programme (i.e. Sentinel 1, Sentinel 2, and Sentinel 3). Those satellites will be identical to their predecessors, and will assure data continuity well into the 2030s.

The year 2015 also marked the end of ESA's Automated Transfer Vehicle (ATV) programme, after its fifth and last ATV Georges Lemaître departed the International Space Station (ISS) on 15 February 2015. Funding for the ISS for the period between 2015 and 2017 was decided at the 2014 ESA Ministerial Council meeting, which allocated €800 million from ten of its participating member governments (Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden and Switzerland) to cover ISS costs during that time. ESA is expected to continue its contribution to the ISS from 2018 until 2020 by providing an ATV-derived service module for NASA's crewed Orion spacecraft. However the fate of Europe's contribution to the ISS after 2020 was left open, as ESA's new Director General (DG) Johann-Dietrich "Jan" Woerner began to set the Agency's sights on developing an international Moon Village by 2030.[252]

The ESA's focus will centre on the following areas: space applications; science and exploration; transportation; space technology and operations; and administration. While the ESA statement did not clarify how the new organisation would become more efficient and reduce bureaucracy, the reorganization and five focus areas are meant to bring the agency closer to the goal of developing a "United Space in Europe through ESA." Yet in order to reach that goal, ESA – with its growing membership – will need to reassess its geo-return policy, which guarantees that 90% of a member state's ESA investment will return in the form of industry contracts, in addition to ESA's one member-one vote policy, wherein all ESA members have an equal say regardless of the disparity/magnitude of their investment.[253]

Following the substantial schedule delays and cost overruns experienced in developing new lidar technologies, ESA changed its contracting procedures for better coordination of instrument availability and full programme funding. The new procedures will stagger an award for the development of an unproven instrument from the contract award for the overall programme, which should permit advanced technologies to be developed to a sufficient Technology Readiness Level (TRL) to be ready to place on an intended mission platform. ESA's Atmospheric Dynamics Mission (ADM)-Aeolus, and its EarthCare satellite are the latest examples of why such a financing arrangement was needed. Development of ADM-Aeolus began in 2003 with an intended launch in 2007, while development of EarthCare began in 2008 with a launch intended for 2013. Delayed development of the lidar instruments pushed back the launch schedule for both satellites to sometime in 2017 and 2018 respectively. In funding the development of new technologies, ESA would like to see the results of full-model tests in a vacuum before beginning work on the rest of the mission. It plans to also use non-fixed price contracts, and to make additional fund-

[250] Henry, Caleb. "Five European Countries Sign Space Surveillance and Tracking Agreement." 17 June 2015. Via Satellite 22 Dec. 2015 <http://www.satellitetoday.com/regional/2015/06/17/five-european-countries-sign-space-surveillance-and-tracking-agreement/>.

[251] "ESA Budget 2015 by Domain. 15 Jan. 2015. ESA 4 Mar. 2016 <http://www.esa.int/spaceinimages/Images/2015/01/ESA_Budget_2015_by_domain>.

[252] David, Leonard. "Lunar Leap: Europe Is Reaching for a Moon Base by the 2030s." 30 Dec. 2015. Space.com 27 June 2016 <http://www.space.com/31488-european-moon-base-2030s.html>.

[253] De Selding, Peter B. "Tough Sledding for Proposed ESA Reorganization." 27 July 2015. SpaceNews 23 Dec. 2015 <http://spacenews.com/tough-sledding-for-proposed-esa-reorganization/>.

ing available if technology roadblocks are encountered.[254]

And as ESA's ties with China have grown throughout the year, with the ESA actively working on eventually placing a European astronaut on China's space station by its completion in 2022. While no specific plans have been made for an ESA astronaut mission, ESA astronauts have visited China's astronaut facilities, while some have begun learning to speak Chinese in collaboration with China's Manned Space Flight Office.[255] As the year progressed, it was increasingly realised by European stakeholders that China's inclusion in the global space exploration endeavour would be an asset. Chinese officials echoed those sentiments, inviting international participation in the form of foreign modules on its space station, along with foreign cargo and crewed visits, at the 66th IAC held on 12-16 October 2015 in Jerusalem, Israel. Europe and Russia have each already signed initial space station cooperation agreements with China.[256] Yet, an open question remains as to whether China's space station will use the same international docking system standard used by Europe and the U.S. on the ISS, or whether a docking adapter will be needed.

## 6.3 EUMETSAT

The European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) is an intergovernmental organisation that supplies weather and climate-related satellite data to the National Meteorological Services of its Member and Cooperating States in Europe, and other users worldwide. Eumetsat's 83rd council meeting took place in Darmstadt, Germany, on 23 and 24 June 2015. At that meeting, the council successfully concluded the approval process for the Eumetsat Polar System Second Generation (EPS-SG) programme securing the commitment of all 30 member states; the meeting also made progress in the approval process for the Jason Continuity of Service (Jason-CS) optional programme, achieving 77.83% of the financial envelope from participating states.[257] By the 84th council meeting in Darmstadt, Germany, held on 2 December 2015, the financial envelope for the Jason-CS optional programme had increased to 93.07% with the inclusion of Norway as the 13th participating state[258]; the programme had entered into force on 9 September 2015 following subscriptions from 12 participating states (Austria, France, Germany, Iceland, Italy, Luxembourg, The Netherlands, Portugal, Sweden, Switzerland, Turkey, and the United Kingdom).[259] Also at the 84th meeting, Eumetsat and the U.S. National Oceanic and Atmospheric Administration (NOAA) signed an agreement to establish and operate their Joint Polar System (JPS), which will consist of Eumetsat's Metop-Second Generation (Metop-SG) satellites, NOAA's JPSS satellites and shared ground systems and services in the period from 2020 to 2040.[260]

Eumetsat's current Metop program consists of three identical satellites launched at six-year intervals between 2006 and 2018, with operations running until 2023. The first polar-orbiting meteorological satellite, Metop-A was launched on 19 October 2006; it was joined by the successful launch of Metop-B on 17 September 2012, which orbits in tandem with Metop-A. The third identical Metop satellite, Metop-C, is expected to launch in October 2018.[261] The entire cost of the Metop program (including development of the three satellites, their launches and the related ground infrastructure) has reached €3.2 billion (at 2011 prices), with Eumetsat covering 75% of the cost, and ESA covering the rest.[262]

[254] "Cost, Schedule Woes on 2 Lidar Missions Push ESA To Change Contract Procedures." 22 May 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/cost-schedule-woes-on-2-lidar-missions-push-esa-to-change-contract-procedures/>.

[255] Clark, Stephen. "Europe, China issue call for joint science mission." 24 Jan. 2015. Spaceflight Now 14 Jan. 2016 <https://spaceflightnow.com/2015/01/24/europe-china-issue-call-for-joint-science-mission/>.

[256] Messier, Doug. "China Looks for Help Building Space Station; NASA is Outsider Looking In." 13 Oct. 2015. Parabolic Ark 11 Jan. 2016 <http://www.parabolicarc.com/2015/10/13/china-building-space-station-nasa-outsider/>.

[257] "EUMETSAT Council concludes the approval of the EPS Second Generation programme and achieves progress on Jason-CS." 24 June 2015. Eumetsat 1 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2681070.html?lang=EN&pState=1>.

[258] "Council takes steps to implement the EPS-SG and Jason-CS programmes." 3 Dec. 2015. Eumetsat 1 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2868481.html?lang=EN&pState=1>.

[259] "Jason-CS Programme enters into force – two months ahead of COP 21." 11 Sept. 2015. Eumetsat 1 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2779482.html?lang=EN&pState=1>.

[260] "EUMETSAT and NOAA sign agreement on Joint Polar System." 2 Dec. 2015. Eumetsat 1 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2867890.html?lang=EN&pState=1>.

[261] "METOP." Eumetsat 1 June 2016 <http://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Metop/index.html>.

[262] "European Weather Satellite Launched after 4-Month Delay." 27 Sept. 2012. SpaceNews 28 Apr. 2014 <http://spacenews.com/article/european-weather-satellite-launched-after-4-month-delay>.

The Metop Second Generation (Metop-SG) is the space segment of Eumetsat's Polar System of Second Generation. On 5 October 2015, Eumetsat and ESA signed a cooperation agreement that secures the development of the six-satellite Metop-SG system. The entire program is budgeted at about €4.1 billion, with Eumetsat contributing about 80% of the budget, while ESA will cover the rest; the satellites are intended to operate between 2021 and around 2042. ESA will develop the Metop-SG satellites according to user and system requirements as defined by Eumetsat and is responsible for the procurement of the recurrent satellites on Eumetsat's behalf, while Eumetsat will procure all launch services and develop the ground control systems, in addition to acquiring and processing their data, and delivering products and services to users in response to their evolving needs.[263] The Metop-SG satellites will operate in 3 pairs, each carrying a different but complementary suite of instruments, and will be manufactured by Airbus Defence and Space under a €1.32 billion contract signed on 16 October 2014.

The Meteosat Third Generation (MTG) system is a series of sounding and imaging satellites in geostationary orbit, being developed by France's Thales Alenia Space and Germany's OHB AG, and is aimed at providing services for the 2020 to 2040 timeframe. On 24 July 2015, the Eumetsat Council approved the contract with Arianespace for the launches of the first three MTG satellites (the MTG-I1, MTG-S1, and one option for MTG–I2).[264] The satellites are scheduled to be launched to GEO orbit within the 2019-2023 timeframe, and will operate from 2020 to 2040.[265]

Eumetsat's existing Meteosat programme, consisting of both Meteosat First Generation (MFG) and the Meteosat Second Generation (MSG) satellites operating in geostationary orbit over Europe and Africa, added the MSG-4 to its MSG programme on 15 July 2015. Upon the successful conclusion of the MSG-4's commissioning phase by Eumetsat, the spacecraft will be renamed Meteosat-11 and will be placed into in-orbit storage for 2.5 years, meant for use prior to the deployment of Eumetsat's MTG system.[266] The MSG programme has three other satellites in operation, Meteosat -8 to -10, which are expected to end service in 2019, 2021, and 2022 respectively.

Additionally, Eumetsat's Meteosat-7, the last of the Meteosat First Generation (MFG) satellites, continued to operate throughout 2015, providing imaging and data collection service coverage over the Indian Ocean. Having been in operation since September 1997, and positioned in GEO above the Indian Ocean in July 2006, the spacecraft is expected to reach the end of its life in 2017.[267] With no replacement spacecraft expected, concerns about a gap in weather coverage have been expressed by the U.S. DoD which uses Meteosat-7 data for cloud characterization and weather imagery over the war-wracked region, both essential for maintaining battlespace awareness.[268] The primary role of the Meteosat satellites is to help detect and forecast rapidly developing high impact weather, including thunderstorms, volcanic ash, and fog, up to six hours ahead through continuous monitoring.[269]

## 6.4 National Governments

### 6.4.1 France

On 5 January 2015, the French space agency (CNES) announced that it had begun a small technology research programme with Germany and other ESA governments to develop the technology needed for a reusable rocket stage.[270] CNES had paused on the idea of reusability a decade ago, after a joint-study with Russia revealed that a first stage

[263] "EUMETSAT and ESA sign cooperation agreement on Metop-SG satellites." 5 Oct. 2015. Eumetsat 1 June 2015 <http://www.eumetsat.int/website/home/News/DAT_2804093.html?lang=EN&pState=1>.

[264] "EUMETSAT and Arianespace announce signature of launch contract for three MTG satellites." 16 July 2015. Eumetsat 3 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2703454.html?lang=EN&pState=1>.

[265] Henry, Caleb. "Arianespace Wins Fresh Eumetsat Contract After MSG 4 Launch." 16 July 2015. Via Satellite 3 June 2016 <http://www.satellitetoday.com/launch/2015/07/16/arianespace-wins-fresh-eumetsat-contract-after-msg-4-launch/>.

[266] "MSG-4 successfully launched." 16 July 2015. Eumetsat 3 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2696903.html?lang=EN&pState=1>.

[267] "Meteosat-7 becomes EUMETSAT's longest-serving operational satellite." 23 Jan. 2015. Eumetsat 3 June 2016 <http://www.eumetsat.int/website/home/News/DAT_2526201.html?lang=EN&pState=1>.

[268] Gruss, Mike. "U.S. Military Faces Weather Coverage Gap over Hot Zones." 13 Mar. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/u-s-central-command-faces-weather-coverage-gap-over-hot-zones/>.

[269] "There are two generations of active Meteosat satellites, Meteosat First Generation (MFG) and Meteosat Second Generation (MSG), providing images of the full Earth disc, and data for weather...." Eumetsat 30 May 2014 <http://www.eumetsat.int/website/home/Satellites/CurrentSatellites/Meteosat/index.html>.

[270] Todd, David. "CNES announces work with Germany on LOx/Methane reusable first stages." 6 Jan. 2015. Seradata,com 30 Dec. 2015 <http://seradata.com/SSI/2015/01/cnes-announces-work-with-germany-on-loxmethane-reusable-first-stages/>.

launcher would need a rhythm of 40 launches per year to bring a return on the investment.[271] That rhythm estimate has since been reduced to 30 per year to complete the business case, as it would also include the cost of return and refurbishment, smaller economies of scale, and therefore higher per unit costs.[272] With interest reignited in light of the progress made by SpaceX's Falcon 9 launcher, CNES, DLR and ESA could use their collective experience in reusability technology to produce a consensus on a future technology roadmap, and hopefully conduct a technology demonstration after 2026. By October 2015, CNES and France's ONERA aerospace research institute announced that they had begun studies on digital aerothermodynamic simulations, but would decide on further deepening collaboration in 2016.

In contrast to CNES' aim to return an entire stage to Earth for reuse, on 5 June 2015, Airbus Defence & Space revealed its own design for a reusable first-stage engine and avionics package intended for a next generation Ariane rocket. Named Adeline (or Advanced Expendable Launcher with Innovative engine Economy), the design was said to have resolved issues related to an engine's exposure to high speed stresses experienced when descending through the atmosphere before landing back on Earth. The Airbus design simplifies that used by SpaceX by separating the propulsion bay (accounting for up to 80% of a rocket's cost) from the rest of the stage, protecting only the motor on re-entry, and returning horizontally on a conventional airstrip using winglets and turbofans. Over the course of five years, Airbus has invested €5 million in the design, but it would require substantial government support if it is needed by 2025.[273] While the Adeline is a proposal for the planned two-stage Ariane 6 launcher, its liquid fuelled engine could also be used with other rockets.

### 6.4.2 Germany

On 8 December 2015, German and French officials at the COP21 meeting in Paris reaffirmed a joint commitment to develop the "Merlin" greenhouse gas monitoring satellite. In the wake of the financial crisis of 2007, the project that was originally endorsed in 2010 had been shelved by the 2 countries for financial reasons, and because the satellite's lidar technology still needed to be developed. The methane monitoring satellite is aimed to be a globally recognised system to verify government commitments to reducing greenhouse gas emissions. The system is expected to cost €250 million ($266 million) covering the satellite's construction and launch, in addition to the associated infrastructure and 3 years of operations. Germany's €150 million contribution to the Merlin programme will go mainly toward the development of the lidar instrument, while France's €100 million will be put toward the development of a next generation Myriade satellite platform and its ground segment. Completion of the satellite is expected sometime in 2019.[274]

### 6.4.3 Italy

Italy's Avio SpA, the industrial prime contractor for the Vega launcher, was in search of a new strategic owner in 2015, as its current 81% majority stakeholder, Cinven sought to sell its shares in the launcher. Italy's Finmeccanica owns a 14% share in Avio, while the remaining 5% share belonged to Avio's company management. The newly established Airbus Safran Launchers (ASL) had its eye on acquiring the company to have Vega join its Ariane 5 and 6 launchers being developed under the Arianespace launch consortium but officials in the Italian government and its industry preferred to keep Avio under Italian control. Those stakeholders would likely welcome a takeover bid by Finmeccanica, provided it meets Cinven's transaction requirements. The Vega launcher is delivered by Avio to Arianespace under a joint venture with the Italian Space Agency (ASI) called ELV SpA (Avio has a 70% stake in ELV, while ASI holds the remaining 30% share). As in the case of the French government selling its shares in Arianespace to ASL to provide industry with more control, one scenario being discussed is whether ASI should sell its share in the ELV joint venture to ASL as well, thereby keeping Avio Italian owned, while attaining market balance among companies in Europe's launch sector.[275]

[271] Messier, Doug. "Europe Eyes Reusable Rockets." 6 Jan. 2015. Parabolic Arc 30 Dec. 2015 <http://www.parabolicarc.com/2015/01/06/europe-eyes-reusable-rockets/>.
[272] De Selding, Peter B. "With Revenue Looking Up, Arianespace Seeks To Bring Ariane 5 Costs Down." 21 Oct. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/with-revenue-looking-up-arianespace-seeks-to-bring-ariane-5-costs-down/>.
[273] Coppinger, Rob. "Airbus' Adeline Project Aims to Build Reusable Rockets and Space Tugs." 10 June 2015. Space.com 5 Jan. 2016 <http://www.space.com/29620-airbus-adeline-reusable-rocket-space-tug.html>.
[274] "Satellites key to monitoring harmful emissions: space agencies." 3 Apr. 2016. Phys.org 15 June 2016 <http://phys.org/news/2016-04-satellites-key-emissions-space-agencies.html>.
[275] Dragoni, Gianni. "Avio, producer of space launchers, is the most courted Italian company at the Paris Air Show." 19 June 2015. ItalyEurope24 5 Jan. 2016 <http://www.italy24.ilsole24ore.com/art/business-and-economy/2015-06-18/le-bourget-133952.php>.

Relatedly, on 12 August 2015, ESA signed a €395 million contract with ELV and ASI to develop the upgraded Vega-C rocket, which includes the cost of the launcher's inaugural flight in 2018.[276] Moreover, €225 million will be dedicated to developing Vega's P120 first stage engine; and will also serve as a strap-on booster for the Ariane 6 launcher, in its 62 and 64 configurations. ELV aims to build a production facility capable of manufacturing 4 Vega launchers per year, along with an additional 31 P120 stages per year for the Ariane 6 launcher.

### 6.4.4 United Kingdom

Effective as of 1 October 2015, the UK Outer Space Act limited the liability of UK-licenced satellite operators to €60 million depending on the results of a risk analysis performed for each new license application; higher-risk missions may expect to be liable for a higher amount. The move was made to encourage growth in Britain's commercial space sector, and to put the United Kingdom's requirements in line with other spacefaring nations. Operators with existing licenses may also apply for the liability cap for their licenses by submitting a formal request to the UK Space Agency, but that option is for now available only to domestic licenses, not including British dependencies and overseas territories. The new policy does not affect the UK's additional requirement for operators to also purchase €60 million in third party liability insurance as a licence requirement regardless of the use of the satellite.[277]

Yet while the UK stands out in Europe for its commercial focus and development in the space sector, it might need to loosen its third party liability insurance requirement on licence applicants even more if it aims to be more competitive with the United States. Even with recent policy changes geared to provide more incentive for small satellite developers by not charging fees for licence applications, and capping the amount of third party insurance needed to a slightly lower amount, those actions may not be enough to kick start its small satellite space sector. For instance, regardless of the size of a satellite being registered in the UK, its owner would likely have to pay an annual premium of about 1%, or €600,000 each year on third party liability insurance. In the case of small satellite makers, that requirement may be still too prohibitive for start-up companies whose total budgets might be about the same size as the amount needed to be paid in additional insurance.[278] By contrast, the cost of licensing a satellite in the U.S. depending on the category might be anywhere from $0 for amateur satellites, to $60 for experimental, to $430,000 for an operational satellite. And aside from requiring third party liability insurance for the 30 days following launch of a payload, or 30 days following the initiation of re-entry, the U.S. has no third-party liability insurance requirement for a satellite's on-orbit activities.[279] Here, as can be seen in recent years, small satellite makers seem to be drawn to this arrangement, as the most popular categories of small satellites have been either amateur or experimental.

The United Kingdom is also getting closer to determining where to build a spaceport to mainly conduct suborbital launch activities. On 3 March 2015, the British government, its UK Space Agency, and other agencies issued a joint public statement on the outcome of a consultation prepared by the UK's Civil Aviation Authority (CAA) on criteria for a commercial spaceport. Having reviewed the eight potential sites that were recommended by the report, the government reduced the list to six after receiving feedback from industry, government, and public stakeholders. The potential sites vary from military airfields to smaller commercial airports, with a majority of options located in Scotland. Four of the six sites are located in Scotland, while one is in Wales, and the other one is in England. The next step in the spaceport's development is for the British government's Department for Transport to publish detailed technical specifications of spaceport requirements, with a particular focus on suborbital vehicles and/or air launch systems that take off on runways.[280]

[276] Clark, Stephen. "Launcher contracts signify shift in Europe's rocket industry." 18 Aug. 2015. Spaceflight Now 13 Jan. 2016 <https://spaceflightnow.com/2015/08/18/launcher-contracts-signify-shift-in-europes-rocket-industry/>.

[277] "SFN announces €60m cap on unlimited indemnity in the UK Outer Space Act." 23 July 2015. UKSpace.org 23 Dec. 2015 <http://www.ukspace.org/news-item/sfn-announces-e60m-cap-on-unlimited-indemnity-in-the-uk-outer-space-act/>.

[278] Wheeler, Joanne. "Competing for Space Business - Level Playing Fields." 20 Aug. 2015. Via Satellite 13 Jan. 2016 <http://interactive.satellitetoday.com/competing-for-space-business-level-playing-fields/>.

[279] *See* 14 C.F.R. §§ 440.9, 440.11, 440.12 (2014); *See also*, Schaefer, Matthew. "The Need for Federal Preemption and International Negotiations Regarding Liability Caps and Waivers of Liability in the U.S. Commercial Space Industry." Berkeley Journal of International Law 33.1.8 (2015): 223-273 <http://scholarship.law.berkeley.edu/bjil/vol33/iss1/8>.

[280] Foust, Jeff. "British Government Narrows List of Potential Spaceport Sites." 3 Mar. 2015. SpaceNews 14 Dec. 2015 <http://spacenews.com/british-government-narrows-list-of-potential-spaceport-sites/>.

## 6.5 United States of America

On 16 December 2015, the U.S. Congress approved the National Defense Authorization Act for 2016 (NDAA-16) which lifted the ban on the Russian-built RD-180 engine that was enacted in the previous year's NDAA. Amid continuing tensions between the U.S. and Russia following Russia's 2014 incursion in Ukraine, the act prohibited U.S. companies from contracting with Russian suppliers of rocket engines or renewing current contracts for space launch activities.[281] The act directly affected United Launch Alliance (ULA) that has had the U.S. government launch services market to itself since its formation in 2006 but now faces increasing competition from SpaceX. Since ULA uses RD-180 engines for the first stage of its Atlas 5 launcher, the restriction limited its use before ULA's follow-on Vulcan launcher - powered by Blue Origin's BE-4 engine - is ready in 2020. While ULA was granted an exemption of 5 RD-180 engines that were already on order at the time of the law's enactment, in addition to a batch of 29 RD-180 engines that were ordered while the NDAA-15 was still pending[282], it needed access to at least 13 more RD-180 engines in order to remain competitive with SpaceX.[283] By 23 December 2015, ULA had ordered 20 more RD-180 engines, in addition to the 29 RD-180 engines it had ordered before Russia's annexation of Crimea from Ukraine.[284] The reversal had mixed responses in the Senate Armed Services Committee, with some considering whether to place a complete and indefinite restriction on RD-180 engines in the NDAA for 2017. The NDAA-16 also provided $143 million in addition to the $84 million requested by the US Air Force to accelerate the development of a U.S. made replacement engine expected to be ready to fly by 2019.[285]

On 25 November 2015, U.S. President Obama signed into law the U.S. Commercial Space Launch Competitiveness Act (CSLCA) of 2015.[286] The CSLCA is the final version of a bill that reconciled a Senate promoted bill by the same name approved in August 2015 with the House bill known as the Spurring Private Aerospace Competitiveness and Entrepreneurship (SPACE) Act that was approved in May 2015.[287] The CSLCA is bound to have reverberating effects on the domestic U.S. space industry, in addition to the global space community, as it brings into question whether the act contravenes international space law treaties in recognising asteroid mining property rights for private commercial actors. The CSLCA also extends federal indemnification of commercial launches for third-party damages, and extends a restriction on the Federal Aviation Administration's (FAA) ability to enact safety regulations for people flying on commercial spacecraft. Moreover, the CSLCA also extends the operation and utilisation of the International Space Station (ISS), introduces a new type of astronaut, and seeks to identify appropriate oversight for the commercial development of space, and to streamline the FAA launch license process. Relatedly, from a previous estimate of the Senate's precursor to the bill, its implementation is likely to cost less than $500,000 over the 2016 to 2020 period, but it will jump to upwards of $14.3 billion between 2020 and 2025, assuming appropriation of the necessary funds.[288]

The most surprising development of the CSLCA concerns the inclusion of a 'groundbreaking' bill that permits prospecting and development of space resources. Intended to create more certainty and clarity for current and future U.S. investors in this burgeoning industry, Title IV of the CSLCA, on Space Resource Exploration and Utilization, promotes the right of U.S. citizens and companies to engage in commercial exploration and commercial recovery of space resources free from harmful interference. With regard to resource rights, the CSLCA grants commercial U.S. prospectors an entitlement to any asteroid resource or space resource obtained, including "to possess, own, transport, use,

[281] Section 1608. Carl Leven and Howard P. "Buck" McKeon National Defense Authorization Act for Fiscal Year 2015, Pub. L. no 113-291 (2014) <http://www.gpo.gov/fdsys/pkg/CPRT-113HPRT92738/pdf/CPRT-113HPRT92738.pdf>.
[282] Gruss, Mike. "House-Senate Conference Measure To End Pentagon Use of RD-180." 5 Dec. 2014. SpaceNews 22 July 2015 <http://spacenews.com/42701house-senate-conference-measure-to-end-pentagon-use-of-rd-180/>.
[283] Ferster, Warren. "Defense Bill Curbs ULA Use of Russian Engines but Draws Veto Threat." 30 Sept. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/defense-bill-limits-ula-to-9-more-russian-built-engines/>.
[284] Shalal, Andrea. "ULA Orders 20 More RD-180 Rocket Engines." 23 Dec. 2015. SpaceNews 14 Jan. 2016 <http://spacenews.com/ula-orders-20-more-rd-180-rocket-engines/>.
[285] Gruss, Mike. "Spending Bill Lifts RD-180 Ban, Puts ULA Back in Competitive Game." 16 Dec. 2015. SpaceNews 7 Jan. 2016 <http://spacenews.com/spending-bill-lifts-rd-180-ban-puts-ula-back-in-competitive-game/>.
[286] "President Obama Signs Bill Recognizing Asteroid Resource Property Rights into Law." 25 Nov. 2015. Planetary Resources 26 Nov. 2015 <http://www.planetaryresources.com/2015/11/president-obama-signs-bill-recognizing-asteroid-resource-property-rights-into-law/>.
[287] Foust, Jeff. "U.S. Senate Passes Compromise Commercial Space Bill." 11 Nov. 2015. SpaceNews 26 Nov. 2015 <http://spacenews.com/u-s-senate-passes-compromise-commercial-space-bill/>.
[288] "S. 1297, U.S. Commercial Space Launch Competitiveness Act." 17 June 2015. Congressional Budget Office 26 Nov. 2015 <https://www.cbo.gov/publication/50323>.

and sell the resource obtained". Aside from the extracted resources, the CSLCA makes sure to disclaim that the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body.[289] However, the U.S. interpretation of Articles I, II, and VI of the international Outer Space Treaty[290] is likely to draw a substantial rebuff from some members within the international community that might view the U.S. asteroid mining property rights for private commercial actors as a violation of international law.

A more domestically-contentious issue in the lead-up to the CSLCA focussed on the duration of third-party launch indemnification. Originally introduced in 1988, with the latest indemnification authority set to expire on 31 December 2016, the indemnification provision means that the U.S. federal government will cover any third-party damages from a commercial launch accident in excess of the "maximum probable loss" insurance level that the U.S. company holding the launch license is responsible for, up to a level of approximately $3 billion.[291] While the initial House bill offered an eight-year extension through 2023, some members found it to be too generous to the priorities of the commercial space industry, wanting to shorten it to a five-year period, in addition to other cutbacks; similarly, the initial Senate bill had launch indemnification run through 2020.[292] Yet following several months of deliberation within the House and Senate, the extension period was increased through September 2025.[293]

Another evolving issue regarded the FAA's ability to enact safety regulations for people flying on commercial spacecraft. With the passing of the Commercial Space Launch Amendments Act of 2004, the commercial spaceflight industry was granted an eight-year 'learning period' – later extended by an additional three years – that restricted the FAA from enacting regulations regarding the safety of people who might actually fly on commercial spacecraft until 1 October 2015. While the original version of the House bill allowed for an eight-year extension of the learning period through 2023, echoing the indemnification issue, some House representatives wished to scale it back to 5 years, running through 2020; similarly, the initial Senate bill had launch indemnification running through 2020.[294] Yet to ensure investment in the industry, the learning period provision in the final CSLCA was extended to 1 October 2023; limiting the FAA's safety regulating ability to cases where there is an accident that causes injury, death, or extensive property damage.[295]

On less contentious issues, the CSLCA extends the operation and utilization of the ISS through 2024, helping to ensure mission certainty to the station even in case of a more financially restrictive future presidential administration.[296] The CSLCA also established a new 'Government Astronaut' class; a separate class from crew and space flight participants. This new class is in regard to government employees that are transported to space on commercial vehicles, such as with the upcoming SpaceX crewed Dragon capsule.[297] Other provisions within the act include a request to the Secretary of Transportation, in consultation with NASA, the U.S. Secretary of State and other federal agencies, and the commercial space sector to identify an appropriate oversight mechanism that would protect public health and safety, safety of property, national security interests, and the foreign policy interests of the United States, in addition to eliminating duplicative requirements relevant to any commercial space launch or re-entry of a vehicle.[298] Here

[289] "President Obama Signs Bill Recognizing Asteroid Resource Property Rights into Law." 25 Nov. 2015. Planetary Resources 26 Nov. 2015 <http://www.planetaryresources.com/2015/11/president-obama-signs-bill-recognizing-asteroid-resource-property-rights-into-law/>.

[290] Treaty on Principles governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), London/Moscow/Washington, done 27 January 1967, entered into force 10 October 1967, 610 UNTS 205, 6 ILM 386 (1967).

[291] Foust, Jeff. "Congress launches commercial space legislation." 26 May 2015. The Space Review 26 Nov. 2015 <http://www.thespacereview.com/article/2759/1>.

[292] Foust, Jeff. "Congress launches commercial space legislation." 26 May 2015. The Space Review 26 Nov. 2015 <http://www.thespacereview.com/article/2759/1>.

[293] Foust, Jeff. "U.S. Senate Passes Compromise Commercial Space Bill." 11 Nov. 2015. SpaceNews 26 Nov. 2015 <http://spacenews.com/u-s-senate-passes-compromise-commercial-space-bill/>.

[294] Foust, Jeff. "Congress launches commercial space legislation." 26 May 2015. The Space Review 26 Nov. 2015 <http://www.thespacereview.com/article/2759/1>.

[295] Dillow, Clay. "Obama is About to Give Private Space Companies a Big Break." 24 Nov. 2015. Fortune.com 26 Nov. 2015 <http://fortune.com/2015/11/24/obama-commercial-space-break/>.

[296] Dillow, Clay. "Obama is About to Give Private Space Companies a Big Break." 24 Nov. 2015. Fortune.com 26 Nov. 2015 <http://fortune.com/2015/11/24/obama-commercial-space-break/>.

[297] Press Releases. "Senate Approves U.S. Commercial Space Launch Competitiveness Act." 4 Aug. 2015. U.S. Senate Committee on Commerce, Science, & Transportation 26 Nov. 2015 <http://www.commerce.senate.gov/public/index.cfm/2015/8/senate-approves-u-s-commercial-space-launch-competitiveness-act>.

[298] "H.R.2262 - U.S. Commercial Space Launch Competitiveness Act | Text: H.R.2262 — 114th Congress (2015-2016)." 25 Nov. 2015. Congress.gov 2 Dec. 2015

the FAA launch licence process allows a company to hold both an experimental permit and launch licence concurrently for the same vehicle, i.e. a licence for commercial missions and a less-restrictive permit for test flights.[299]

On April 2015, the U.S. Congress began to consider whether to renew the authorization of the U.S. Export-Import Bank (Ex-Im Bank). The Ex-Im Bank, and its regular partner Coface of France, entered the spotlight in 2015 while struggling with their near $400 million backing of the Australian start-up satellite operator, NewSat.[300] A decision of the U.S. Bankruptcy Court of Delaware on 22 May 2015 resulted in the cancellation of NewSat's contract with Lockheed Martin, allowing Lockheed to take possession of the nearly completed Jabiru-1 satellite. That decision put Ex-Im Bank's contract with NewSat in limbo, as Ex-Im Bank appeared to be in danger of having an unrecoverable loss of over $100 million.[301] To compound the situation, the decision arrived about a month prior to the set expiry of the Ex-Im Bank's charter (i.e. 30 June 2015), with industry opinions varying as to whether it would tip Congress' opinion in opposition of reauthorizing the bank, or maybe increase the amount of scrutiny over its investments.[302] The Ex-Im Bank, like its counterpart agencies in France, China, Russia, and elsewhere, finance overseas projects that provide export business for its domestic companies; in the space sector, the Ex-Im Bank often pairs up with France's Coface to launch U.S. built telecommunications satellites into orbit on Europe's Ariane 5 launcher. Similarly, China's government-backed loans, and soon Russia's as well, stimulate the sale of their commercial satellites to other countries by offering bundled packages to place them into orbit.[303] Yet, these practices have drawn criticism by some representatives in the U.S. Congress who deride it as a form of market-distorting corporate welfare.[304]

The Ex-Im Bank's authority lapsed on 1 July 2015, closing its doors to new satellite and other export business, but continuing all pre-existing loans, guarantees, and insurance policies into their maturity.[305] Nevertheless, even with other export credit agencies leaping in to fill the gap in financing, the effect of the Ex-Im Bank closure meant that there was not enough money available in the market to finance every new order of telecommunications satellites.[306] One casualty of the Ex-Im Bank closure was ABS of Hong Kong, which was forced to suspend its order for the ABS-8 satellite from Boeing, as the contract was in the midst of arranging financing when the lapse occurred[307]; and another deal was said to be lost by Orbital ATK who had been the frontrunner bidder to construct a second Azerspace-2 satellite for the government of Azerbaijan.[308]

Yet by 27 October 2015, lawmakers in the U.S. House of Representatives gave bipartisan approval to reauthorize the Ex-Im Bank after a clutch of representatives succeeded in forcing its vote using the rarely invoked discharge petition mechanism earlier in the month.[309] With the bill having gained Senate approval shortly thereafter, U.S. President Obama signed the legislation into law on 4 December 2015, extending the bank's life through September 2019. However, a lack of quorum in the Ex-Im Bank's five-seat board meant that satellite financing continued to be stalled by the end of 2015; such loans must await confirmation of President Obama's

<https://www.congress.gov/bill/114th-congress/house-bill/2262>.

[299] Foust, Jeff. "Senate Passes Commercial Space Bill." 5 Aug. 2015. SpaceNews 26 Nov. 2015 <http://spacenews.com/senate-passes-commercial-space-bill/>.

[300] De Selding, Peter B. "As Ex-Im Battle Brews, Novel Satellite Export Deals Stir Pot." 7 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/as-ex-im-battle-brews-novel-satellite-export-deals-stir-pot/>.

[301] De Selding, Peter B. "NewSat Bankruptcy is Costly for U.S. Ex-Im Bank." 28 May 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/newsat-bankruptcy-is-costly-for-u-s-ex-im-bank/>.

[302] De Selding, Peter B. "Will NewSat's Failure Dim Ex-Im's Appetite for Satellite Deals?" 1 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/will-newsats-failure-dim-ex-ims-appetite-for-satellite-deals/>.

[303] De Selding, Peter B. "As Ex-Im Battle Brews, Novel Satellite Export Deals Stir Pot." 7 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/as-ex-im-battle-brews-novel-satellite-export-deals-stir-pot/>.

[304] SpaceNews Editor. "Editorial | NewSat's Failure and the Ex-Im Bank." 15 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/editorial-newsats-failure-and-the-ex-im-bank/>.

[305] De Selding, Peter B. "Ex-Im is Closed to New Business; Will the U.S. Space Industry Suffer?" 2 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/ex-im-is-closed-to-new-business-will-the-u-s-space-industry-suffer/>.

[306] De Selding, Peter B. "MDA Corp. Explains Drop in Satellite Orders, Says Move Out of U.S. Possible." 3 Aug. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/mda-corp-explains-drop-in-satellite-orders-says-move-out-of-u-s-possible/>.

[307] De Selding, Peter B. "Boeing, Lockheed Gaze Abroad as Ex-Im Closure Costs them Satellite Sales." 18 Sept. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/boeing-lockheed-gaze-abroad-as-ex-im-closure-costs-them-satellite-sales/>.

[308] Foust, Jeff. "The Import of the Satellite Exporter's Bank." 29 Sept. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/the-import-of-the-satellite-exporters-bank/>.

[309] Timiraos, Nick. "House Votes to Reauthorize U.S. Export-Import Bank." 27 Oct. 2015. The Wall Street Journal 11 Mar. 2016 <http://www.wsj.com/articles/house-votes-to-reauthorize-u-s-export-import-bank-1445986019>.

nominees by the Senate.[310] Another open question is the legal mechanism the Ex-Im Bank could use to recoup some of its NewSat investment.[311]

### 6.5.1 National Aeronautics and Space Administration (NASA)

On 2 February 2015, the White House submitted its 2016 NASA budget proposal to the U.S. Congress, seeking $18.53 billion for 2016, an increase of 2.9% from the $18.01 billion it received in 2015. The proposal contained few significant changes to the agency's programmes aside from a new initiative for the development of new Earth science missions, including the development of the Landsat 9 satellite and a Thermal-Infrared Free Flyer satellite, under the agency's Sustainable Land Imaging (SLI) multi-decade initiative. The Landsat 9 satellite, planned for launch in 2023, will be based on the Landsat 8 launched in 2013, but will correct design flaws in one of Landsat 8's instruments. The Thermal-Infrared Free Flyer, planned for launch in 2019, is meant to be a data gap-filler for the Landsat 7 mission which is expected to run out of propellant in that same year. Funding for other initiatives such as the Asteroid Redirect Mission (ARM) - initially proposed in 2014 but in stasis at the beginning of 2015 as planners were undecided on whether to redirect an entire 10 metre asteroid or capture a small boulder off the surface of a larger asteroid – amounted to $220 million spread among the science, human exploration and operations, and space technology mission directorates. Funding for NASA's Orion programme decreased by 8.4% to $1.1 billion from $1.19 billion in 2015, while funding for its SLS programme dropped by 20% to 1.36 billion from 1.7 billion in 2015. However, the funding requested for NASA's Commercial Crew Programme received a significant boost reaching $1.24 billion for 2016, an increase of 54.5% from $805 million in 2015; that increase is tied to milestones NASA awarded to Boeing and SpaceX in September 2014. The budget request also cut funding for the Lunar Reconnaissance Orbiter (LRO) and Mars rover Opportunity in 2016.[312] The U.S. House Science Committee Chair expressed disapproval, finding too much funding going toward Earth science while not enough went to the Orion and SLS programmes[313]; the U.S. Senate Commerce space subcommittee voiced similar concerns in March 2015, with the essential issue boiling down to whether NASA's core mission of space exploration included Earth science rather than this being a competing priority.[314]

On 18 December 2015, U.S. President Obama signed the 2016 omnibus spending bill into law, including an adjusted NASA budget for 2016 amounting to $19.285 billion; an increase of $785 million above the White House budget request, and $1.285 billion more than NASA's budget in 2015.[315] The approved bill was a windfall for planetary science, and the Orion and SLS programmes, which drew substantially more funding than the initial budget request, while funding for the Earth Science SLI programme's Landsat 9 satellite and the Thermal-Infrared Free Flyer satellite appeared to survive the May 2015 budget cuts by the House Appropriations Committee.[316]

### 6.5.2 National Oceanic and Atmospheric Administration (NOAA)

The U.S. White House sent its 2017 fiscal budget request to Congress for NOAA on 9 February 2016, which asked for additional funding to sustain its polar-orbiting environmental satellite fleet. While NOAA's Joint Polar Satellite System (JPSS) plans to launch its JPSS-1 satellite in 2017 and JPSS-2 in 2021, work on a Polar Follow-on system is already underway to mitigate the risk of a premature failure of the JPSS-2, which would result in gap in critical weather data. The overall budget request decreased by 2.1% to $2.304 billion from the adjusted $2.351 billion it received in 2016. The 2017 budget request for the JPSS system decreased by

[310] Calmes, Jackie. "Ex-Im Bank Is Reopened, but Big Loans Are Stalled." 7 Dec. 2015. The New York Times 11 Mar. 2016 <http://www.nytimes.com/2015/12/08/business/ex-im-bank-is-reopened-but-big-loans-are-stalled.html>.

[311] De Selding, Peter B. "Ex-Im Hasn't Given Up on Recovering $100 Million NewSat Loss." 9 June 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/ex-im-hasnt-given-up-on-recovering-100-million-newsat-launch/>.

[312] Foust, Jeff. "For NASA, a New Budget But Old Battles Continue." 6 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/for-nasa-a-new-budget-but-old-battles-continue/>.

[313] Ferster, Warren. "Editorial | NASA's Groundhog Day Budget Foreshadows More Stalemate." 16 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/editorial-nasas-groundhog-day-budget-foreshadows-more-stalemate/>.

[314] Foust, Jeff. "Senators, Bolden Clash over the "Core Mission" of NASA." 12 Mar. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/senators-bolden-clash-over-the-core-mission-of-nasa/>.

[315] Smith, Marcia S. "NASA Gets Big Boost in Final FY2016 Appropriations Bill." 16 Dec. 2015. Space Policy Online 30 June 2016 <http://www.spacepolicyonline.com/news/nasa-gets-big-boost-in-final-fy2016-appropriations-bill>.

[316] C.f. Foust, Jeff. "House Budget Cuts NASA Earth Science By More Than $250 Million." 19 May 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/house-budget-cuts-nasa-earth-science-by-more-than-250-million/>.

2.7% to $787.2 million from $809.0 million received in 2016; meanwhile the Polar Follow-On programme request increased by 6.2% to $393 million, from the $370 million initial tranche appropriated in 2016, to work on the two final JPSS-3 and JPSS-4 satellites. The funding request for NOAA's Geostationary Operational Environmental Satellite Systems (GOES-R) four satellite constellation decreased by 10.2% amounting to $752.8 million from $837.9 million received in 2016; the first GEOS-R satellite is expected to launch in October 2016.[317] Funding for the joint U.S.-Taiwan COSMIC-2 constellation grew by 60.4% to total $16.2 million from the $10.1 million it received in 2016; half the funding went to ground reception and processing of equatorial GNSS radio occultation satellite data, while the other half went to the acquisition of GNSS radio occultation data in the polar orbit. Finally, funding for Jason 3 decreased by 3.8% to $4.4 million from $4.5 million in 2016, while funding for the DSCOVR programme increased by 63.4% to $3.7 million from $2.3 million in 2016.[318] By 24 May 2016, U.S. House Appropriators met to mark up the overall Fiscal Year 2017 Commerce, Justice, and Science (CJS) Appropriations Bill (which funds NOAA, NASA, and the National Science Foundation (NSF)), after receiving the U.S. Senate Appropriations version on 21 April 2016[319]; by the end of May 2016, the two bills still needed to be debated in their respective bodies before reaching a compromise on funding.[320]

## 6.6 Canada

On 27 February 2015, Canada's Prime Minister Stephen Harper announced the selection of Sylvain Laporte as president of the Canadian Space Agency (CSA). Effective 9 March 2015, Laporte replaced Luc Brûlé who had been sitting as the acting president of the CSA following the departure of the previous CSA president, Walter Natynczyk in November 2014. Laporte's experience stems from a broad background within Industry Canada, Canada Post Corp., and the Royal Canadian Air Force.[321]

The CSA fiscal budget for 2015, extending from 1 April 2015 to 31 March 2016, increased by 27.65% to C$483.43 from C$378.72 million the previous 2014 fiscal year.[322] Moreover, on 21 April 2015, Canada announced its commitment to increasing its member contribution to the European Space Agency (ESA). Under its Economic Action Plan, Canada plans to increase its spending by an additional C$30 million for ESA's ARTES programme, distributed over the period of 2016 to 2019. Canada also committed to extending its participation in the ISS to 2024, and has historically provided 2.3% of the ISS's common operating costs.[323] Canada's contribution to ESA was €15.5 million (C$16.7 million) in 2015.[324]

With the U.S. Export-Import Bank (Ex-Im Bank) shut down for financing satellite contracts for part of 2015, business across its border and across the Atlantic Ocean looked to gain a noticeable uptick; here, Canada's Export Development Canada (EDC), and France's Coface export credit agency sought to fill the void left by the Ex-Im Bank. One company that is in a favourable position is Canada's MacDonald, Dettwiler and Associates Ltd. (MDA), the parent company of top prime contractor Space Systems/Loral (SS/L). In this case, because SS/L's parent is a Canadian company, under the EDC credit agency the U.S. based SS/L would be considered a Canadian company as well, and would be eligible for EDC backing without being required to provide work in Canada in return. Unlike with other top prime contractors in the U.S. and in Europe, with a Canadian identity SS/L is able to keep its entire operation in the U.S. with Canadian financing. In contrast, if Boeing had turned to the EDC or France's Coface export credit agency when its com-

[317] Werner, Debra. "A larger share of NOAA's declining space budget would go to polar satellites" 10 Feb. 2016. SpaceNews 24 Oct. 2016 <http://spacenews.com/a-larger-share-of-noaas-declining-space-budget-would-go-to-polar-satellites/>.
[318] FY 2017 NOAA Budget Summary. 9 Feb. 2016. NOAA 24 Oct. 2016: 31-38, 54, 58 <http://www.corporateservices.noaa.gov/nbo/fy17_blueboo k/FY17_BB_Final_508.pdf>.
[319] "Senate Committee Passes FY17 Appropriations for NSF, NOAA & NASA." 26 Apr. 2016. UCAR 24 Oct. 2016 <https://president.ucar.edu/government-relations/washington-update/3795/senate-committee-passes-fy17-appropriations-nsf-noaa>.
[320] "House CJS Committee Passes FY17 Appropriations for NSF, NOAA & NASA." 26 May 2016. UCAR 24 Oct. 2016 <https://president.ucar.edu/government-relations/washington-update/3818/house-cjs-committee-passes-fy17-appropriations-nsf-noaa>.
[321] Foust, Jeff. "Laporte Named President of Canadian Space Agency." 2 Mar. 2015. SpaceNews 14 Dec. 2015 <http://spacenews.com/laporte-named-president-of-canadian-space-agency/>.
[322] "2015–16 Report on Plans and Priorities." 31 Mar. 2015. Canadian Space Agency 3 July 2015: 12 <http://www.asc-csa.gc.ca/pdf/eng/publications/rpp-2015.pdf>.
[323] SpaceNews Editor. "Editorial | Canadian Commitment Builds Momentum for Space Station Extension." 5 May 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/editorial-canadian-commitment-builds-momentum-for-space-station-extension/>.
[324] De Selding, Peter B. "Canada's New Space Budget Extends ISS Commitment to 2024." 22 Apr. 2015. SpaceNews 10 Jan. 2016 <http://spacenews.com/canadas-new-space-budget-extends-iss-commitment-to-2024/>.

mercial satellite contract with ABS of Hong Kong stalled in mid-2015 following the shut-down of the Ex-Im Bank, it is likely that part of the work would have had to be conducted within those countries as an additional requirement for funding.[325]

## 6.7 Russia

Russia's merger of its Federal Space Agency (Roscosmos) and the newly-founded state-owned holding company United Rocket and Space Corporation (URSC) was approved by President Vladimir Putin on 22 January 2015. While the two organisations were initially meant to co-exist in an arms-length customer and contractor relationship, merging the two into one entity was seen as a step in raising Russia's competitiveness, both in gaining market share, and in securing parity and advantage over geopolitical opponents.[326] The merger might help to strengthen Russia's struggling space industry, which has a seen a number of high-profile failures in recent years.

While in the midst of its restructuring, Russia's space industry experienced a 13% decrease in export revenue, earning 4.374 billion roubles ($76.99 million) for the year in 2014; most of that decline occurred prior to the rouble's fall late in the year.[327] The rouble fell even further in 2015, bottoming out at US¢14.09 to 1 rouble near the end of the year – less than half its value in 2013 when Russia planned to spend 2.1 trillion roubles (~$63 billion in 2013 prices) including extra-budgetary sources, to boost the development of its national space activities from 2013 to 2020. The rouble's free-fall led to Russia's reassessment of its draft Federal Space Program 2016-2025 proposal, which initially requested 3.4 trillion roubles ($52.5 billion) in March 2015, but was granted just 1.5 trillion roubles ($22.5 billion) as at 1 December 2015 for the ten year period.[328]

[325] De Selding, Peter B. "Boeing, Lockheed Gaze Abroad as Ex-Im Closure Costs them Satellite Sales." 18 Sept. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/boeing-lockheed-gaze-abroad-as-ex-im-closure-costs-them-satellite-sales/>.
[326] Bodner, Matthew. "Putin Approves Roscosmos Merger with Conglomerate." 23 Jan. 2015. SpaceNews 12 Jan. 2016 <http://spacenews.com/putin-approves-roscosmos-merger-with-conglomerate/>.
[327] De Selding, Peter B. "Roscosmos Details Russia's Struggling Space Sector." 20 Apr. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/roscosmos-details-russias-struggling-space-sector/>.
[328] "Roscosmos 10-Year Budget Cut For Third Time." 1 Dec. 2015. The Moscow Times 1 July 2016 <http://www.themoscowtimes.com/business/article/roscosmos-10-year-budget-cut-for-third-time/551337.html>.

## 6.8 Japan

Japan's Space Policy Commission published a third iteration of its Basic Plan for Space Policy on 9 January 2015. Marking a shift in priorities from the two previous iterations published in 2009, and updated early in 2013, the new 10-year roadmap focuses on security and commerce from its earlier emphasis on the peaceful use of outer space. Another departure in this policy is in its naming of China as a destabilizing factor in global security, particularly in its growing counter-space capability and development of anti-satellite weapons.[329] The new policy puts greater focus on developing Japan's Information Gathering Satellites (IGS) to further enable the country's surveillance and reconnaissance competencies. Moreover, it looks to increasing its cooperation with the U.S. on an equal basis, while also maintaining and strengthening its own industrial and science and technology sector.[330] A revised version of the plan was released on 11 November 2015, this time recommending that the IGS system be expanded from the original two optical and two radar satellites (plus one on-orbit spare), to eight satellites (plus two relay satellites to support the constellation).[331] The current constellation has four optical satellites, and three radar satellites (including one spare) in orbit; Japan launched its IGS-Radar Spare on 1 February 2015, and its IGS-Optical 5 on 26 March 2015.

In line with its new policy, Japan's combined space budget was increased by 18.5%, amounting to ¥324.5 billion for the fiscal year 2015 (beginning on 1 April 2015 and ending 30 March 2016).[332] Its 2014 budget in the same fiscal period is estimated to be around ¥274 billion.[333] The new budget, encompassing the space activity of 11 government ministries, saw a 68% increase in funding (i.e. ¥22.3 billion) moving toward the government's Cabinet Office (with most of the funding going toward its Quasi-Zenith regional

[329] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[330] Rajagopalan, Rajeswari Pillai. "Op-ed | Japan's Space Policy Shift Reflects New Asian Realities." 23 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/op-ed-japans-space-policy-shift-reflects-new-asian-realities/>.
[331] Kallender-Umezu, Paul. "What's Behind Japan's Sudden Thirst for More Spy Satellites." 13 Nov. 2015. SpaceNews 7 Jan. 2016 <http://spacenews.com/whats-behind-japan-sudden-thirst-for-more-spy-satellites/>.
[332] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[333] Euroconsult 2015. Profiles of Government Space Programs.

navigation system); its Cabinet Secretariat, tasked with controlling Japan's IGS system, received a 14% funding increase (i.e. ¥69.7 billion). The Education Ministry, governing the Japan Aerospace Exploration Agency (JAXA), also had a 19% funding increase (i.e. ¥182 billion); within JAXA's allocation, its next-generation H-3 launcher (to be completed in 2020) received a 78% increase to ¥12.5 billion.[334]

And in line with its enhanced cooperation with the U.S., Japan indicated that it would agree to extend its participation in the International Space Station (ISS) through 2024. Yet by the end of 2015, no formal agreement on extending the station was in place, as the Japanese and U.S. governments were still coordinating a new cooperation framework. Japan spends about ¥40 billion on the ISS annually; however sustaining that contribution might call for greater participation in the ISS, in addition to its symbolic value showing bilateral cooperation with the U.S.[335]

## 6.9 China

The year 2015 ended the cycle of China's 12th Five Year Plan (2011-2015); its 13th Five Year Plan (2016-2020) was preliminarily approved by China's Communist Party on 29 October 2015 with its details to be finalised in March 2016.[336] Nevertheless, the 13th Plan is expected to address the following four economic thematic areas: 1) secure a high growth target for 2020; 2) place more emphasis on domestic consumption with less focus on investment and exports; 3) further embrace competitive market mechanisms as part of its structural reform; and 4) enhance individual well-being through social welfare and healthcare reforms.[337] In that last thematic area, China is expected to end its 35-year-running one-child family planning policy, which has resulted in a top-heavy aging population.[338] However, some of the rhetoric behind this 'new normal' benchmark for China has raised some mixed concerns; while it promises a real-time environmental monitoring system, increased low-carbon public transportation, and more alternative energy vehicles – it also conveys an aim to tighten controls over the internet, art and culture, and increase its say in areas including the exploration of space, the deep sea and polar regions.[339]

The year also brought new prospects for space cooperation between China and other major space actors. Europe signed a framework agreement with the China Manned Space Agency (CMSA) in December 2014, thereafter establishing three working groups: space experiments and utilisation; astronaut selection, training and flight; and space infrastructure to analyse and propose concrete cooperation areas of mutual interest.[340] Russia has also signed an initial space station cooperation agreement with China.[341] And there are also indications that China and the U.S. will increase cooperation in the near future. While the export controls entrenched in the U.S. Strom Thurmond National Defense Authorization Act of 1999 restrict U.S. manufacturers from selling launchers, satellites and their components to China over concerns of technology transfer, it was the U.S. Consolidated and Further Continuing Appropriations Act of 2012 (signed into law on 18 November 2011) that banned any funding meant for bilateral cooperation or communication between NASA and the White House Office of Science and Technology Policy (OSTP) with China.[342] Since then, it has become increasingly apparent to both NASA and the OSTP that the U.S. is at risk of being left behind if it continues to exclude China in space exploration projects. However in mid-2015 meetings between China and the U.S. State Department (not barred by those restrictions), the two bodies agreed to consult with one another as part of a new U.S.-China Civil Space Cooperation Dialogue, for the

[334] Kallender-Umezu, Paul. "Japan Boosts Space Spending In Support of Security Focus." 2 Feb. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/japan-boosts-space-spending-in-support-of-security-focus/>.
[335] Foust, Jeff. "Japan Seeks To Become Full Partner with U.S. in Space." 11 Dec. 2015. SpaceNews 7 Jan. 2016 <http://spacenews.com/japan-seeks-to-become-full-partner-with-u-s-in-space/>.
[336] Magnier, Mark. "China's Communist Party Approves Five-Year Plan." 29 Oct. 2015. The Wall Street Journal 1 Feb. 2016 <http://www.wsj.com/articles/chinas-communist-party-approves-five-year-plan-1446124597>.
[337] Reeves, Martin, and David He. "What China's 13th Five-Year Plan Means for Business." 7 Dec. 2015. Harvard Business Review 1 Feb. 2016 <https://hbr.org/2015/12/what-chinas-13th-five-year-plan-means-for-business>.
[338] Moody, Andrew. "Dissecting China's Five-Year Plan." 23 Nov. 2015. The Telegraph 1 Feb. 2016 <http://www.telegraph.co.uk/sponsored/china-watch/politics/12006280/china-five-year-plan.html>.
[339] Shi, Ting. "China's Big Development Plan Has Xi's Fingerprints All Over It." 3 Nov. 2015. Bloomberg.com 1 Feb. 2016 <http://www.bloomberg.com/news/articles/2015-11-03/china-s-big-development-plan-has-xi-s-fingerprints-all-over-it>.
[340] David, Leonard. "US-China Cooperation in Space: Is It Possible, and What's in Store?" 16 June 2015. Space.com 22 Jan. 2016 <http://www.space.com/29671-china-nasa-space-station-cooperation.html>.
[341] De Selding, Peter B. "China's Space Station Planners Put out Welcome Mat." 13 Oct. 2015. SpaceNews 11 Jan. 2016 <http://spacenews.com/chinas-space-station-planners-put-out-welcome-mat/>.
[342] Section 539 Consolidated And Further Continuing Appropriations Act, 2012, Pub. L. no 112-55, 125 Stat. 639 (18 Nov. 2011) <https://www.gpo.gov/fdsys/pkg/PLAW-112publ55/pdf/PLAW-112publ55.pdf>.

purpose of satellite collision avoidance and the long-term sustainability of space.[343] The first meeting took place on 28 September 2015 in Beijing, China; a second dialogue meeting was expected to take place in Washington, D.C., in 2016.[344] Additionally, a Chinese experiment may be sent to Japan's Kibo module on the ISS in 2016, as part of a commercial arrangement brokered by the private U.S. company, NanoRacks.[345]

China also released its Middle and Long Term Development Plan for State Civil Space Infrastructure (2015-2025) on 26 October 2015.[346] Under this new roadmap, satellite remote sensing, communications, broadcasting, and navigation systems will be built during the 13th Five Year Plan to establish the state civil space infrastructure system. Using those systems, the 2015-2025 space development plan aims to produce comprehensive application demonstrations in 12 fields (including territory, mapping, energy, communications, and environmental protection) to provide core business with timely, accurate, and stable space information service. Additionally, the 2015-2025 plan stresses the importance of investment in its domestic industry, and calls for more investment of private capital.[347] For instance, it foresees 100 launches of its Long March launcher family during the 2015-2025 period to meet domestic demand; it also aims to court commercial launch contracts by providing commercial launch services outside of its territory.[348]

In the month preceding the 2015 United Nations Climate Change Conference (COP 21) held in Paris, France on 30 November – 12 December 2015, Chinese news sources reported that China planned on launching a global carbon dioxide observatory satellite into orbit in 2016. The so-called "$CO_2$ Observatory" satellite will carry carbon dioxide sensors that will have an accuracy better than 4 parts per millions.[349] The system would allow China to monitor its own carbon dioxide emissions, along with emissions in other major regions across the globe. Across the Pacific, an open question remains as to whether the U.S. NOAA or any other U.S. institution will rely on Chinese environmental data, despite anticipating a gap in U.S. weather coverage as early as 2017 for parts of Asia, including the Middle East and Afghanistan.[350]

And in anticipation of the inevitability of reusable launch services, China looks eager to compete on the global commercial launch market. At the 66th International Astronautical Congress (IAC) held on 12-16 October 2015 in Jerusalem, Israel, the China Academy of Launch Vehicle Technology (CALT) announced that it was designing a new rocket that would be launched at sites outside of China which would allow it to bypass some U.S. ITAR restrictions and launch international commercial satellites.[351] The two-stage Naga-L launcher will be able to lift small satellites into LEO orbit (i.e. 1,550 kg to 400 km LEO, 820 kg to 500 km SSO, and 620 kg to 700 km) at a cost of $10 million per flight. Its first flight is expected to take place at the end of 2017.[352] CALT has already begun negotiations with authorities in Indonesia, Sweden, and Tanzania to host its launcher. Previously, in July 2015, the Chinese government had been in talks with Russia's Energia over the purchase of the struggling commercial launch service provider, Sea Launch AG. As with the Naga-L launcher, China was considering stationing the launcher in international waters outside its territory to skirt ITAR restrictions and court the global commercial launch market. Yet the sale of the multinational Sea Launch to China would likely come with an array of regulatory and political

[343] Smith, Marcia S. "U.S., China Agree to Bilateral Civil Space Cooperation Dialogue." 26 June 2015. SpacePolicyOnline.com 22 Jan. 2016 <http://www.spacepolicyonline.com/news/u-s-china-agree-to-bilateral-civil-space-cooperation-dialogue>.
[344] "The First Meeting of the U.S.-China Space Dialogue." 28 Sept. 2015. U.S. Department of State 22 Jan. 2015 <http://www.state.gov/r/pa/prs/ps/2015/09/247394.htm>.
[345] David, Leonard. "US-China Space Freeze May Thaw with Historic New Experiment." 21 Aug. 2015. Space.com 22 Jan. 2016 <http://www.space.com/30337-chinese-experiment-international-space-station.html>.
[346] Google Translated.
"关于印发国家民用空间基础设施中长期发展规划(2015-2025年)的通知." 26 Oct. 2015. National Development and Reform Commission 2 Feb. 2016 <http://www.sdpc.gov.cn/zcfb/zcfbghwb/201510/t20151029_756376.html>.
[347] "Middle and Long Term Development Plan for Civil Space Infrastructure Issued." 13 Jan. 2016. LexisNexis 2 Feb. 2016 <https://hk.lexiscn.com/latest_message.php?access=show_detail&id=184408>.
[348] De Selding, Peter B. "With Naga-L Rocket, China Would Turn Tables on U.S. Export Ban." 15 Oct. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/with-naga-l-rocket-china-would-turn-tables-on-u-s-export-ban/>.
[349] "China plans to launch CO2 monitoring satellite in 2016." 23 Oct. 2015. English.News.Cn 22 Jan. 2016 <http://news.xinhuanet.com/english/sci/2015-10/23/c_134743536.htm>.
[350] Gruss, Mike. "U.S. Military Faces Weather Coverage Gap over Hot Zones." 13 Mar. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/u-s-central-command-faces-weather-coverage-gap-over-hot-zones/>.
[351] De Selding, Peter B. "With Naga-L Rocket, China Would Turn Tables on U.S. Export Ban." 15 Oct. 2015. SpaceNews 24 Dec. 2015 <http://spacenews.com/with-naga-l-rocket-china-would-turn-tables-on-u-s-export-ban/>.
[352] Messier, Doug. "China Developing New Smallsat Launch Vehicle." 15 Oct. 2015. Parabolic Arc 29 Jan. 2016 <http://www.parabolicarc.com/2015/10/15/china-developing-smallsat-launch-vehicle/>.

hurdles.[353] China may have lost interest in the purchase in the following months, as Energia was still in search of a buyer by the end of 2015.[354]

## 6.10 India

The Indian government is in the middle of its 12th five-year plan (2012-2017), which puts emphasis on speeding up the implementation of infrastructure projects, and aims to achieve an annual average economic growth rate of 8.2%.[355] India's space programme aims to strengthen its operational services in communications and navigation; enhance its remote sensing imaging capability; continue space science missions for better understanding of the solar system and the universe; and to build on its experience in planetary exploratory missions.

On 9 March 2015, India's parliament allocated 73.9 billion rupees ($1.18 billion) to the Indian Space Research Organisation (ISRO) for the fiscal year 2015-2016, beginning on 1 April 2015. The budget is a modest increase from the 72.4 billion rupees ($1.21 billion) initially allocated in the previous fiscal year. However, as with the previous fiscal year budget which was later revised to 52 billion rupees, it is possible that ISRO's spending budget for 2015-2016 will be less than initially allocated.[356] About 35.5% of the new fiscal budget was allocated toward launch vehicle technology, covering the continued development and operation of India's Geosynchronous Satellite Launch Vehicle (GSLV)-Mark 3 launcher, its workhorse Polar Satellite Launch Vehicle (PSLV), and other related technologies. Another 17.9% was allocated toward ISRO's INSAT constellation of communications and meteorological satellites, while 15.0% went toward ISRO's satellite technology budget. Moreover, 13.0% of the budget will be put toward India's space applications, while another 11.7% will be put toward launch support, tracking network and range facilities such as increasing India's satellite launching capacity by increasing ISRO's Satish Dhawan Space Centre launch range infrastructure. Just 4.1% of the budget will go toward ISRO's space sciences, a notable decrease from the 5.8% initially allocated in the previous fiscal year; and lastly, direction and administration including other programmes amount to the remaining 1.6% of the fiscal year budget.[357]

On 21 May 2015, India's office of the Prime Minister announced that it had approved an order to build 15 additional PSLV launchers to be used between 2017 and 2020, at a rate of 4-5 launches per year. Upon the completion of that order, the ISRO's docket of PSLV launchers will have reached 50 in total. While the launch system has mainly been used for India's institutional missions, the PSLV has also provided low-cost commercial launch services to governments and commercial operators from Europe, Canada, Algeria, and the U.S. (when granted by a waiver).[358] As the U.S. government reconsiders its policy on discouraging the use of the PSLV toward U.S. commercial and government operators based on its earlier view of unfair market-based pricing, ISRO's commercial arm Antrix may be in a position to win additional commercial launch service contracts for both its PSLV and GSLV launchers.[359]

At the start of 2015, Shailesh Nayak, India's Ministry of Earth Sciences secretary, was asked to also be the interim secretary of the Department of Space following the retirement of ISRO's Chairman Koppillil Radhakrishnan on 31 December 2014. The Department of Space secretary typically has the dual function of also serving as the Chairman of ISRO.[360] Nearly two weeks into his role, on 13 January 2015, the Indian government announced that Alur Seelin Kiran Kumar would relieve Nayak, and run ISRO for three years beginning in 2015.[361]

Following the 14 September 2015 International Criminal Court (ICC) ruling directing

[353] De Selding, Peter B. "China Eyes Purchase of Sea Launch Assets." 17 July 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/china-eyes-purchase-of-sea-launch-assets/>.
[354] "Sea Launch On the Sales Block?" 3 Dec. 2015. Satnews 29 Jan. 2016 <http://www.satnews.com/story.php?number=25117559>.
[355] "Government Approves 12th Five Year Plan." 4 Oct. 2012. The Times of India 3 May 2014 <http://timesofindia.indiatimes.com/business/india-business/Government-approves-12th-five-year-plan/articleshow/16672927.cms>.
[356] Jayaraman, K.S. "India Allocates $1.2 Billion for Space Activities." 9 Mar. 2015. SpaceNews 14 Dec. 2015 <http://spacenews.com/india-allocates-1-2-billion-for-space-activities/>.
[357] "Department of Space | No.93/Department of Space." 1 Mar. 2015. Indiabudget.nic.in 11 Feb. 2016 <http://indiabudget.nic.in/ub2015-16/eb/sbe93.pdf>.
[358] De Selding, Peter B. "India OKs Budget for Building, Launching 15 PSLV Rockets by 2020." 22 May 2015. SpaceNews 5 Jan. 2016 <http://spacenews.com/india-to-build-and-launch-15-pslv-rockets-by-2020/>.
[359] SpaceNews Editor. "Getting the Cubesat Revolution Out of Low Gear." 24 Nov. 2015. SpaceNews 6 Jan. 2016 <http://spacenews.com/getting-the-cubesat-revolution-out-of-low-gear/>.
[360] Jayaraman, K.S. "Nayak Named Interim Chief at ISRO." 6 Jan. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/nayak-named-interim-chief-at-isro/>.
[361] Jayaraman, K.S. "India Taps ISRO Veteran To Run Space Program." 13 Jan. 2015. SpaceNews 10 Dec. 2015 <http://spacenews.com/india-taps-isro-veteran-to-run-space-program/>.

ISRO's commercial arm Antrix Corp. to pay $672 million in damages to Devas Multimedia (an Indian company backed by German and U.S. investors), the Indian government announced that it will challenge the ruling and apply for remedy. In January 2005, Antrix and Devas agreed to have ISRO build and launch the GSAT-6 and GSAT-6A S-band communication satellites, and lease 90% of its transponder capacity to Devas for 12 years, in exchange for $300 million. The deal was nullified by the Indian government on 25 February 2011, when the S-band spectrum used by the satellites was reallocated to India's defence forces. Devas subsequently turned to the ICC seeking $1.6 billion in damages, arguing that the cancellation had been arbitrary and illegal.[362] According to the arbitration statement, interest on the award will accrue at 18% per year until damages are settled.[363]

## 6.11 Brazil

Despite long-standing obstacles for Brazil's space and R&D development, and the lack of expertise in its workforce, Brazil is still an important space player of the future due to its geographic position on the equator, and its growing economy.

In terms of partnerships with space powers around the globe, Brazil has formed a number of cooperation arrangements including cooperation with China on Earth observation through the China-Brazil Earth Resources Satellite (CBERS) project since 1988, hosting three monitoring stations for Russia's Glonass GNSS system, small satellite development with Argentina and Japan, and space technology agreements involving manufacturers in Canada and France, among others. However, the broad application of the United States' International Traffic in Arms Regulations (ITAR) export controls, even after modifications entered into force in November 2014, has been a main factor in Brazil's resistance in forming closer ties with the U.S. space sector. While the U.S. is the main source of components in the global space sector, Brazilian authorities tend to favour competitive bids that have the fewest U.S. parts to avoid potential ITAR restrictions.[364]

Yet in the midst of a slumping economy, Brazil's government has decided to end its decade-long space launch cooperation agreement with Ukraine to operate Ukraine's Cyclone-4 rocket from Brazil's Alcântara Launch Centre (CLA) due to budget constraints, cost overruns, and uncertainty about the future market success of the arrangement.[365] Brazil and Ukraine had created the binational company "Alcântara Cyclone Space" (ACS), with financing divided equally, for commercial launches using the Ukrainian vehicle Cyclone-4 from the CLA spaceport whose proximity to the equator gives the launch vehicle more capacity to orbit than can be offered from Russian spaceports.[366] The launcher development program cost an estimated 1.58 billion reals over the 10-year period, while the Cyclone-4 program was allocated an additional 459.8 million reals during that time. Another 1.9 billion reals had been allocated for space infrastructure improvements, mostly going toward development of the CLA.[367] It is unclear whether Brazil will have to pay Ukraine any financial penalties for the unilateral cancellation of their agreement.[368]

[362] Jayaraman, K. S. "Antrix To Appeal $672M Judgment for Nixed Satellite Contract." 30 Sept. 2015. SpaceNews 13 Jan. 2016 <http://spacenews.com/antrix-to-appeal-672m-judgment-for-nixed-satellite-contract/>.
[363] Jai Krishna, R. "ISRO's Antrix Corp asked to pay $562 million in damages in Devas Multimedia dispute." 30 Sept. 2015. The Financial Express 12 Feb. 2016 <http://www.financialexpress.com/article/industry/companies/antrix-corp-asked-to-pay-562-million-in-damages-in-devas-multimedia-dispute/143518/>.

[364] De Selding, Peter B. "Brazil Bypassing the U.S. as It Builds out a Space Sector." 16 Apr. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/brazil-bypassing-the-us-as-it-builds-out-a-space-sector/>.
[365] De Selding, Peter B. "Brazil Pulling Out of Ukrainian Launcher Project." 16 Apr. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/brazil-pulling-out-of-ukrainian-launcher-project/>.
[366] "News from the 64th International Astronautical Congress | Backers Insist Brazilian Spaceport Is Nearing Launch Readiness." 4 Oct. 2013. SpaceNews 3 May 2014 <http://www.spacenews.com/article/launch-report/37550news-from-the-64th-international-astronautical-congress-backers-insist>.
[367] "Brazil Scales Back Launch Vehicle Plans." 10 Feb. 2013. Parabolic Arc 3 May 2014 <http://www.parabolicarc.com/2013/02/10/brazil-scales-back-launch-vehicle-plans/>.
[368] De Selding, Peter B. "Brazil Pulling Out of Ukrainian Launcher Project." 16 Apr. 2015. SpaceNews 22 Dec. 2015 <http://spacenews.com/brazil-pulling-out-of-ukrainian-launcher-project/>.

# List of Acronyms

| Acronym | Explanation |
|---|---|
| **#** | |
| 21AT | Twenty-First Century Aerospace Technology Co. |
| | |
| **A** | |
| AAD | Advanced Air Defence |
| ABS | Asia Broadcast Satellite |
| ACS | Alcântara Cyclone Space |
| ADF | Aerospace Defence Forces |
| ADM | Atmospheric Dynamics Mission |
| AG | Aktiengesellschaft |
| AIA | Aerospace Industry Association |
| Airbus D&S | Airbus Defence and Space |
| AIS | Automatic Identification Satellites |
| ARM | Asteroid Redirect Mission |
| ASAT | Anti-Satellite |
| ASI | Agenzia Spaziale Italiana (Italian Space Agency) |
| ASL | Airbus Safran Launchers |
| ASNARO | Advanced Satellite with New System Architecture for Observation |
| ATV | Automated Transfer Vehicle |
| | |
| **B** | |
| BMD | Ballistic Missile Defence |
| | |
| **C** | |
| CAA | Civil Aviation Authority |
| CAGR | Compound Annual Growth Rate |
| CALT | China Academy of Launch Vehicle Technology |
| CAST | China Aerospace Science and Technology Corp. |
| CBERS | China-Brazil Earth Resources Satellite |
| CCP | Commercial Crew Programme |
| CD | Conference on Disarmament |
| CGWIC | China Great Wall Industry Corporation |
| CHF | Swiss franc |
| CLA | Alcântara Launch Center |

| Acronym | Explanation |
|---|---|
| CMSA | China Manned Space Agency |
| CNES | Centre National d'Études Spatiales (French Space Agency) |
| COP | Conference of the Parties |
| COPUOS | Committee on the Peaceful Uses of Outer Space |
| CRS | Commercial Resupply Services |
| CSA | Canadian Space Agency |
| CSLCA | Commercial Space Launch Competitiveness Act |
| | |
| **D** | |
| DAMPE | Dark Matter Particle Explorer |
| DARS | Digital Audio Radio Service |
| DBS | Direct Broadcast Services |
| DLR | Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center) |
| DoD | Department of Defence |
| DRDO | Defence Research and Development Organisation |
| DSCOVR | Deep Space Climate ObserVatoRy |
| DTH | Direct To Home |
| | |
| **E** | |
| EBITDA | Earnings Before Interest, Taxes, Depreciation and Amortization |
| ECA | Evolution Cryotechnique type A |
| ECB | European Central Bank |
| EDA | European Defence Agency |
| EDC | Export Development Canada |
| EDRS | European Data Relay Satellite System |
| EPS-SG | European Polar System Second Generation |
| ESA | European Space Agency |
| ESA DG | ESA Director General |
| EU | European Union |
| EUMETSAT | The European Organisation for the Exploitation of Meteorological Satellites |
| EUTELSAT | European Telecommunications Satellite Organisation |
| Ex-Im Bank | U.S. Export-Import Bank |
| | |
| **F** | |
| FAA | Federal Aviation Administration |
| FSS | Fixed Satellite Services |
| FY | Fiscal Year |
| | |
| | |

| Acronym | Explanation |
|---|---|
| **G** | |
| GDP | Gross Domestic Product |
| GEO | Geostationary Earth Orbit |
| GmbH | Gesellschaft mit beschränkter Haftung |
| GNSS | Global Navigation Satellite Systems |
| GPS | Global Positioning System |
| GSLV | Geosynchronous Satellite Launch Vehicle |
| GTO | Geosynchronous Transfer Orbits |
| | |
| **H** | |
| HTV | H-2 Transfer Vehicle |
| | |
| **I** | |
| IAC | International Astronautical Congress |
| IAEA | International Atomic Energy Agency |
| ICC | International Criminal Court |
| ICoC | International Space Code of Conduct for Outer Space Activities |
| ICS | Information and Communication Systems |
| IGS | International GNSS Service |
| ILS | International Launch Services |
| IMF | International Monetary Fund |
| INDC | Intended Nationally Determined Contributions |
| IOV | In-Orbit Validation |
| IR | Infrared |
| IRNSS | India Regional Navigation Satellite System |
| ISIS | Islamic State |
| ISRO | Indian Space Research Organization |
| ISS | International Space Station |
| ITAR | International Traffic in Arms Regulations |
| ITU | International Telecommunication Union |
| IXV | Intermediate Experimental Vehicle |
| | |
| **J** | |
| JAXA | Japan Aerospace Exploration Agency |
| JCPOA | Joint Comprehensive Plan of Action |
| JPS | Joint Polar System |
| | |
| **L** | |
| LEO | Low Earth Orbit |

| Acronym | Explanation |
|---|---|
| LRO | Lunar Reconnaissance Orbiter |
| | |
| **M** | |
| MATS | Mesospheric Airglow/Aerosol Tomography and Spectroscopy |
| MDA | MacDonald, Dettwiler and Associates Ltd. |
| Melco | Mitsubishi Electric Co. |
| MEO | Medium Earth Orbit |
| Metop | Meteorological Operational Satellite |
| Metop-SG | Metop Second Generation |
| MFF | Multiannual Financial Framework |
| MFG | Meteosat First Generation |
| MOD | Ministry of National Defense |
| MSG | Meteosat Second Generation |
| MSS | Mobile Satellite Service |
| MTG | Meteosat Third Generation |
| | |
| **N** | |
| NASA | National Aeronautics and Space Administration |
| NATO | North Atlantic Treaty Organisation |
| NDAA | National Defense Authorization Act |
| NEC | Nippon Electric Company |
| NEO | Near-Earth Orbit |
| NOAA | National Oceanic and Atmospheric Administration |
| NRO | National Reconnaissance Office |
| | |
| **O** | |
| OECD | Organisation for Economic Co-operation and Development |
| OHB | Orbitale Hochtechnologie Bremen |
| OPEC | Organization of the Petroleum Exporting Countries |
| OSTP | Office of Science and Technology Policy |
| | |
| **P** | |
| PAD | Prithvi Air Defense |
| PLA | People's Liberation Army |
| PND | Portable Navigation Devices |
| PPP | Public-Private Partnership |
| PRS | Public Regulated Service |
| PSLV | Polar Satellite Launch Vehicle |
| | |

| Acronym | Explanation |
|---|---|
| **Q** | |
| QZSS | Quasi-Zenith Satellite System |
| | |
| **R** | |
| RKV | Redesigned kill vehicle |
| Roscosmos | Russian Federal Space Agency |
| | |
| **S** | |
| SAR | Synthetic Aperture Radar |
| SES | Société Européenne des Satellites |
| SIA | Satellite Industry Association |
| SLA | Service Level Agreement |
| SLI | Sustainable Land Imaging |
| SLS | Space Launch System |
| SNSB | Swedish National Space Board |
| SpaceX | Space Exploration Technologies |
| SS/L | Space Systems/Loral |
| SSO | Sun-synchronous orbit |
| SSTL | Surrey Satellite Technology Ltd. |
| | |
| **T** | |
| TPP | Trans-Pacific Partnership |
| TRL | Technology Readiness Level |
| | |
| **U** | |
| UAV | Unmanned Aerial Vehicle |
| UK | United Kingdom |
| ULA | United Launch Alliance |
| UN | United Nations |
| UNCTAD | United Nations Conference on Trade and Development |
| UNFCCC | United Nations Framework Convention on Climate Change |
| U.S. | United States of America |
| U.S. MDA | Missile Defense Agency |
| USAF | U.S. Air Force |
| | |
| **V** | |
| VSAT | Very Small Aperture Terminals |
| | |
| | |

| Acronym | Explanation |
|---|---|
| **W** | |
| WGP | World Gross Product |
| WRC | World Radiocommunication Conference |

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# About the Author

Cenan Al-Ekabi joined the European Space Policy Institute in Vienna in 2011, functioning as a project manager from 2012, and a Resident Fellow from 2013. Prior to that, he obtained two advanced studies LL.M. degrees in Air & Space Law, and in European & International Business Law from Leiden University in the Netherlands. He also holds a US JD with concentration in studies in international law from the Thomas M. Cooley law school, and a bachelor's degree in Political Science from McMaster University in Canada.

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