ESPI

European Space Policy Institute

ESPI Yearbook 2019

Space policies, issues and trends

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Foreword

Dear members and readers,

I am happy and proud to introduce to you this new edition of our ESPI Yearbook. This long-established annual publication has gained along the years a solid reputation of being a reliable source of information and a useful tool for monitoring the development of the European space policy in a global context.

With this new issue we tried to better meet the expectations of our readers and we paid substantial efforts to ensure a consistent overall coverage of the 2019 space activities and business.

We do not pretend establishing with this yearbook THE reference document describing and analyzing the evolution of the global space sector. Some other publications have such ambition, but none of them has such a strong and permanent focus on the situation of Europe. And this is exactly the purpose we pursue with this publication, highlighting the position of Europe on the space international stage and putting forward the trends at work that deserve being considered in the further development of the European space policy.

This approach builds on the permanent "Space Sector Watch" effort that we initiated last year with our new ESPInsights quarterly publication structured along four major areas of interest to our members:

- Policy & Programmes, where we report on the latest developments of space public, governmental and institutional affairs,
- Industry & Innovation, where we gather prominent announcements related to space industry evolutions worldwide and technology's most promising progress,
- Economy & Business, which is based on a collection of indicators relevant to the global space economy and markets,
- Launches & Satellites, which presents some exploitations of our in-house databases related to launch site activities worldwide over the past year.

Actually, 2019 has been quite remarkable regarding the development of space policy-related matters with:

- The enactment of a few new national space policies both in civil and security & defence realms worldwide,
- Unprecedented financial commitments from European member states both at ESA Space19+ Council and at EU level during the negotiation of the next Multi-annual Financial Framework (still to be confirmed though…),
- The reorganisation of the European Commission and the setting-up of a Directorate-General for Defence Industry and Space,
- The rise of space security and sustainability concerns fuelling renewed interest in Space Situational Awareness and Space Traffic Management,
- Intense efforts to consolidate future space exploration plans.

Regarding space industry, 2019 has also been quite dense with the advent of major initiatives that might have disruptive consequences in the medium term:

- First operational steps for a handful of microlaunchers projects,
- Start of the deployment of mega-constellations in a grim GEO satcom environment,
- Initiation of spectacular breakthrough In-Orbit Servicing for life-extension of geostationary spacecraft,

- Decisive progress in Ariane-6 and Vega-C developments along with other super-heavy capacities in the United States, Russia and China,
- Emergence of promising innovations regarding Artificial Intelligence capabilities for space applications, connectivity

I hope you will enjoy going through this publication as much as we did preparing it and that you will share with us the need to fill-in a gap with solid Europe-centered socio-economic indicators to support the further development of the European space policy in order to best foster effectiveness of public expenditures, business development and investment.

I would be more than happy to receive feedback on ways we could further tailor this publication to your needs.

In the meantime, I remain,

Sincerely yours,

Jean-Jacques Tortora

Director of the European Space Policy Institute

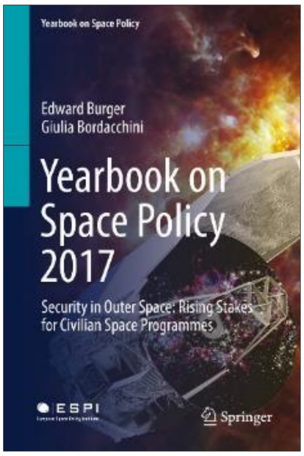
About ESPI Yearbook and Space Sector Watch

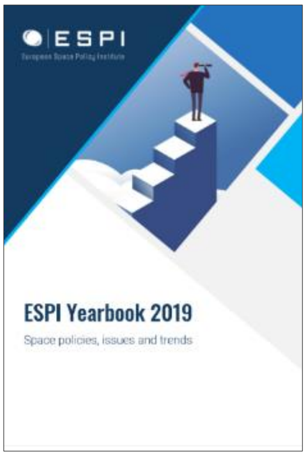
New ESPI Yearbook

The Yearbook on Space Policy is an annual publication of the European Space Policy Institute (ESPI) providing an overview of major developments and trends in space policy, industry, programmes, economy and overall worldwide activity over the year.

After 10 successful editions published by Springer, ESPI decided to update the editorial formula and publication policy of the Yearbook.

The new "ESPI Yearbook" series will now be directly available on ESPI website, like other public reports of the Institute. It also replaces the former "Space Policies, Issues and Trends" series which was another annual publication of the Institute providing additional information and data about the state of the global space sector.





The 2019 edition is the first of this new Yearbook series and adopts a revised structure and content, organised in four complementary chapters:

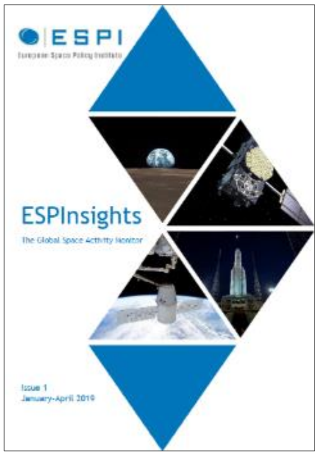
- Policy & Programmes: space policy highlights and trends, major space programme developments
- Industry & Innovation: launcher and satellite industry developments, selected company infosheets
- Economy & Business: global and European space economy indicators (turnover, budgets, investment)
- Launches & Satellites: space activity statistics, mission highlights and ESPI launch log

ESPI Yearbook does not aim to be comprehensive but rather to provide useful information, data and insights on a selection of topics expected to shape the future of the global and European space sector.

ESPI Space Sector Watch

ESPI continuously monitors international space affairs and tracks a selection of indicators in proprietary databases. The ESPI Yearbook is part of this broader space sector watch activity of the Institute, together with the following publications:

- ESPInsights: every quarter, a synthetic overview of major developments in the space sector providing useful links to official documents, public reports, web articles or conference websites. Starting from 2020, ESPI plans to publish ESPInsights reports more regularly, on a monthly basis, and to offer the option of an automatic delivery to registered users.
- ESPI Executive Briefs: every month, ESPI team views and analysis of an outstanding space policy topic.
- Other ESPI publications such as the "Space Venture Europe" series which provides statistics and information about private investment and entrepreneurship in the European space sector.



1 Policy & Programmes

1.1 2019 in a nutshell

Between the passing of new space policies and the substantial progress achieved by important space programmes, 2019 was yet another eventful year for the space sector. While some developments were certainly groundbreaking, involving important changes with far-reaching consequences, many others were long-anticipated milestones in already established processes. This chapter, alike the rest of the Yearbook, does not aim at comprehensiveness but rather tries to offer a synthetic overview and selection of developments that marked the year and which are expected to shape the future of the space sector.

In Europe, 2019 offered great promises for the future of the space sector with an unprecedented financial commitment to European space programmes at the ESA Council at Ministerial Level with total subscriptions of €14.5 billion. In parallel, space was also the subject of intense discussions at European Union level with the election of a new Parliament in May, a reorganisation of the Commission in November, including the setup of a new Directorate-General for Defence Industry and Space, and the negotiation of the next Multiannual Financial Framework which will cover the period 2021-2027. No final agreement has been reached on the future of the EU space programme at the end of 2019 but the main lines were drawn and it could legitimately be expected that the overall budget will stand around €16 billion for the next seven years, excluding complementary funding from Horizon Europe and other relevant EU budget lines. Of course, the COVID-19 crisis may very well reshuffle some of the cards in 2020.

At the global level, 2019 has been a landmark year in the space defence domain, confirming a change of paradigm in the approach of various spacefaring nations and intergovernmental organisations to military space activities. Multiple policies were issued over the year, characterised by a more assertive posture of some governments starting to address space as an operational military domain, reorganising their armed forces and programmes and developing offensive and defensive space capabilities as part of new doctrines. Notably highlights include the publication of new strategies in France and Italy, the establishment of the U.S. Space Force and Space Development Agency but also the Indian Anti-Satellite Test in March or the adoption of a new NATO space defence policy.

Public and private actors of the space sector are also concerned by the rising challenge to ensure the safety and sustainability of space operations at a time of globalization, diversification and intensification of space activities. In this regard, the year has been marked by important developments such as the adoption of guidelines for the long-term sustainability of outer space activities by the UN COPUOS but also by the emergence of several industry-led initiatives to promote the adoption of better suited standards and best practices for space operations.

Another important area for space policy and programmes in 2019 concerns space exploration plans and in particular the reignited lunar ambitions through the Artemis programme which is progressively taking shape. Despite the many milestones reached, some questions remain regarding funding, formalisation of partnerships and the future of the ISS.

These are only a few outstanding highlights of a year that saw many more space policy and programme developments across the entire spectrum of space activities ranging from Earth Observation to Space Science.

1.2 Space policy highlights and trends in 2019

1.2.1 ESA Space 19+: record breaking subscriptions bolstering ESA programmes

Undoubtedly the most important development for ESA in the year 2019 was the ESA Council Meeting at Ministerial Level – Space19+ – which took place in Seville, Spain in November 2019. ESA Ministerial Councils take place every two to three years and bring together ESA Member States and observers to make decisions on programme proposals and the funding for ESA.[1] The last ESA Ministerial Council took place in Switzerland in 2016 under the vision of a *United Space in Europe in the era of Space 4.0* and resulted in the allocation of €10.3B for ESA's space activities and programmes[2].

The 2019 ESA Council at Ministerial Level was held under the motto *Space19+* with the aim to "approve a comprehensive set of programmes to secure Europe's independent access to and use of space in the 2020s, boost Europe's growing space economy, and make breakthrough discoveries about Earth, our Solar System and the Universe beyond, all the while making the responsible choice to strengthen the efforts we are making to secure and protect our planet".[3]

This year, ministers committed the biggest ever budget with total subscriptions amounting to €14.5B[4] with Germany as the largest contributor (€3,294 million), followed by France (€2,664 million) and Italy (€2,282 Million).[5] Interestingly, the science programme received the most "significant boost in funding" in 25 years. The Space Science programme is embedded in one of the four pillars according to which ESA's programmes and activities will be carried out, as proposed by DG Wörner in 2018. The four pillars are:

- Science and exploration: comprising Space Science and Human and Robotic Exploration;
- Safety and Security: comprising Space Safety, Safety and Security Applications and Cybersecurity;
- Applications: comprising Telecommunications, Earth Observation, Navigation;
- Enabling and Support: comprising Technology, Space Transportation and Operations.

1 "ESA on the way to Space19+ and beyond…". ESA (October 2018): https://www.esa.int/About_Us/Corporate_news/ESA_on_the_way_to_Space19_and_beyond
2 "European ministers ready ESA for a United Space in Europe in the era of Space 4.0". ESA (December 2016): https://www.esa.int/About_Us/Ministerial_Council_2016/European_ministers_ready_ESA_for_a_United_Space_in_Europe_in_the_era_of_Space_4.0
3 "ESA ministers commit to biggest ever budget". ESA (November 2019): http://www.esa.int/About_Us/Corporate_news/ESA_ministers_commit_to_biggest_ever_budget
4 Total revised amount including subscriptions from Romania, see Replay of ESA Director General's press briefing. Available at https://www.esa.int/ESA_Multimedia/Videos/2020/01/Replay_ESA_Director_General_s_press_briefing
5 Charts on subscription to ESA programmes (November 2019). Available at: https://esamultimedia.esa.int/docs/corporate/Space19plus_charts.pdf

A detailed break-down of Member State contributions at the ESA Ministerial Council 2019 is provided below:

Contributor	Subscriptions in M€	Share per Contributor in %
Austria	190	1.3%
Belgium	816	5.7%
Czech Republic	150	1.0%
Denmark	128	0.9%
Estonia	9	0.1%
Finland	110	0.8%
France	2,664	18.5%
Germany	3,294	22.9%
Greece	84	0.6%
Hungary	97	0.7%
Ireland	81	0.6%
Italy	2,282	15.9%
Luxembourg	129	0.9%
Netherlands	345	2.4%
Norway	284	2.0%
Poland	166	1.2%
Portugal	102	0.7%
Romania*	44	0.3%
Spain	852	5.9%
Sweden	244	1.7%
Switzerland	542	3.8%
United Kingdom	1,655	11.5%
Slovenia	5	0.0%
Canada	114	0.8%
Total contributions	14,388	100.0%

*Subscription from Romania updated after Space19+ conference, final amount not communicated yet

Table 1: Total subscriptions per contributor (Source: ESA)[6]

[6] *Ibid.*

ESA also released the breakdown of subscription allocation per line of activity:

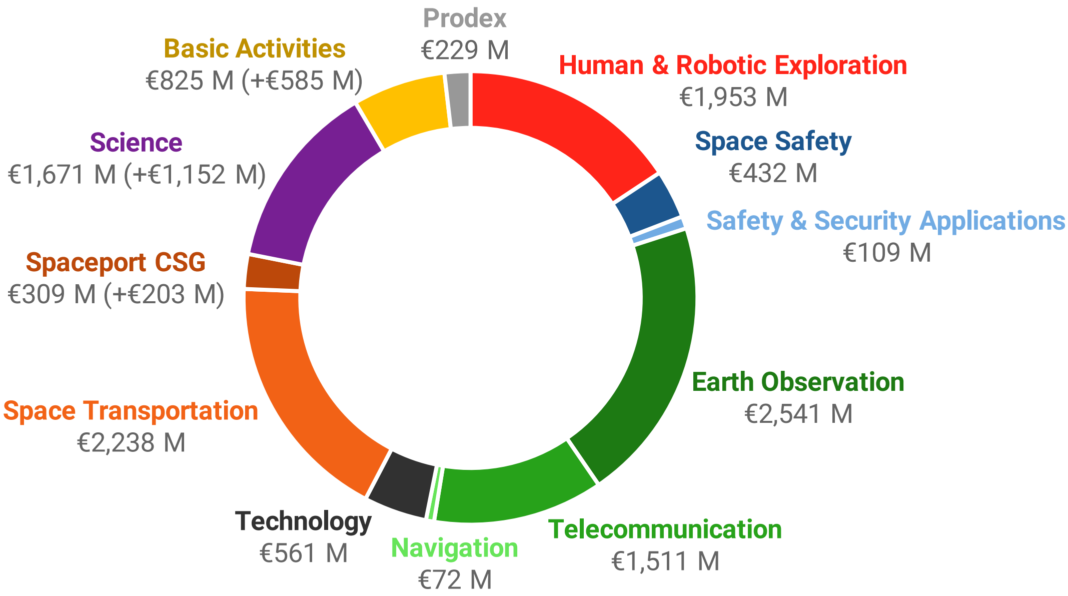


Figure 1: Total subscriptions per line of activity (adapted from ESA)[7]

Three resolutions were passed as a result of the ESA Ministerial Council 2019:

Resolution 1

The first resolution, titled Resolution on Space: The five dimensions of Space 4.0,[8] opens with reflections on the ESA Convention, preceding resolutions on ESA-EU cooperation and acknowledges the work of ESA, as well as the role of Member States vis-à-vis and within ESA. It then invites the ESA Director General to foster ESA's transformation into "a space agency that innovates, informs, inspires and interacts based on reliable and sustainable capabilities and infrastructure" – along the five dimensions of Space 4.0 put forward by an ESA Director General. According to the resolution, this should be achieved, inter alia, by:

- strengthening ESA's position as a "leader and reliable partner" and making "Europe central to the new era of global space exploration";
- "ensuring the implementation of Space19+ decisions" and the optimal use of common infrastructure;
- boosting existing Member States' capabilities as well as innovation; and,
- "contributing to European autonomy in accessing, exploring and using outer space".

Resolution 2

The second resolution, titled Resolution on the Scientific Programme and the Basic Activities for Space19+,[9] provides a breakdown of "the resources to be made available to the Agency for the period 2020-2024" for the Scientific Programme and Basic Activities, having regard to the Director General's Proposal. This covers the allocation of €4,228M, including €1,405M for ESA's basic activities and €2823M for the Scientific Programme. The resolution also provides guidelines for future ESA activities in different fields.

[7] *Ibid.*
[8] "Resolution on Space: The five dimensions of Space 4.0" (Resolution 1), adopted by ESA Ministerial Council on 28 November 2019. Available at: https://esamultimedia.esa.int/docs/corporate/Resolution_1_Space19+Final-28Nov-12h30.pdf
[9] "Resolution on the Scientific Programme and the Basic Activities for Space19+ - Level of Resources for 2020-2024" (Resolution 2), adopted by ESA Ministerial Council on 28 November 2019. Available at: https://esamultimedia.esa.int/docs/corporate/Resolution_2_Space19+Final-28Nov-12h30.pdf

Resolution 3

The third resolution, titled Resolution on ESA programmes: addressing the challenges ahead,[10] reflects on the Director General's Long-Term Plan 2020-2029 which pertains to the expected evolution of European space activities, and the roles that stakeholders and ESA's activities and programmes are expected to play in this timeframe. The resolution continues to detail – along the four programmatic pillars of ESA – new plans of the Agency, reflections on ongoing programmes and new priorities for the future:

- Science and Exploration: the resolution acknowledges the successful space science missions and notes the utility of the Second Period of the European Exploration Envelope Programme (E3P) – now structured along "four cornerstone mission campaigns": Humans in Low Earth Orbit (LEO), Humans beyond LEO, Lunar robotic, Mars robotic exploration. The resolution recalls that the E3P particularly aids in meeting "the European Partner's financial obligations arising from both the ISS Intergovernmental Agreement (IGA) and Memorandum of Understanding (MOU)". The resolution goes on to express the prioritization of the formalisation of the European participation in the Lunar Gateway and the Mars Sample Return campaign with NASA in order to meet "the ambitious schedule for the actual development, launch and operation of the corresponding hardware elements".

- Safety and Security: the resolution outlines that the successor to the Space Situational Awareness programme – the Space Safety Programme (S2P) – aims to protect Earth and humanity as well as assets from hazards with their origin in space, inter alia through "effective risk management, addressing hazards originating in space through the identification of their different types, the analysis of their status, severity and magnitude". Furthermore, the resolution refers to the eventual aim of "establishing a long-term framework for in-orbit servicing starting with active debris removal performed on an ESA space object".

- Applications: the resolution addresses Earth Observation Programmes, Telecommunication Programmes, and the Navigation Programme.
  - Within the section on Earth Observation, the resolution elaborates on three groups of missions into which ESA's Earth Observation programmes have been reoriented, namely Future Earth Observation, Operational Earth Observation and Customized Earth Observation. Regarding the Future EO programme – which was formerly the Earth Observation Envelope Programme – ESA welcomes the creation of new Scout and Φ-sat missions to foster the NewSpace domain. For the Operational EO group, the resolution focuses primarily on the "development of six new Sentinel missions and the related ground segment" for Copernicus.
  - Regarding the Telecommunication Programmes, the resolution states the succession of the ARTES Programme by the Programme of Advanced Research in Telecommunication Systems, ARTES 4.0, which is designed to "provide a streamlined and more responsive programmatic toolset to support industry in the increasingly dynamic and fierce competitive market environment". The programme is meant to "ensure that European industry is at the leading edge of the fiercely competitive global telecommunications market".
  - Regarding Navigation, ESA primarily reflects on the progress of the Navigation Innovation and Support Programme (NAVISP) in its first three years and notes that NAVISP "will continue to act along the entire PNT value chain" during Phase 2, to "maintain and develop a technological edge beyond the scope of H2020 and future Horizon Europe activities".

[10] "Resolution on ESA programmes: addressing the challenges ahead" (Resolution 3), adopted by ESA Ministerial Council on 28 November 2019. Available at: https://esamultimedia.esa.int/docs/corporate/Resolution_3_Space19+Final-28Nov-12h30.pdf

- **Enabling and Support:** the resolution reflects on the progress of the development of the Ariane 6 and Vega C launchers and in particular stresses that "the Ariane and Vega launchers not only guarantee Europe's autonomous access to space from Europe's Spaceport in French Guiana but also constitute market enablers beyond the space sector for the European economy". Furthermore, the resolution endorses the ESA Technology Strategy and deems it "necessary for the transformation of the European space sector and the full-scale integration of space into modern economies".

Lastly, in addition to the four pillars of ESA's space activities and programmes, a chapter on the Evolution of the Agency's Industrial Policy reiterates the need for the evolution of ESA's industrial policy and suggests measures to achieve a framework that caters to Europe's diverse industrial landscape within a competitive international market.

Notably, throughout all resolutions, the importance of the relationship between ESA and the EU was stressed, specifically through the mentioning of successful past and present cooperation – e.g. the Copernicus programme, the 2016 ESA-EU Joint Statement on the "shared vision and goals for the future of Europe in space" – or through encouraging future cooperation. In sum, according to ESA Director General Jan Wörner, the Ministerial Council 2019 "put in place a structure that sees inspiration, competitiveness and responsibility underpin our actions for the coming years, with ESA and Europe going beyond our previous achievements with challenging new missions and targets for growth along with the wider industry".[11]

Official group photo Space19+ (Credit: ESA - S. Corvaja)

[11] "ESA ministers commit to biggest ever budget". ESA (November 2019): http://www.esa.int/About_Us/Corporate_news/ESA_ministers_commit_to_biggest_ever_budget

1.2.2 European Union prepares for 2021-2027 with new Commission

New European Commission

2019 has been a key year for the European Union. Between the 23rd and 26th of May 2019 took place the elections for the renewal of the European Parliament (EP). The first task of the new EP has been the appointment of a new Commission. Ms. Ursula von der Leyen, former German Ministry of Defence, was elected President of the European Commission on July 16th 2019 and the new Commission received the Parliament's approval on November 27th 2019 and officially entered office on December 1st 2019.

The new European Commission organisation has contributed to raise the visibility of space as a domain of strategic importance for Europe. For the first time in the history of the European Commission, the Commissioner for the Internal Market – Thierry Breton – will be supported by a Directorate-General exclusively devoted to Defence Industry and Space (DG DEFIS). This development entails the transfer of certain units and directorates from the DG Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) to the new DG for Defence Industry and Space, namely:

- Unit GROW.02 (Financial Management of Space Programmes)
- Directorate GROW I (Space Policy, Copernicus and Defence)
- Directorate GROW J (EU Satellite Navigation Programmes)
- The part of Unit GROW G3 (Access to Procurement Markets) dealing with defence procurement.

DG DEFIS organigramme (as of April 20th 2020) is provided hereafter.[12]

In her Mission Letter to Thierry Breton, Ursula von der Leyen states that space policy is one of the European Union's "most valuable and strategic assets".[13] She calls on the Commissioner to "foster a strong and innovative space industry, maintaining the EU's autonomous, reliable and cost-effective access to space", to implement the future Space Programme (including Galileo, EGNOS and Copernicus), and makes "improving the crucial link between space and defence and security" a priority[14]. It remains to be seen what the dynamic of pairing space with defence industry will yield both in terms of policy and public action.

[12] DG DEFIS organigramme (as of 20 April 2020). Available at: https://ec.europa.eu/info/sites/info/files/organisation_charts/dg-defis-organigramme_en.pdf
[13] Ursula von der Leyen, "Mission Letter to Thierry Breton, Commissioner for Internal Market" (December 2019): https://ec.europa.eu/commission/commissioners/sites/comm-cwt2019/files/commissioner_mission_letters/president-elect_von_der_leyens_mission_letter_to_thierry_breton.pdf
[14] *Ibid.*

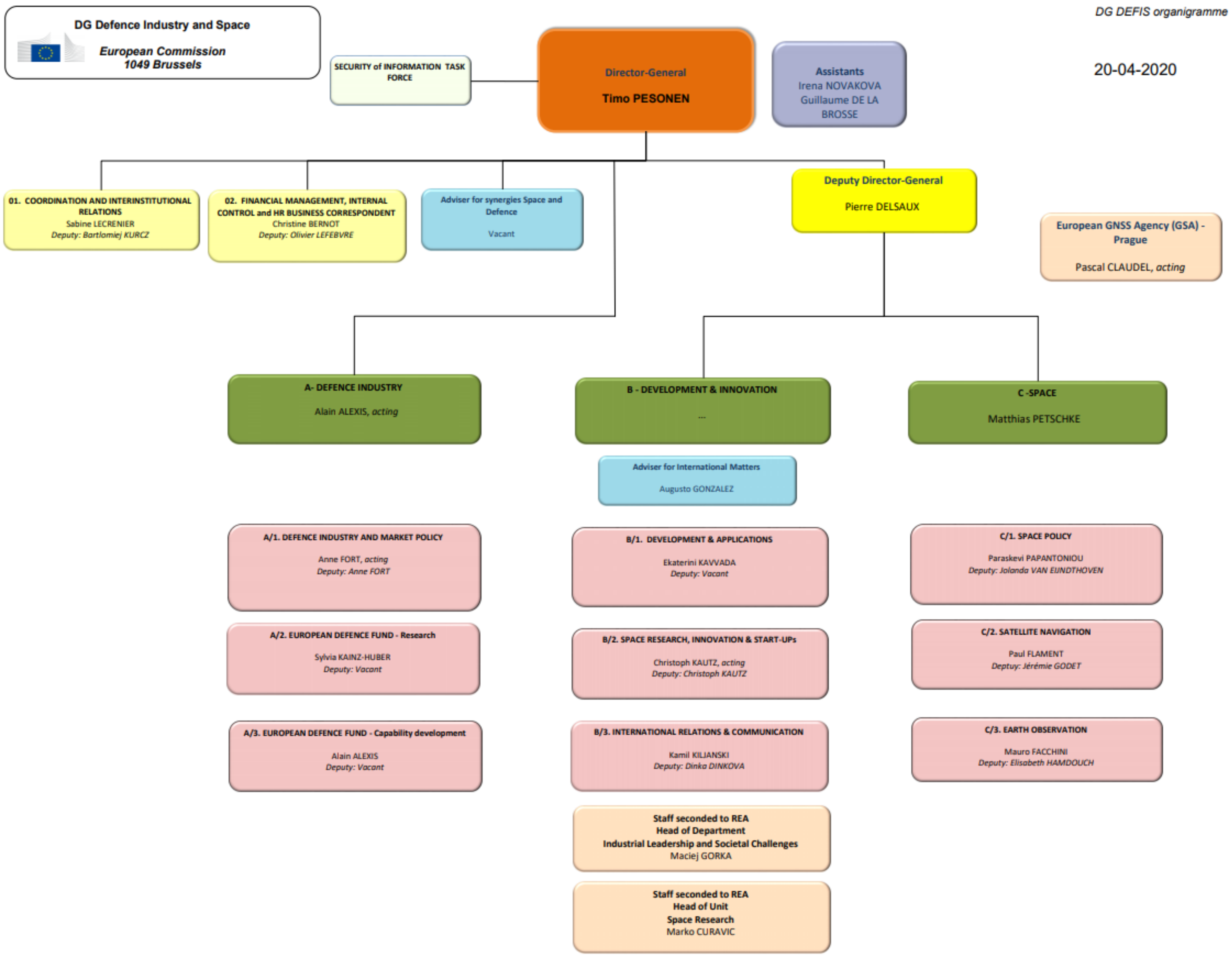


Figure 2: DG DEFIS organigramme – as of April 20th 2020 (Source: European Commission)

The establishment of this new Directorate General marks a crucial step forward in a long-standing political development process. This pairing of defence industry and space clearly yields an interesting dynamic regarding the long-term development of both sectors in the EU framework. In addition, it paves the way towards further potential synergies and raises important questions for the future conduct of EU space affairs:

- On a programmatic level, how will defence-oriented applications and operations be integrated in the EU space programme? How will this rapprochement support the EU space agenda and priorities, in particular with regards to strategic autonomy?
- On a budgetary level, the current ratio of institutional funding supporting R&D between these two domains is quite in favour of space. Will this balance be impacted in the future according to the relative size of the industrial sectors and the needs expressed by Member States?
- On a political level, to what extent will Member States with limited industrial military capabilities support the further growth of EU space defence-related budgets and responsibilities? Will the more active ones agree on any additional transfer of sovereignty towards the EU?
- On an institutional level, what will be the role of the freshly created EU Space Programme Agency (EUSPA) in defence-oriented activities? What will be the distribution of responsibilities between the various EU actors concerned, namely EUSPA, EEAS, EDA, as well as ESA?

These are just a few of the questions that the next Commissioner and Director General in charge of Defence industry and Space will have to tackle in order to clarify the scope of this enlargement of responsibilities of the European Commission. He will be challenged to propose a way forward towards a clear and ambitious European Space, Security and Defence policy adapted to the current evolution of threats posed to EU citizens and assets.

Preparation of the next Multiannual Financial Framework of the Union (MFF 2021-2027)

The roadmap to the adoption of the next European Union Multiannual Financial Framework for 2021-2027 has been drawn although it is still unclear if the contributions will be set according to the cautious level proposed by the outgoing Commission and accounting for the 1.114% of EU27 GNI (Gross National Income) or for the more ambitious proposal made by the Parliament calling for a 1.3% of GNI.[15] (Update 2020: the impact of the COVID-19 on EU budgets including for space activities is still unknown).

Commissioner Thierry Breton at the 12th European Space Conference (Credit: Business Bridge Europe)

Several proposals have been made with reference to the budget allocated to space activities within the next MFF. As of today, the European Space Programme is expected to receive a total endowment of €16 billion for the period 2021-2027. The Commission's objective of the financing

[15] European Commission, "Communication from the Commission to the European Parliament, the European Council and the Council: Time to decide on the Union's financial framework for 2021-2027 - The European Commission's contribution to the European Council meeting on 17-18 October 2019" (October 2019): https://ec.europa.eu/commission/sites/beta-political/files/communication-euco-mff-oct2019_en.pdf

is: "Ensure the continuity of the existing space infrastructures and services and the development of new ones, […] Foster an innovative European space sector that can compete globally, […] Reinforce the EU's capacity to have a guaranteed access to space and space services".[16] This budget includes €9.7 billion for Galileo and EGNOS programmes and €5.8 billion for Copernicus. New activities in the field of Govsatcom and Space Situational Awareness are also proposed within this budget.

As part of the MFF preparation, the next Research and Innovation Framework Programme for the period 2021-2027 (Horizon Europe which will follow Horizon 2020) is also actively discussed. The European Commission allocated a total budget of €100 billion for this programme. This framework is divided in 3 Pillars: 1) Excellent Science, 2) Global Challenges and European Industrial Competitiveness, 3) Innovative Europe. Space would be included under the scope of the second programme which has an earmarked budget of €15 billion. In the space domain, Horizon Europe aims to support EU's strategic flagship programmes (Copernicus, Galileo, EGNOS) and to develop technology and components for future EU space infrastructures such as SSA and Govsatcom programmes. The programme is also expected to support the development and harmonization of a common European technology base and, moreover, to sustain the space industrial ecosystem in order to foster European competitive position in global markets across the space value chain.

The COVID-19 crisis will likely have a profound impact on the overall MFF budget as well as on priorities and provisions of the various resolutions, including for the space programme.

[16] European Commission, "Communication from the Commission to the European Parliament, the European Council and the Council: A Modern Budget for a Europe that Protects, Empowers and Defends – The Multiannual Financial Framework for 2021-2027" (May 2018): https://ec.europa.eu/commission/sites/beta-political/files/communication-modern-budget-may_2018_en.pdf

1.2.3 A change of paradigm in the space defence domain

2019 will likely be remembered as a landmark year in the space defence domain confirming a change of paradigm in the approach of various spacefaring nations and intergovernmental organisations.

Space applications have become central to the conduct of military operations, in particular since the first Gulf War, and satellites have become strategic targets for a range of actors with various motivations and objectives. Security threats to the space infrastructure have multiplied, diversified and intensified. This is taking place in a changing international and geopolitical environment marked by rising tensions and changes in the global balance of power. In this context, the potential vulnerability of space systems has become a major concern, leading some governments to reconsider their doctrines and to adopt more assertive postures in the space domain. More specifically, several space powers are:

- … starting to address space as an operational war faring domain alongside land, air and sea: Many nations are now seeking to improve and demonstrate their capacity and readiness to treat outer space as a theatre of military operations. As a consequence, space increasingly appears as a field of rivalry that could become an arena of conflict.
- … reorganising their armed forces to better address and integrate the space domain: Overall, it is the whole spectrum of space defence activities, from research, development and acquisition to operation and command that is concerned, following new national doctrines and objectives.
- … developing offensive and defensive capabilities as part of space security and deterrence strategies: Major space powers are advancing technologies to disrupt space systems (e.g. kinetic or energy weapons, RPO, electronic and cyber) but also exploring new approaches to reinforce the resilience of their critical space infrastructure (e.g. distributed architectures, responsive capabilities).

The year 2019 was marked by important developments in the space defence domain contributing to this change of paradigm.

New French Space Defence Strategy

On July 13th 2019, French President Emmanuel Macron addressed military personnel at the Defence Minister's residence to announce the approval of the creation of a Space Command within the French Air Force.[17] According to Macron's announcement, the Space Command would "improve the country's defence capabilities" and the "protection of French satellites".[18] Building on the statement made in 2018 on her commitment to increasing France's strategic autonomy in space,[19] French Defence Minister Florence Parly announced on July 25th 2019 France's forthcoming Defence Space Strategy built on the following pillars:

- "a better understanding of the space context",
- "increased and active protection of France's orbital systems",
- "and a strengthened military space capability."[20]

The new French Defence Space Strategy was eventually published a few days later.

Important announcements included that the Space Command would officially be established in Toulouse on September 1st 2019 and would be "placed under the authority of the French Air Force set to become the French Air and Space Force and moreover will replace the existing Joint Space Command (JSC)".[21]

[17] "France to create space command within air force". Reuters (July 2019): https://www.reuters.com/article/us-france-nationalday-defence/france-to-create-space-command-within-air-force-macron-idUSKCN1U80LE
[18] *Ibid.*
[19] *Ibid.*
[20] "Defence, Space Command to be created". CNES (July 2019): https://presse.cnes.fr/en/defence-space-command-be-created
[21] *Ibid.*

The Command has three objectives: reinforcing French capacities regarding space support to operations; developing autonomy in the field of space situational awareness in all orbits; and developing capabilities for active defence in space.

French Minister of Defence Florence Parly at Airbase 942 in Lyon-Mont Verdun (Credit: © Philippe Desmazes/AFP/Getty)

Furthermore, Florence Parly announced that she would like to "see the texts governing the use of space evolving to take into account the specific nature of military space operations"[22]. The objectives of these moves are to provide a greater capacity of action to the armies in space, and to better protect French space capacities that are of strategic nature. To this end, the Minister announced the creation of a draft legislation, designating the Ministry of the Armed Forces the operator of all defence satellites, yet in continuous cooperation with CNES. Moreover, the announcement included the "improvement of space defence capabilities through a new weapons programme called 'Maîtrise de l'Espace' (Space Control)", which will "integrate two components: surveillance and active defence". Surveillance capabilities will be enhanced and a very long-range radar demonstrator will be tested. Active defence capabilities will inter alia include anti-satellite laser capabilities for self-defence purposes[23]. Should French satellites be threatened, France reserves "the right and the means to be able to respond: that could imply the use of powerful lasers deployed from our satellites or from patrolling nanosatellites", with the goal of blinding satellites of the adversaries.[24]

To support these measures and renew French satellite capabilities, Florence Parly announced an investment of €700M (in addition to the €3.6B budget provided by the military planning law) with the aim of reaching full capacity in 2030.[25]

New Italian National Security Strategy for Space

In Italy, 2019 was marked by the release of the "National Security Strategy for Space".[26] The document explores the global nature of the space security issue and calls for of a systemic approach to strengthen the national space sector. Five strategic objectives were set to support the growth and strengthening of the national space sector:

- To ensure the safety and security of space infrastructures;
- To safeguard national security, including through space, by ensuring access to and use of national security capabilities in any situation;

[22] "Florence Parly unveils the French space defence strategy". Permanent Representation of France to the Conference on Disarmament (January 2020): https://cd-geneve.delegfrance.org/Florence-Parly-unveils-the-French-space-defence-strategy
[23] *Ibid.*
[24] "France to develop anti-satellite laser weapons". RFI (July 2019): http://www.rfi.fr/en/france/20190725-france-develop-anti-satellite-laser-weapons
[25] "Defence, Space Command to be created". CNES (July 2019): https://presse.cnes.fr/en/defence-space-command-be-created
[26] Presidency of the Council of Ministers of Italy, *National Security Strategy for Space* (July 2019): http://presidenza.governo.it/AmministrazioneTrasparente/Organizzazione/ArticolazioneUffici/UfficiDirettaPresidente/UfficiDiretta_CONTE/COMINT/NationalSecurityStrategySpace.pdf

- To strengthen and protect the institutional, industrial and scientific sectors;
- To promote a space governance capable of ensuring sustainable, safe and secure space operations at international level;
- To ensure that the development of private initiatives in the space sector (upstream and downstream) is consistent with the country's overriding interests.

The document calls for SST/SSA capabilities development, support to STM initiatives, promotion of a regulatory framework, to address also the growing role of commercial activities. The strategy promotes the adoption of a comprehensive approach to protect all national interests but also asserts that it is part of a European Space Strategy aimed at preserving the leading position of the European Union in this sector. More generally, a strong emphasis is put on international cooperation and diplomacy at bilateral and multilateral levels, enabling the reduction of threats and ensuring a more sustainable space environment. In line with the security strategy, the Ministry of Defence initiated the creation of a space operations command within the Joint Chiefs of Defence Staff, after an overall reorganisation of the Space General Office.[27]

U.S. Space Force and new U.S. approach and posture in space defence

2019 was also a very significant year for U.S. space defence developments, particularly in regards to the reorganisation of the U.S. Armed Forces and the creation of the U.S. Space Force. This is in line with views already expressed in 2018 when President Donald Trump reasserted the vision of space as a war faring domain and expressed the will to set up a Space Force within U.S. Armed Forces.

On 19 February 2019, President Trump signed the Space Policy Directive 4, directing the U.S. Department of Defense to deliver to the Congress a legislative proposal for the creation of a Space Force which was approved in December 2019. This service, which is initially integrated within the Department of the Air Force, aims to "organize, train and equip military space forces of the United States" and "ensure that needed space capabilities are integrated and available to all United States Combatant Commands". The Space Force has the mission to ensure "unfettered access to, and freedom to operate in, space" for the United States and its allies, deter aggression and defend their interests from hostile acts in and from space and project military power in, from, and to space in support of these interests. In addition, the directive also re-established a U.S. Space Command to lead space war faring with forces provided by the U.S. Space Force and other U.S. Armed Forces. By moving space operations from a support function to a fully operational role, this decision "reflects the importance of warfighting in space". This Command was reactivated on the 29 August 2019, and had a staff of 400 people by the end of the year (with an increase to 500 staffers planned by 2020). It is headed by the General John Raymond, who serves also as the first Space Force's Chief of Space Operations.

The Space Policy Directive 4 is actually part of a broader move of the Trump administration to adapt U.S. Armed Forces to a changing military space landscape and achieve space dominance and control. Apart from the Space Force and Space Command initiatives aforementioned, the United States is also seeking to improve and streamline its acquisition process to foster innovation, responsiveness and efficiency. This objective stimulated the creation of a Space Development Agency in March 2019, with the responsibility to unify the various space defence programmes and accelerate technological developments by reducing R&D time cycles and encouraging the integration of commercial solutions. The first project of the SDA is a mega-constellation in low Earth orbit which would fulfil communications

[27] Stefano Pioppi, "Space Force e difesa spaziale secondo il sottosegretario Tofalo". AirPress (December 2019): https://www.airpressonline.it/41094/space-force-difesa-tofalo/

needs, surveillance purposes (especially focused on hypersonic weapons and missile threats), and provide an alternative to GPS.

Eventually, the whole spectrum of U.S. space defence activities is being overhauled, from Research, Development and Acquisition (Space Development Agency) to Operations (U.S. Space Force) and Command (U.S. Space Command). The administration requested $72.4 million for the establishment of the Space Force, $83.8 million for the Space Command and $149.8 million for the Space Development Agency. Overall, the reorganisation of the U.S. space military sector would have cost $306 million as part of Fiscal Year 2020. Yet, decisions of the Appropriations Committees of the Congress modified these numbers. Eventually, the Congress provided around $40 million in FY2020 for the "operations and maintenance" of the Space Force. Debates were more arduous regarding the funding of the SDA, which finally obtained $125M for FY2020 ($30.5M for operations and maintenance, $20M for R&D and $75M for technology prototyping). The positions of Assistant Secretary of the Air Force for space acquisition and integration and Assistant Secretary of Defense for space policy were also created.

Beyond the intent to optimize the functioning of national organisations, these recent decisions also illustrate a changing posture of the United States in the field of military space. Indeed, although some of the proposed changes build on the legacy of previous administrations (e.g. the Space Command already existed until 2002) or are not as ambitious as initially planned (e.g. the Space Force is not yet an independent department), they form part of a broad move toward a more open and assertive stance of the United States in the rising context of a space "security dilemma".

2020 update: Stephen Kitay, Deputy Assistant Secretary of Defense for Space Policy, stated in February 2020 that the United States is developing a new defence space strategy to replace the document elaborated in 2011 under Barack Obama. The new version will revolve around three pillars: maintaining space superiority, providing space support to U.S. and allied forces, and ensuring stability in space.

New NATO space defence policy

NATO members approved in June 2019 an overarching space policy for the organisation. In line with national announcements from some of its member states, NATO also officially recognized space as an operational domain in the same way as air, land, sea or cyber in December 2019. The declaration is firstly a recognition of the significance of space technologies; however, NATO does not own any capabilities in space and declines plans to build its own infrastructures. Nonetheless, the importance of the London Declaration should not be diminished: firstly, the need of a space policy has been shared at various levels during the year, from the Defence Ministers and the Military Committee to the Foreign Ministers; secondly and most importantly, the recognition of space as an operational domain aims to increase opportunities of cooperation and coordination among the large forum of NATO Member States within a consolidated framework of sharing information. Yet, the issues of the potential activation of Article 5 because of a hostile action in space and the management of national space assets during potential space operations still have to be clarified.

Indian ASAT test and new Defence Space Agency

On 27 March 2019, the Indian Ministry of Foreign Affairs announced the successful execution of an anti-satellite (ASAT) missile test launched from Dr. APJ Abdul Kalam Island launch complex, which destroyed an Indian satellite in Low-Earth Orbit (LEO).

Mission Shakti was conducted by the Defence Research and Development Organisation (DRDO) and reportedly was a demonstration of a hit-to-kill ballistic missile interceptor. This ASAT test – announced

Missile launched in anti-satellite test (Credit: DRDO)

by the Indian government and detected by the U.S. military's early warning and surveillance network – makes India the 4th nation to demonstrate such capabilities after the United States, Russia and China. Beyond their implications for possibly increased deployment of weapons in space, ASAT weapon tests are also heavily scrutinised due to their contribution to space debris creation. India claimed that debris created as a result of the test would quickly decay and have very limited consequences for space safety. The impact, which occurred at an altitude of 283 km[28] in fact has proven to be more problematic than claimed, with many debris fragments having high apogee altitudes as well as a life-time well beyond 45 days[29]. Prime Minister Narendra Modi hailed this test, which was conducted with domestic technology, as a moment of national pride and a demonstration of India's status as a space power. While reaffirming India's commitment to the peaceful use of outer space, he also stressed the importance of space for India and for the World, explaining that the defence of space assets is crucial for India.[30]

April 2019 also saw the establishment of India's Defence Space Agency (DSA) – a tri-service agency tasked with commanding "the space assets of the Army, Navy and Air Force, including the military's anti-satellite capability"[31] and is projected to begin operation in Fall 2019.[32] According to a Ministry of Defence official, the agency will have a staff of approximately 200 people from the three branches of the armed forces and also incorporate the previously existing military space agencies, which include the Defence Imagery Processing and Analysis Centre and the Defence Satellite Control Centre[33]. According to an announcement made in June 2019 by the Indian Cabinet Committee on Security, the work of the DSA will be supported through the creation of the Defence Space Research Organization (DSRO). This organisation is tasked to "provide technical and research support to its parent organisation, the Defence Space Agency"[34] and thus, in conjunction with the DSA, will aid India "at developing a multidimensional approach to using outer space for strategic purposes".[35]

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[28] "Frequently Asked Questions on Mission Shakti, India's Anti-Satellite Missile test conducted on 27 March, 2019". Ministry of External Affairs (March 2019): https://mea.gov.in/press-releases.htm?dtl/31179/Frequently+Asked+Questions+on+Mission+Shakti+Indias+AntiSatellite+Missile+test+conducted+on+27+March+2019

[29] Marco Langbroek, "Why India's ASAT Test Was Reckless". The Diplomat (April 2019): https://thediplomat.com/2019/05/why-indias-asat-test-was-reckless/

[30] "Speech by Prime Minister on "Mission Shakti", India's Anti-Satellite Missile test conducted on 27 March, 2019". Ministry of External Affairs of India (March 2019): https://mea.gov.in/Speeches-Statements.htm?dtl/31180/Speech_by_Prime_Minister_on_Mission_Shakti_Indias_AntiSatellite_Missile_test_conducted_on_27_March_2019

[31] Vivek Raghuvanshi, "India to launch a defense-based space research agency". DefenseNews (June 2019): https://www.defensenews.com/space/2019/06/12/india-to-launch-a-defense-based-space-research-agency/

[32] Rajat Pandit, "Agencies take shape for special operations, space, cyber war". The Times of India (May 2019): https://timesofindia.indiatimes.com/india/india-begins-setting-up-new-tri-service-agencies-to-handle-special-operations-space-and-cyberspace/articleshow/69346012.cms

[33] Vivek Raghuvanshi, "India to launch a defense-based space research agency".

[34] *Ibid.*

[35] *Ibid.*

United Nations: adoption of three resolutions related to the militarisation of outer space

The First Committee (Disarmament and International Security) of the United Nations General Assembly adopted three resolutions related to the militarisation of outer space in November 2019.

Resolution 1: "No first placement of weapons in outer space" (A/C.1/74/L.59)

- Resolution was approved with 123 in favour, 14 against and 40 abstentions. The resolution concerns the continuation of work in the Conference on Disarmament on the topic on the basis of a revised draft treaty proposed by Russia and China in 2008 and the "possibility of undertaking political commitments not to be the first to place weapons in outer space".The resolution proposed by a group of countries including Russia, China, Cuba, North Korea and Syria was met with concern by some delegations, including Germany, as being insufficient to "respond to the objectives of maintaining and strengthening trust" while also including "ambiguities and shortcomings" regarding the issue of anti-satellite capabilities and a clear definition of space weapons.

Resolution 2: "Further practical measures for the prevention of an arms race in outer space" (A/C.1/74/L.58/Rev.1)

- Resolution was approved with 124 in favour, 41 against and 10 abstentions. The resolution includes an endorsement of the 2018-2019 work of the Group of Governmental Experts regarding the "elements of an international legally binding instrument on the prevention of an arms race in outer space" and advocates for further work in this regard.

Resolution 3: "Transparency and confidence-building measures in outer space activities" (A/C.1/74/L.60)

- Resolution was approved with 166 in favour, 2 against and 5 abstentions. Particularly, Member States are encouraged to "continue to review and implement the transparency and confidence-building measures proposed in the 2013 report of the Group of Governmental Experts on the issue".

Figure 3: Resolutions adopted by the United Nations General Assembly in November 2019 related to the militarisation of outer space[36, 37]

Other outstanding developments and events

The UK Ministry of Defence, announced a series of initiatives for its 'ambitious space programme" at the RAF Air and Space Power conference in July 2019.[38] First and foremost, the former Defence Secretary Penny Mordaunt announced the transformation of the Joint Forces Command into a Strategic Command (UKStratCom) and giving it "a greater strategic role across the five war-fighting domains: Air, Land, Sea,

[36] "First Committee Approves 11 Drafts Covering Control over Conventional Arms, Outer Space Security, as United States Withdraws Text on Transparency". United Nations (November 2019): https://www.un.org/press/en/2019/gadis3642.doc.htm
[37] United Nations General Assembly, First Committee, "Further practical measures for the prevention of an arms race in outer space" (October 2019): https://undocs.org/en/A/C.1/74/L.58/Rev.1
[38] "Defence Secretary outlines ambitious space programme". UK Ministry of Defence (July 2019): https://www.gov.uk/government/news/defence-secretary-outlines-ambitious-space-programme. See also: "Raytheon and UK Ministry of Defence team to develop new UK space capabilities". Raytheon (July 2019): http://investor.raytheon.com/news-releases/news-release-details/raytheon-and-uk-ministry-defence-team-develop-new-uk-space?ID=2404238&c=84193&p=irol-newsArticle

Cyber and Space"[39]. Moreover, the Ministry announced a €33M investment in a small satellite demonstrator project, to be supported by a joint UK-US team called Team ARTEMIS. The Defence Secretary further announced the UK becoming the "first formal partner in the US-led Operation Olympic Defender: a multinational coalition formed to strengthen deterrence against hostile actors in space and reduce the spread of debris in orbit"[40].

In addition to these initiatives, the Ministry of Defence also announced the secondment of an RAF member of staff to the Virgin Orbit programme[41] and the assignment of Airbus with the Oberon project, a study on ultra-high-resolution SAR satellites.[42]

Japan's Ministry of Defence states in its "Defence of Japan 2019" whitepaper that a Space Domain Mission Unit will be established within the Air Self Defence Force (ASDF) "in order to conduct persistent monitoring of situations in outer space, and to ensure superiority in this domain at all stages, from peacetime to armed contingencies".[43] It is aimed to establish this space situation monitoring system by FY2022.

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[39] "Defence Secretary outlines ambitious space programme". Government of the United Kingdom (July 2019)
[40] *Ibid.*
[41] *Ibid.*
[42] "Airbus to develop technology for ultra-high-resolution satellites for UK MOD". Airbus (September 2019): https://www.airbus.com/newsroom/press-releases/en/2019/09/airbus-to-develop-technology-for-ultrahighresolution-satellites-for-uk-mod.html
[43] Ministry of Defense of Japan. *Defense of Japan 2019* (September 2019): https://www.mod.go.jp/e/publ/w_paper/pdf/2019/DOJ2019_Full.pdf

1.2.4 Space safety and sustainability, rising issues in space policy agendas

The year 2019 has also been marked by major developments in the field of space safety and sustainability, confirming the growing importance of this topic in space policy and diplomacy agendas.

ESA's Annual Space Environment Report highlighting space debris issues

The European Space Agency publishes every year a comprehensive report on the evolution of debris environment in near-Earth orbits. [44]

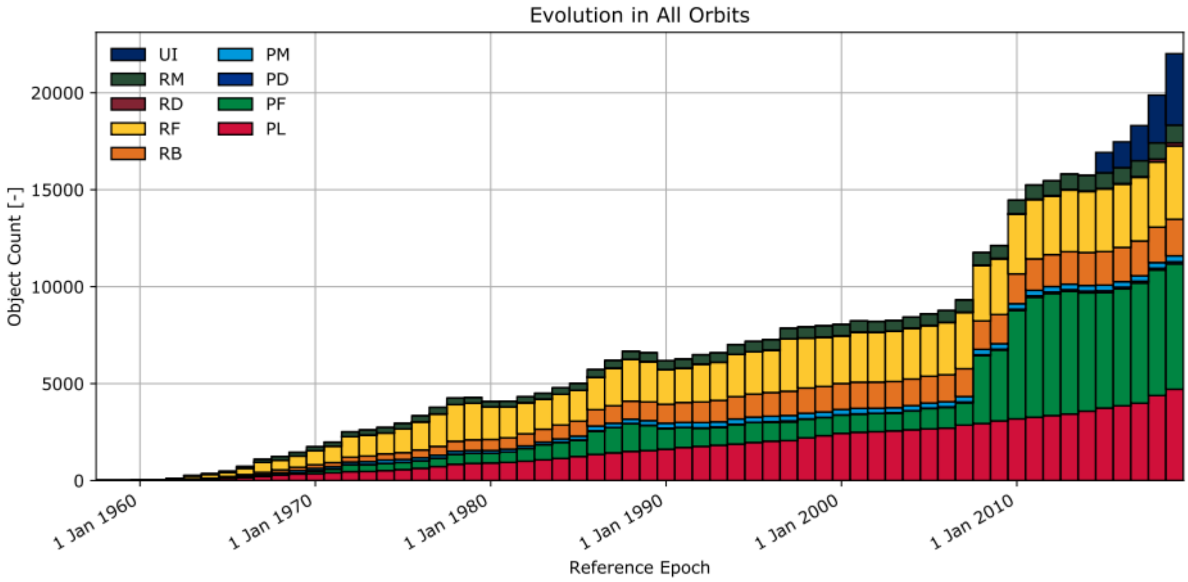

Figure 4: Evolution of the number of objects in all orbits (Source: ESA)[45]

The report provides a very large set of data and indicators but also puts the evolution of man-made space debris in perspective with existing space debris mitigation best practises, particularly when with respect to two "protected" orbital regions – the Low Earth Orbit (LEO) and the geostationary arc (GEO). The 2019 edition of ESA's Space Environment Report reached the following conclusions:[46]

- The number, mass and combined area of space objects keeps on rising, leading to the possibility of involuntary collisions between operational payloads and space debris. Launch traffic into the LEO protected region is changing significantly, fuelled by the proliferation of small payloads (below 10kg).
- Between 30% and 60% of all payload mass reaching end-of-life in the LEO protected region does so in orbits estimated to adhere to space debris mitigation measures. Between 15 and 25% of payloads reaching end-of-life in non-compliant orbits attempt to comply with space debris mitigation measures. Between 5% and 15% do so successfully.
- Around 70% of all rocket body mass reaching end-of-life do so in orbits that are estimated to adhere to the space debris mitigation measures on protecting LEOIADC. A significant amount of this is due to controlled re-entries after launch, a practice which is increasing. Between 40 and 70% of rocket bodies reaching end-of-life in non-compliant orbits attempt to comply with the space debris mitigation measures. Between 30% and 60% do so successfully.

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[44] ESA/ESOC. *ESA's Annual Space Environment Report* (July 2019): https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf

[45] PL: Payload, PF: Payload Fragmentation Debris, PD: Payload Debris, PM: Payload Mission Related Object, RB: Rocket Body, RF: Rocket Fragmentation Debris, RD: Rocket Debris, RM: Rocket Mission Related Object, UI: Unidentified

[46] ESA/ESOC. *ESA's Annual Space Environment Report* (July 2019)

United Nations adopts Long-Term Sustainability guidelines

UN COPUOS session (Credit: UN Office of Outer Space Affairs)

The adoption of the Guidelines for the Long-term Sustainability of Outer Space Activities (LTS guidelines) by the UN COPUOS in June 2019 has been a major step from the international space community. This is also the outcome of a long process started by the Scientific and Technical Subcommittee in 2010 with the appointment of a dedicated Working Group to identify the priorities related to the sustainability of space activities.[47] Nine years later, during its 62nd session, the UN COPUOS eventually adopted the preamble and final version of 21 guidelines expected to enhance the safety and sustainability of space operations.[48]

The LTS Guidelines defines "long-term sustainability of outer space activities" as "the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations.[49]" The Guidelines provide non-legally binding guidance on:

- Policy and regulatory framework for space activities: national regulatory frameworks; supervision of national space activities; best practices concerning the registration of space objects; and the use of the radio frequency spectrum;
- Safety of space operations: sharing contact information, accurate orbital data and information on space objects, space debris and space weather; conjunction assessment performed during all orbital phases; risks of uncontrolled re-entry of space objects;

[47] United Nations Committee on the Peaceful Uses of Outer Space. "Report of the Scientific and Technical Subcommittee on its fourty-seventh session, held in Vienna from 8 to 19 February 2010" (March 2010): https://www.unoosa.org/pdf/reports/ac105/AC105_958E.pdf
[48] United Nations General Assembly. "Report of the Committee on the Peaceful Uses of Outer Space, Sixty-second session (12-21 June 2019)" (July 2019): https://www.unoosa.org/res/oosadoc/data/documents/2019/a/a7420_0_html/V1906077.pdf
[49] United Nations Committee on the Peaceful Uses of Outer Space. "Guidelines for the Long-term Sustainability of Outer Space Activities": https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf

- International cooperation, capacity-building and awareness: promote and support the implementation of the guidelines and capacity-building at national level, share of experiences and expertise, raise public awareness on the societal benefits of space;
- Scientific and technical research and development: promote research to enhance the guidelines and investigate new measures to manage space debris, related also to in-orbit servicing.

The United Nations General Assembly decided in September 2019 to include the agenda item titled "International cooperation in the peaceful uses of outer space" in the Special Political and Decolonization Committee (Fourth Committee), which presented a draft resolution in November 2019 (A/74/408).[50] The resolution included a paragraph specifically related to the guidelines which stated that the General Assembly welcomes *the adoption by the UN COPUOS of the preamble and 21 LTS guidelines and notes that the UN COPUOS encouraged States and international intergovernmental organisations to voluntarily take measures to ensure that the guidelines were implemented to the greatest extent feasible and practicable. The document also emphasizes that the UN COPUOS serves as the principal forum for continued institutionalized dialogue on issues related to the implementation and review of the guidelines*. The draft resolution on International Cooperation in the Peaceful Uses of Outer Space was adopted by the General Assembly on 13 December 2019 (A/RES/74/82).[51]

European External Action Service introduces the 3SOS initiative

Carine Claeys (right) Special Envoy for Space and Head of the Space Task Force for the EEAS (Credit: EEAS)

Fall 2019 saw the creation of a new initiative by the European Union – more specifically the EEAS. Carine Claeys, Special Envoy for Space and Head of the EEAS Space Task Force announced the creation of a new public diplomacy initiative on 13 September during a panel discussion at Euroconsult's World Satellite Business Week. According to Claeys, the "'Safety, Security and Sustainability of Outer Space (3SOS)[52]' public diplomacy initiative will promote 'ethical conduct' in space amid concerns about orbital debris". The initiative will initially enlist the support from industry, space agencies and think tanks to build "a common understanding of reasonable behaviour"[53] in space, building on efforts such as the Guidelines for the Long-term Sustainability of Outer Space Activities approved by UNCOPUOS in June 2019.

[50] United Nations General Assembly, Fourth Committee. "International cooperation in the peaceful uses of outer space" (November 2019): https://undocs.org/pdf?symbol=en/A/74/408
[51] United Nations General Assembly. Resolution A/RES/74/82 "International cooperation in the peaceful uses of outer space" (December 2019): https://undocs.org/en/A/RES/74/82
[52] "SOS SOS SOS : EU calls for ethical conduct in space to avoid collision and orbital debris". European External Action Service (September 2019): https://eeas.europa.eu/headquarters/headquarters-Homepage/67538/sos-sos-sos-eu-calls-ethical-conduct-space-avoid-collision-and-orbital-debris_id
[53] *Ibid.*

Progress on U.S. national Space Traffic Management policy implementation despite political uncertainties

In June 2018, the White House issued the Space Policy Directive-3 (SPD-3), a.k.a National Space Traffic Management Policy, which defines the principles, goals, roles and responsibilities as well as guidelines to be followed for the establishment of a new U.S. approach to STM, including a new sharing of responsibility between the U.S. Department of Defense (DoD) and Department of Commerce (DoC).[54]

With regards to the implementation of this policy, 2018 and 2019 have been marked by political discussions within the U.S. Congress about the office/agency best suited to handle responsibilities and tasks related to SSA/STM. Two legislative proposals with diverging views were submitted: the American Space SAFE Management Act (put forward in the House of Representatives and giving a broader authority to the DoC) and the Space Frontier Act (put forward in the Senate and reinforcing the role of the FAA). None of these acts have yet been transformed into legislation. Beyond mandate issues, progress has also been stalled by budget allocation. To properly fulfil envisioned functions, the DoC requested a budget of $10 million starting in 2020 for a new Bureau of Space Commerce reporting directly to the Secretary of Commerce. The Bureau would merge past and new responsibilities of the current Office of Space Commerce and of the Office of Commercial Remote Sensing Regulatory Affairs. In 2019, this question had not yet been resolved either.

Despite some administrative and policy blocking points, U.S. departments and agencies already started to work on the concrete implementation. Some preliminary steps were made to prepare the transfer of civil-oriented SSA/STM responsibilities and competences from the DoD to the DoC and to start the development of an Open Architecture Data Repository of SSA data. Based on the DoD catalogue, the repository is planned to become the main instrument to provide civil SSA data and STM services.

Also, during 2019, the DoC as well as other U.S. agencies for space, namely the Federal Aviation Administration (FAA) and Federal Communications Commission (FCC), conducted independent public consultation processes to gather views from industry and experts on future necessary actions related to best practices, standards, regulation and commercial perspectives. There were three consultations in the context of SPD-3:

- FCC's Notice of Proposed Rulemaking on "Mitigation of Orbital Debris in the New Space Age" (released on 19 February 2019): The consultation aimed to prepare the first major overhaul of the FCC's satellite debris mitigation rules since 2004.
- FAA's Notice of Proposed Rulemaking on "Streamlined Launch and Re-entry Licensing Requirements" (released on 14 May 2019): The FAA proposed updating, streamlining and increasing regulation flexibility to establish a single set of licensing and safety regulations across several types of operations and vehicles.
- DoC's Request for Information on "Commercial Capabilities in SSA and STM" (released on 11 April 2019): The consultation involved three primary questions on commercial enhanced SSA/STM capabilities, on orbital debris mitigation best practices, and on appropriate SSA/STM-related regulations to spur U.S. space commerce.

In parallel, an interagency working group led by NASA worked on the update of U.S. Orbital Debris Mitigation Standard Practices (ODMSP) which set rules for all U.S. satellite operators, including the military. Several points of disagreements slowed down the progress of the working group but the federal government eventually issued updated guidelines in November 2019[55]. Overall, updates to the ODMSP were rather limited and the new version does not require a much more stringent approach to debris mitigation from satellite operators.

[54] The White House. "Space Policy Directive-3 National Space Traffic Management Policy" (18 June 2018)
[55] *U.S. Government Orbital Debris Mitigation Standard Practices* (November 2019)

Multiple industry-led initiatives

The awareness of space actors regarding the issue of space debris and the risk of collision, which would result in the loss of active spacecraft and the production of even more debris, is getting more acute. Industrial stakeholders are particularly sensitive to this topic, given the fact that their financial results can be strongly impacted in case of an accident. Therefore, given the slow pace of the political initiatives aiming at setting up regulations, industry has started to propose some standards to limit the risks associated with space junk. The main event of the year in this domain was the creation of the Space Safety Coalition (SCC) in September, which gathers 34 companies ranging from manufacturers to launch providers and satellite operators, and from big companies (Airbus, SES, Inmarsat…) to smaller ones (Astroscale, D-Orbit, Rocket Lab…)[56]. The Coalition published a set of propositions, called "Best Practices for the Sustainability of Space Operations", which were endorsed by its members. The best practices apply to spacecraft of all sizes and aim at facilitating the implementation of the 21 Long-Term Sustainability Guidelines approved by the UN COPUOS in June 2019[57].

In addition to the SCC, two other industry-led associations also engaged in the publication of principles for the safety of space operations.

First, the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS), an organisation focused on RPO and IOS activities and which mainly gathers industrial actors but, also, governmental ones, released in February its "Recommended Design and Operational Practices"[58]. These practices intend to make RPO and IOS activities safer; some of them address the issue of debris, especially by highlighting the need to take measures in order to mitigate their production. This initiative demonstrates the will of industry, even if limited here to a specific activity, to contribute to make the space environment cleaner and safer.

Finally, national organisations also share this mindset: for instance, in the United States, the Satellite Industry Association (SIA) issued in October several "Principles of Space Safety for the Commercial Satellite Industry", to which SIA members committed. These principles include, here again, proposals to avoid an overproduction of debris, through means like the selection of spacecraft designs enabling passivation, regular monitoring of a spacecraft's health to avoid an unplanned loss, etc.[59]

In addition to these industry-led initiatives, active discussions are reportedly taking place in standardisation bodies such as the ISO and CCSDS.

EU SST Consortium: progress toward a European catalogue of space objects

Important steps forward have also been reported by the European SST Consortium, a group of EU Member States interested in reinforcing European capabilities and cooperation in the field of Space Surveillance and Tracking. In 2019, the membership of the Consortium increased to include Poland, Portugal and Romania (in addition to France, Germany, Italy, Spain, United Kingdom) New agreements were signed to include Poland (POLSA), Portugal (GPSST), and Romania (ROSA).[60]

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[56] "Endorsees", Space Safety Coalition: https://spacesafety.org/?page_id=310
[57] "About", Space Safety Coalition: https://spacesafety.org/?page_id=9
[58] "CONFERS Recommended Design and Operational Practices". Consortium for Execution of Rendezvous and Servicing Operations (October 2019): https://www.satelliteconfers.org/wp-content/uploads/2019/10/CONFERS_Operating_Practices.pdf
[59] "Principles of Space Safety for the Commercial Satellite Industry", Satellite Industry Association (October 2019): https://www.sia.org/space_safety/
[60] Pascal Faucher, Regina Peldszus and Amélie Gravier. *Operational Space Surveillance and Tracking in Europe*, Paper for the First International Orbital Debris Conference (December 2019). Abstract available at: https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6165.pdf

In April 2019, the data sharing process of this consortium evolved with the "development of a dedicated European Database", serving "as a common platform for data sharing between the members of the Consortium".[61] According to the SST Consortium, "this database is the starting point for the building and maintenance of a European catalogue of space objects, where measurements will be correlated and combined in order to determine and refine the orbit of space objects. This European catalogue precursor is currently in development and represents a fundamental element of European cooperation between Member States in the area of SSA."[62]

Other outstanding developments and events

In August 2019, the Chairman of the Indian Space Research Organisation – Dr K. Sivan – laid the foundation stone for the Space Situational Awareness Control Centre. While ISRO already had set up a Directorate of Space Situational Awareness and Management, the Control Centre was established to more systematically carry out a variety of activities related to Space Situational Awareness & Management (SSAM) and thus protecting "Indian Space assets from inactive satellites, pieces of orbiting objects, near earth asteroids and adverse space weather conditions"[63]. Furthermore, the Control Centre will be built with the aim of enabling "research activities pertaining to active debris removal, space debris modelling and mitigation".[64] Contrary to the Indian claim of minimal risk to other satellites, of the debris fragments tracked and published by the CSpOC in May 2019, around 79% "have apogee altitudes above the orbital altitude of the International Space Station", some "up to as high as 2,250km"[65] with the strongest concentration "between 200km and 900km altitude" – "well into the realm of the orbital altitudes of many commercial as well as scientific and military satellites". Moreover, orbital lifetime estimates of some of the debris fragments far exceed 45 days and are estimated to rather have orbital lifetimes of weeks if not years in some cases[66].

CNES signed a Declaration of Intent on SSA and STM with the U.S. Department of Commerce on 23 October 2019. This Declaration reflects on the importance of SSA and STM for the safe pursuit of space commerce and exploration. While acknowledging that France and the United States already share many priorities and objectives regarding both SSA and STM – the Declaration shows both countries intent to further cooperate on these matters, including inter alia through the exchange of scientific and technological information, discussions and dialogues, as well as through the formalisation of a Memorandum of Understanding. Notably, the Declaration states that "international regulation in space traffic management is neither necessary nor desirable in the short term".[67]

[61] *Ibid.*
[62] *Ibid.*
[63] "Foundation stone of Space Situational Awareness Control Centre by Chairman, ISRO". ISRO (August 2019): https://www.isro.gov.in/update/03-aug-2019/foundation-stone-of-space-situational-awareness-control-centre-chairman-isro
[64] *Ibid.*
[65] Marco Langbroek, "Why India's ASAT Test Was Reckless". The Diplomat (April 2019): https://thediplomat.com/2019/05/why-indias-asat-test-was-reckless/
[66] *Ibid.*
[67] *Declaration of Intent between the Department of Commerce of the United States of America and the Centre National d'Etudes Spatiales of France for Collaboration in Space Situational Awareness and Space Traffic Management* (October 2019): https://www.commerce.gov/sites/default/files/2019-10/DeclarationofIntentDOCCNES.pdf

1.2.5 Progress of Moon exploration plans despite unresolved questions

Progress on the Artemis programme and the Lunar Gateway

2019 has also been marked by various developments and announcements regarding U.S. space exploration plans. In particular, with regards to the implementation of the 2017 U.S. Space Policy Directive 1 which set the goal to "lead an innovative and sustainable programme of exploration with commercial and international partners" and to "lead the return of humans to the Moon for long-term exploration and utilisation, followed by human missions to Mars and other destinations".[68]

The U.S. plans and objectives were specified along the year. In March 2019, President Trump directed NASA to land the first American woman and the next American man on the lunar South Pole in the next five years, thus setting the goal for NASA to complete its first crewed mission to the moon by 2024.

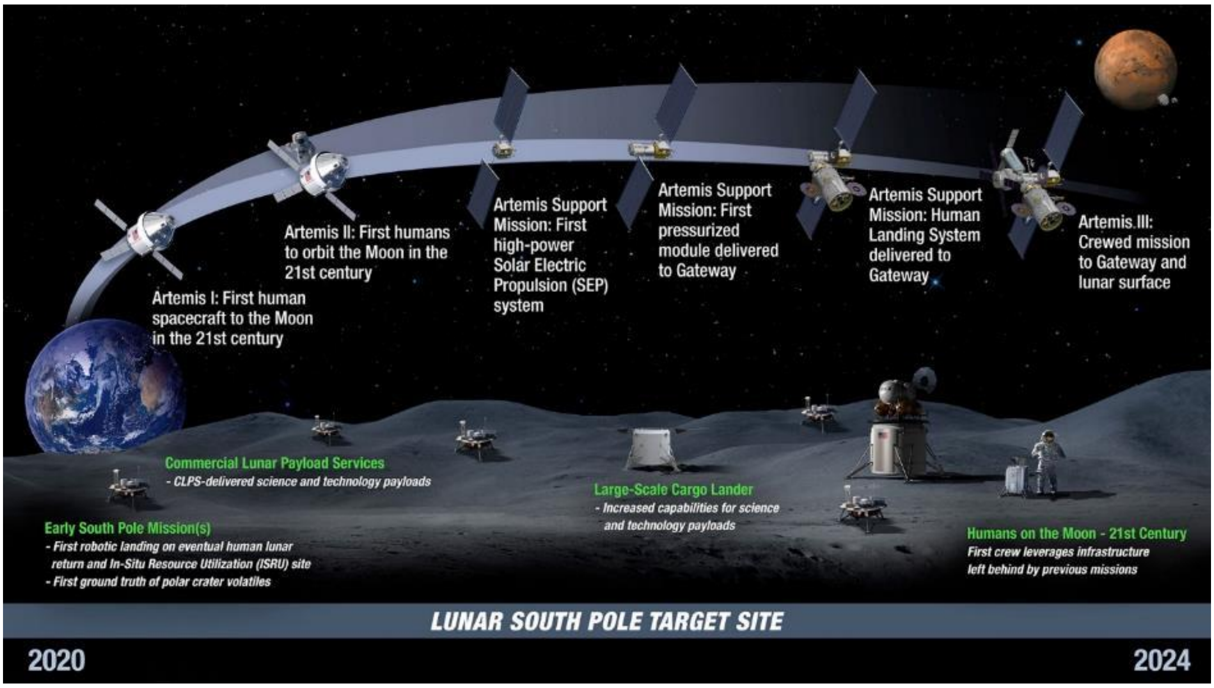

Figure 5: Artemis phase 1 – Path to the Lunar surface (Credit: NASA)

The program to achieve this feat was coined Artemis, and comprises three main programme components:

- The Orion spacecraft: According to NASA, Orion is "a human spacecraft for deep-space missions that will usher in a new era of space exploration"[69]. More specifically, "Orion will serve as the exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain astronauts during their missions and provide safe re-entry from deep space return velocities"[70].
- The Lunar Gateway: Formerly known as the Deep Space Gateway (DSG) and then as the Lunar Orbital Platform-Gateway (LOP-G), the Lunar Gateway is a structure meant to function as an outpost in a highly-elliptical lunar orbit, thus enabling ease of access to the Moon and return to Earth. Primarily, "it will provide shelter and a place to stock up on supplies for astronauts en route to more distant

[68] The White House. "Presidential Memorandum on Reinvigorating America's Human Space Exploration Program" (December 2017): https://www.whitehouse.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/
[69] "Orion Overview". NASA (last updated: July 2019): https://www.nasa.gov/exploration/systems/orion/about/index.html
[70] *Ibid.*

destinations. It will also offer a place to relay communications and can act as a base for scientific research."[71]

- The Space Launch System (SLS): The SLS is the heavy-lift rocket "designed for deep space missions and will send Orion or other cargo to the Moon", "offering more payload mass, volume capability and energy to speed missions through space than any current launch vehicle", and is to be launched from Kennedy Space Center in Florida.[72]

The programme will also involve the development of:

- Lunar Landers: Human lunar landing systems designed and developed by American companies, for which NASA is has sought proposals in 2019. [73]
- Exploration Ground Systems: a NASA programme aiming to ensure that the Kennedy Space Center can handle several different kinds of spacecraft and rockets – both governmental and commercial"[74]
- Artemis Generation Spacesuits, also called the Exploration Extravehicular Mobility Unit (xEMU)[75]

The Artemis programme will also involve other public-private partnerships to be established by NASA such as Gateway Logistics Services (delivery of cargo to the Lunar Gateway) or Commercial Lunar Payload Services (transportation of small systems to the Moon surface, through end-to-end commercial payload delivery services contracts). Industry involvement in the Artemis programme is addressed in more details in the Industry & Innovation part of this Yearbook.

Formalisation of some international partnerships for the Artemis programme

The United States has repeatedly called upon international partners for their contributions and cooperation.

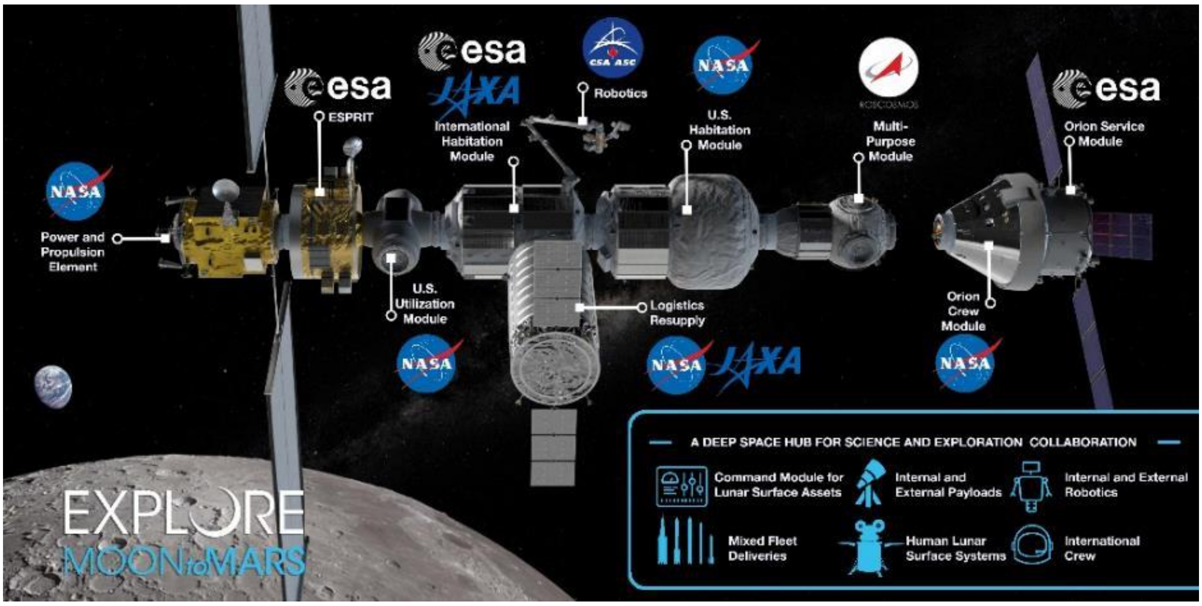

Figure 6: Gateway configuration concept and international contributions (Credit. NASA)

[71] "Gateway with Orion". ESA (May 2019): https://www.esa.int/ESA_Multimedia/Images/2019/05/Gateway_with_Orion
[72] "Space Launch System (SLS) Overview". NASA (last updated: November 2019): https://www.nasa.gov/exploration/systems/sls/overview.html
[73] "Fast-Track to the Moon: NASA Opens Call for Artemis Lunar Landers". NASA (last updated: April 2020): https://www.nasa.gov/feature/fast-track-to-the-moon-nasa-opens-call-for-artemis-lunar-landers
[74] "Exploration Ground Systems Overview". NASA (last updated: January 2020): https://www.nasa.gov/content/exploration-ground-systems-overview
[75] "A Next Generation Spacesuit for the Artemis Generation of Astronauts". NASA (last updated: April 2020): https://www.nasa.gov/feature/a-next-generation-spacesuit-for-the-artemis-generation-of-astronauts/

Already in March 2019, the International Space Station (ISS) Multilateral Coordination Board (MCB) endorsed the development of the Lunar Gateway as the "critical next step" within "a broader open architecture for human lunar exploration".[76] The MCB members are the cooperating ISS partner organisations, which include NASA, ESA, JAXA, the Canadian Space Agency and Roscosmos.

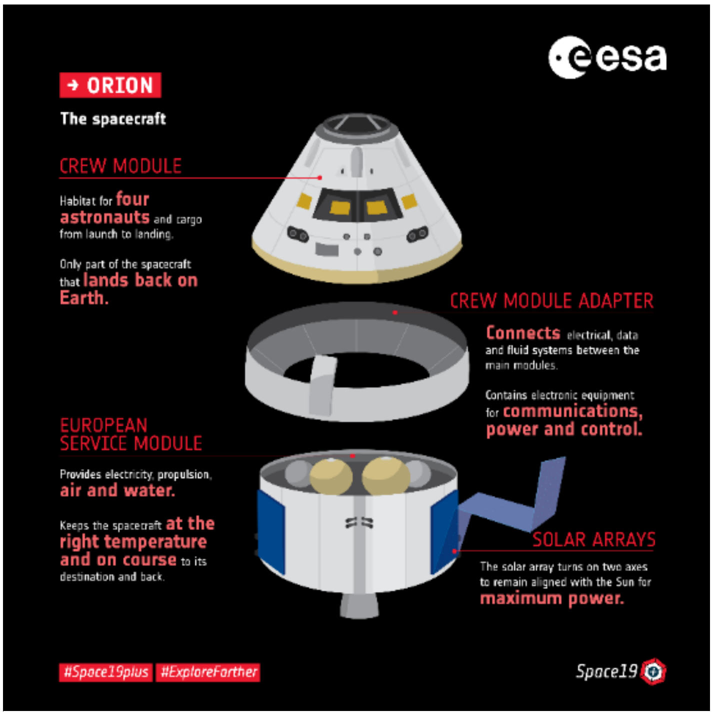

Figure 7: European contribution to Orion (Credit: ESA)

The European Space Agency is contributing to the Orion spacecraft (Orion Multi-Purpose Crew Vehicle), which consists of the Crew Module and the European Service Module[77]. The European Service Module "provides electricity, water, oxygen and nitrogen as well as keeping the spacecraft at the right temperature and on course"[78]. In November 2018, the European Service Module arrived in Florida, USA from Bremen, Germany to complete assembly, joining and testing. In November 2019, the spacecraft was transported to NASA's Plum Brook Station for further testing in a thermal vacuum chamber[79]. The module includes solar arrays, three different engines, tanks for fuel and consumables (oxygen, nitrogen and water), as well as radiators and heat exchangers[80]. The Crew Module provides room for four astronauts and cargo, sits on top of the service module and through its heatshield is able to re-enter the Earth's atmosphere[81]. The main contractor for the European Service Module is Airbus DS with other European companies supplying components. Orion is scheduled to fly in an un-crewed flight to the Moon in 2020, send astronauts to lunar orbit in 2022 and complete a crewed landing on the Moon in 2024.

In addition to ESA's contributions to the Orion spacecraft, potential involvement of ESA includes "the ESPRIT module to provide communications and refuelling of the Gateway and a science airlock for deploying science payloads and cubesats".[82] European participation in in the Lunar Gateway endeavour remains to be formalised as stated in the third resolution of the ESA Ministerial Council of November 2019. Nonetheless, through the European participation in the development of the Orion spacecraft, the

[76] NASA, CSA, ESA, Roscosmos and Japan's MEXT. *Multilateral Coordination Board Joint Statement* (March 2019): https://www.nasa.gov/feature/multilateral-coordination-board-joint-statement
[77] "Orion: The spacecraft". ESA (November 2018): http://www.esa.int/ESA_Multimedia/Images/2018/11/Orion_The_spacecraft
[78] "European Service Module". ESA: https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Orion/European_Service_Module
[79] "Orion spacecraft arrives at Plum Brook". ESA (November 2019): https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Orion/Orion_spacecraft_arrives_at_Plum_Brook
[80] "European Service Module". ESA.
[81] "The spacecraft". ESA: https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Orion/The_spacecraft
[82] "Gateway to the Moon". ESA (Mars 2019): https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Gateway_to_the_Moon

European Space Agency considers itself "already an important stakeholder in the Lunar Gateway endeavour".[83]

Alongside the celebrations for the Moon landing anniversary, the UK Space Agency and NASA signed a Joint Statement of Intent for Lunar Research and Exploration to create a working group to coordinate and optimise the scientific research and future opportunities.[84]

Building on decades-long international cooperation, particularly with ISS partners, Canada will contribute primarily to the Lunar Gateway through "Canadarm3, a smart robotic system which includes a next-generation robotic arm as well as equipment and specialised tools".[85] According to the Canadian Space Agency, this highly autonomous system will use artificial intelligence and will be able to:

- "maintain, repair and inspect the Gateway";
- "capture visiting vehicles";
- "relocate Gateway modules";
- "help astronauts during spacewalks";
- "enable science both in lunar orbit and on the surface of the Moon"[86].

The Canadarm3 forms a particularly crucial part to the success of the Lunar Gateway, as the Gateway will not be continuously crewed – unlike the ISS – and therefore requires the Canadarm3 to perform these tasks without real-time human intervention[87]. To this end, the Canadian Space Agency announced on 19 August that it has awarded two contracts with a combined value of approximately $7 million Canadian dollars to the Canadian company MacDonald, Dettwiler and Associates (MDA) in preparation of Canadarm3 – the first of which "covers concept and technology development activities of robotics interfaces" for the *exploration large arm* (XLA), while the other covers similar activities for the smaller *exploration dexterous arm* (XDA)[88].

Regarding its contribution to the U.S.-led Gateway and Artemis mission, JAXA President Hiroshi Yamakawa welcomed NASA Administrator James Bridenstine at the JAXA Headquarters in Tokyo on 24 September 2019. During their meeting, they discussed ongoing and future cooperation between JAXA and NASA and signed a Joint Statement of Intent on Cooperation, referring to shared goals regarding JAXA's participation in NASA's Artemis programme and the participation of Japanese astronauts in lunar exploration. Furthermore, during a joint press conference with Prime Minister Abe during President Trump's visit to Tokyo in May, the two expressed their intention to "accelerate discussions on cooperation regarding lunar exploration and affirmed their joint commitment for NASA and JAXA to collaborate in lunar exploration with a view toward Mars"[89].

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[83] "Resolution on ESA programmes: addressing the challenges ahead" (Resolution 3), adopted by ESA Ministerial Council on 28 November 2019. Available at: https://esamultimedia.esa.int/docs/corporate/Resolution_3_Space19+Final-28Nov-12h30.pdf
[84] "On 50th anniversary of Apollo 11 launch, UK and NASA state intent to work on future Moon missions". UK Space Agency (July 2019): https://www.gov.uk/government/news/on-50th-anniversary-of-apollo-11-launch-uk-and-nasa-state-intent-to-work-on-future-moon-missions
[85] "Canada's role in Moon exploration". Canadian Space Agency (last updated: January 2020): http://www.asc-csa.gc.ca/eng/astronomy/moon-exploration/canada-role.asp
[86] *Ibid.*
[87] *Ibid.*
[88] "Two contracts awarded in preparation for Canadarm3, Canada's contribution to the Lunar Gateway". Canadian Space Agency (August 2019): http://www.asc-csa.gc.ca/eng/astronomy/moon-exploration/news.asp?utm_source=website&utm_medium=news&utm_campaign=moon-exploration&utm_content=contracts-canadarm3&utm_term=home-page#20190819
[89] JAXA and NASA. *Joint Statement on Cooperation in Lunar Exploration* (September 2019): https://global.jaxa.jp/press/2019/09/20190924a.html

Japanese proposals include “cooperation on Gateway, including habitation functions and logistics missions, utilising the Japanese HTV-X spacecraft and H3 launch vehicle”.[90] In more concrete terms, JAXA will participate with ESA on the International Habitation Module,[91] contributing through the development of the “ECLSS system, Thermal control system, power system component, Air (O2/N2) high-pressure tank”.[92] Moreover, JAXA will cooperate with NASA on Logistics Resupply[93], which entails contributing to “transport utilisation on the Gateway”, “transport [of] small probe and equipment on lunar orbit” as well as “share-ride of mission equipment”.[94] Further plans for lunar exploration include the development of a Human Pressurized Rover, the study of which is in collaboration with Toyota. This rover would contribute through “long range excursion capability for human lunar surface exploration as well as autonomous or remote operate excursion capability during unmanned period”.[95]

At the International Astronautical Congress in October 2019, the topic of Russian participation in the U.S.-led endeavour to return to the Moon was discussed. During a session attended by representatives from Europe, India, Canada, Japan and Russia, NASA Administrator Jim Bridenstine advocated strongly for international cooperation, while Sergey Krikalev, executive director for piloted spaceflight at Roscosmos, mirrored the favourable statements on international cooperation and stated that Russia is “planning to participate in the Gateway, but we don’t have a final decision how”[96]. Two months prior in August, the joint statement released by the ISS MCB endorsing the Lunar Gateway stated that “the State Space Corporation ROSCOSMOS anticipates providing a multi-purpose crew airlock module for Gateway”.[97].

Remaining questions on the future of the ISS

Despite some progress on the Artemis programme, there are still a number of unresolved questions to be addressed, one of which is the way the United States and international partners will bear the cost, organisation and operation of both the ISS and the Artemis projects.

Since the launch of its first module in 1998, the ISS project has long surpassed its originally planned lifespan in orbit of 15 year – NASA alone is spending between $3B and $4B each year towards the operation of the station and the deployment of astronauts. The pledge of the United States and its international partners to continue running the station stands until 2024 but the situation beyond this date is unknown.

International Space Station (Credit ESA)

[90] *Ibid*.
[91] “Multilateral Coordination Board Joint Statement toward the development of the Gateway”. JAXA (March 2019): https://global.jaxa.jp/press/2019/03/20190312b.html
[92] Hiroshi Sasaki, “JAXA’s Lunar Exploration Activities”, presentation at the 62nd Session of the United Nations Committee on the Peaceful Uses of Outer Space (June 2019)
[93] “Multilateral Coordination Board Joint Statement toward the development of the Gateway”. JAXA (March 2019)
[94] Sasaki, *op. cit.*
[95] Sasaki, *op. cit.*
[96] Jeff Foust, “Space agencies endorse continued cooperation in lunar exploration”. SpaceNews (October 2019): https://spacenews.com/space-agencies-endorse-continued-cooperation-in-lunar-exploration/
[97] NASA, CSA, ESA, Roscosmos and Japan’s MEXT. *Multilateral Coordination Board Joint Statement* (August 2019): https://www.nasa.gov/feature/multilateral-coordination-board-joint-statement-august-2019

The future of the ISS raises many technical, financial and programmatic questions. A way out envisioned by the White House concerns a handover of the station to the private industry. Former NASA chief financial officer Jeff DeWit presented a 5-year proposal for the continued utilisation of the ISS at a press conference in June 2019, according to which the ISS project would be handed off to the private sector. DeWit stated that “the commercialization of low Earth orbit will enable NASA to focus resources to land the first woman and next man on the moon by 2024”[98]. According to the plans presented, NASA wants to “continue research and testing in low-Earth orbit to inform its lunar exploration plans”, but widely expand on the existing commercial utilisation of the ISS: While the ISS is already successfully used by numerous commercial partners through the International Space Station U.S. National Laboratory, this plan would entail the commercial operation or even private ownership of the ISS modules, and to create “a strong ecosystem in which NASA is one of the many customers purchasing services and capabilities at lower cost”[99]. The possibility of the commercialization of Low Earth Orbit is not a new topic, in fact, a study by NanoRacks as part of the NASA NEXTstep public-private model explored the opportunities for LEO commercialization, the actions desired from government actors to foster an ecosystem for commercial stakeholders, and the possible opportunities and constraints[100].

Through a new policy – the NASA Interim Directive (NID) on Use of International Space Station (ISS) for Commercial and Marketing Activities[101] – NASA has specified some aspects of the aforementioned proposal, which include the ability of U.S. Entities to pursue:

- “Manufacturing, production, transportation, or marketing of commercial resources and goods, including products intended for commercial sale on Earth”;
- “Inclusion of private astronauts on USG or commercial missions to the International Space Station and associated on-orbit activities, including commercial and marketing activities”;
- “U.S. government astronauts conducting coordinated and scheduled activities in support of commercial and marketing activities”;
- And “purchasing resources available for use on the International Space Station for commercial and marketing activities”.[102]

NASA further details some of the steps it already plans towards making this transition, including steps towards the allocation of crew resources and cargo capability, the attachment of a commercial module, reducing “uncertainty for commercial destination providers about NASA as a customer”.[103]

In November 2019, the international partner organisations provided their perspectives on the status and future of the ISS:

- According to ESA, its “Space 4.0” strategy “aims to transition LEO activities from focusing on operating the ISS as a government-run laboratory to stimulating a vibrant LEO economy and providing added value services to ESA and other institutional and private actors”.[104]

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[98] Nell Greenfieldboyce, “As NASA Aims For The Moon, An Aging Space Station Faces An Uncertain Future”. NPR (July 2019): https://www.npr.org/2019/07/07/734474121/as-nasa-aims-for-the-moon-an-aging-space-station-faces-an-uncertain-future
[99] “NASA Opens International Space Station to New Commercial Opportunities, Private Astronauts”. NASA (last updated: March 2020): https://www.nasa.gov/press-release/nasa-opens-international-space-station-to-new-commercial-opportunities-private
[100] Adrian Mangiuca (NanoRacks). *Outpost: An In-Orbit Commercial Space Station Habitat Development Enabling Cost-Effective and Sustainable U.S. Presence in Low-Earth Orbit* (January 2019): http://nanoracks.com/wp-content/uploads/NanoRacks-LEOCOM-Study-RELEASE.pdf
[101] NASA. “NASA Interim Directive (NID): Use ofIntemational Space Station (ISS) for Commercial and Marketing Activities” (June 2019): https://www.nasa.gov/sites/default/files/atoms/files/nid_8600_121_tagged.pdf
[102] “Introduction to ISS Commercial Use Policy”. NASA (last updated: August 2019): https://www.nasa.gov/leo-economy/commercial-use/introduction-to-policy
[103] “NASA Opens International Space Station to New Commercial Opportunities, Private Astronauts”. NASA (last updated: March 2020): https://www.nasa.gov/press-release/nasa-opens-international-space-station-to-new-commercial-opportunities-private
[104] “International Space Station Partner Perspectives”. NASA (November 2019): https://www.nasa.gov/mission_pages/station/research/news/b4h-3rd/ev-iss-ip-perspectives

- JAXA noted its successful industry collaboration through its Kibo module and states that "the sustained use of the ISS and the Japanese Kibo module, to their full extend through 2024 and beyond, shows significant promise for continued scientific, innovative and economic devleopments."[105]
- ROSCOSMOS stated that it is "enabling the transition of the Russian Segment on the ISS (ISS RS) to focus on the end users", which includes "creating an operating organisation to provide ISS RS utilisation services to interested ministries, government departments and private companies" and "focusing on the development of additive technologies in partnership with private companies".[106]
- The Canadian Space Agency reiterated its commitment as partner of the ISS program until the end of 2024 and underlined that for Canada, "returns on investments in space exploration are incommensurable". According to the statement, the CSA will present proposals to the Canadian government on the continued engagement in human exploration after 2024.[107]

The proposal by NASA naturally brings up many questions, particularly on how to perform such a transition bearing in mind the diplomatic, political, technical and programmatic considerations. The question of U.S. funding for the ISS also remains – currently allocated until the end of 2024, albeit some efforts in Congress to extend funding until 2030.[108] Lastly, the lack of clear directives and plans from its international partners leads to many remaining questions on the future of the ISS project and human spaceflight in the near and distant future.

Steady progress of the Chinese Lunar Exploration Programme

Beyond the Artemis mission, there are ongoing lunar ambitions of countries not participating in the ISS or taking on a prominent role in the Artemis programme thus far – in particular China.

The year 2019 began with a substantial success for the Chinese Lunar Exploration Programme (CLEP). Named Chang'e – after the Chinese moon goddess – the programme began in 2004 and set the objectives of orbiting, landing on and returning samples from the Moon to be achieved through multiple missions.

Mission	Year	Mission details and purpose	Status
Chang'e-1	2007	• Lunar orbiter • 200km altitude in lunar orbit • 8 scientific payloads • "detect the topography and geomorphology, chemical composition and the first microwave detection of the moon, and near lunar surface space environment"[109]	Completed
Chang'e-2	2010	• Lunar orbiter • 100km altitude in lunar orbit • Back-up mission of Chang'e-1 with increased spatial resolution[110]	Completed

[105] *Ibid.*
[106] *Ibid.*
[107] *Ibid.*
[108] United States Senate. *Advancing Human Spaceflight Act* (introduced in February 2019): https://www.congress.gov/bill/116th-congress/senate-bill/584/text.
[109] L. Xu, Y. L. Zou and L. Qing. *Overview of China's Lunar Exploration Program and scientific vision for future mission*, Paper for the 50th Lunar and Planetary Science Conference (March 2019): https://www.hou.usra.edu/meetings/lpsc2019/pdf/2440.pdf
[110] *Ibid.*

Chang'e-3	2013	• Lunar lander and rover • Achieved soft landing and patrol of Moon • Acquisition of data on Imbrium basin • Monitoring of Earth's plasmasphere using Extreme Ultra-Violet (EUV) camera • Monitoring of "bright active galactic nuclei by a Moon-based ultraviolet telescope (LUT)"[111]	Completed
Chang'e-5 T1	2014	• Precursor mission for Chang'e 5 lunar sample return mission • Chang'e-2 spacecraft featuring Chang'e 5 return capsule • Carried experiments "to expose bacteria and plants to radiation environment beyond low earth orbit"	Completed
Chang'e-4	2019	• Lunar lander, rover and telecommunication relay satellite • Landing on moon's space-facing hemisphere in Von Karman crater of South Pole-Aitken basin[112] • Downlink of measurements, images and data through relay satellite, inter alia on rock formations, structure of lunar crust, solar activity and underground water content[113]	Completed
Chang'e-5	late 2020	• Four modules: - 1st module: will land on Moon and collect samples - 2nd module: will land on Moon, gather samples from first lander and ascend into orbit, dock with third module - 3rd module: will bring samples from second module to orbiting fourth module - 4th module: will bring samples back to Earth • Will use information gathered during Chang'e-5 T1 misison on re-entry design for sample return capsule[114]	Planned
Chang'e-6	2023-2024	• Lander "designed to return samples from the lunar south pole"[115]	Planned
Chang'e-7	TBD	• Planned to survey south polar region, "covering the terrain, geological composition, locations of water ice, and space environment"[116]	Planned
Chang'e-8	TBD	• "designed to test technologies necessary to the construction of a lunar science base"[117]	Planned

Table 2: Past and future Chang'e missions

[111] *Ibid.*
[112] Adam Mann, "China's Chang'e Program: Missions to the Moon". Space.com (February 2019): https://www.space.com/43199-chang-e-program.html
[113] Stephen Clark, "China publishes Chang'e 4 data one year after first landing on far side of the moon". Spaceflight Now (January 2020): https://spaceflightnow.com/2020/01/06/china-publishes-change-4-data-one-year-after-first-landing-on-far-side-of-the-moon/
[114] David R. Williams, "Future Chinese Lunar Missions". NASA Space Science Data Coordinated Archive (last updated: December 2019): https://nssdc.gsfc.nasa.gov/planetary/lunar/cnsa_moon_future.html
[115] *Ibid.*
[116] *Ibid.*
[117] *Ibid.*

In August 2019 China has announced a cooperation plan for its Chang'e-6 lunar mission, which aims to return samples from the Moon. Through this new cooperation plan, China is offering to carry one payload of 10 kg on its orbiter and lander respectively. The payloads will be solicited from "domestic colleges, universities, private enterprises and foreign scientific research institutions"[118]. In March 2019, CNES President Jean-Yves Le Gall and CNSA Vice-Administrator Zhang Jianhua signed a cooperation agreement on space cooperation between China and France. The agreement signed in the presence of both Presidents Emmanuel Macron and Xi Jinping pertains notably to the flight of French Experiments on the Chinese Chang'e 6 mission "to return samples from the Moon in 2023-2024".

Eventually, the China National Space Administration plans to "build a research station in the region of the Moon's south pole", according to Zhang KeJian, head of the agency, in a public statement reported by the state news agency Xinhua[119]. The details of this endeavour are to be announced.

Indian Moon plans: Chandrayaan-2 achievements and Chandrayaan-3 ambitions

India has made significant progress in lunar exploration in 2019, most notable is its Chandrayaan-2 mission. The mission was comprised of a lunar orbiter, a lander and a rover with the goal to "explore the unexplored South Pole of the Moon" and aimed to increase lunar knowledge "through detailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of top soil and composition of the tenuous lunar atmosphere"[120]. The Chandrayaan-2 orbiter carried the following scientific payloads[121]:

- Terrain Mapping Camera 2 (TMC 2)
- Chandrayaan 2 Large Area Soft X-ray Spectrometer (CLASS)
- Solar X-ray Monitor (XSM)
- Orbiter High Resolution Camera (OHRC)
- Imaging IR Spectrometer (IIRS)
- Dual Frequency Synthetic Aperture Radar (DFSAR)
- Chandrayaan 2 Atmospheric Compositional Explorer 2 (CHACE 2)
- Dual Frequency Radio Science (DFRS) experiment

The Vikram lander carried the following payloads[122]:

- Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere (RHAMBA)
- Chandra's Surface Thermo-physical Experiment (ChaSTE)
- Instrument for Lunar Seismic Activity (ILSA)

Chandrayaan-2 successfully reached lunar orbit in August 2019 and released the lunar lander Vikram – of which the landing on the lunar surface was long-awaited. The lander successfully separated from the Chandrayaan-2 orbiter on 2 September and started its descent, which followed the planned trajectory until just below 2 km above the lunar surface. Its soft landing on the lunar surface was not successful as the communication to Vikram lander was lost. A few days after loss of contact, the Chandrayaan-2 orbiter

[118] "China opens Chang'e-6 for international payloads, asteroids next". Space Daily (April 2019): http://www.spacedaily.com/reports/China_opens_Change_6_for_international_payloads_asteroids_next_999.html
[119] Rafi Letzter, "China plans to build a moon base". The Washington Post (April 2019): https://www.washingtonpost.com/national/health-science/china-plans-to-build-a-moon-base/2019/04/26/d22406f2-6768-11e9-a1b6-b29b90efa879_story.html
[120] "Chandrayaan 2: Indian Ambitions, Universal Aspirations". ISRO: https://www.isro.gov.in/chandrayaan2-mission
[121] "Chandrayaan 2: Complete Project Payload". ISRO: https://www.isro.gov.in/chandrayaan2-payloads
[122] *Ibid.*

was able to locate the Vikram lander, however failed to re-establish communication – a circumstance which a "national level committee of academics and ISRO experts" studied[123]. The Chandrayaan-2 orbiter continues its studies and gathers data.

Amidst news of the confirmation of the Vikram lander's crash site location on the Moon,[124] reports were released that the Indian Space Research Organisation (ISRO) is seeking funding for the Chandrayaan-3 mission.[125] According to the Times of India, ISRO "has sought Rs 75 crore from the Centre specifically for the mission as an addition to its existing budget" (equivalent to €9.5M, at exchange rate of 8 December 2019). Initial plans indicate that Chandrayaan-3 will comprise a lander, a rover, as well as "a detachable propulsion module to carry fuel". The Chandrayaan-3 plans were officially confirmed on 1 January 2020 by the head of ISRO[126]. In the meantime, the Union Minister of State for Atomic Energy and Space – Jitendra Singh – stressed that the Chandrayaan-2 orbiter functions well and will carry out its designed mission for the next 7 years.

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[123] "Chandrayaan 2: Latest Updates". ISRO: https://www.isro.gov.in/chandrayaan2-latest-updates
[124] Jeff Foust, "NASA orbiter spots crash site of Indian lunar lander". SpaceNews (December 2019): https://spacenews.com/nasa-orbiter-spots-crash-site-of-indian-lunar-lander/
[125] Chethan Kumar, "Chandrayaan-3 is official, Isro seeks Rs 75 crore". The Times of India (December 2019): https://timesofindia.indiatimes.com/india/chandrayaan-3-is-official-isro-seeks-rs-75-crore/articleshow/72421303.cms
[126] Jeff Foust, "India confirms plans for second lunar lander mission". SpaceNews (January 2020): https://spacenews.com/india-confirms-plans-for-second-lunar-lander-mission/

1.2.6 Other outstanding space policy developments

The year 2019 also saw multiple countries pass new space policies and strategies, some general, others more specialised on topics ranging from the commercial space sector to space security.

New space governance and strategy in Italy

Passed in 2018, Italian Law n. 7/2018 completely reformed the Italian national space governance, creating a systemic approach by:

- Conferring to the Prime Minister the key management, political responsibility and policy coordination of all the Ministries involved in space programmes;
- Establishing a new institutional body, the "Inter-Ministerial Committee for Space and Aerospace-related Policies" (COMINT), composed of about twelve Ministers plus the Presidency of the Regional Governments[127]. Compared to the previous governance centred around the primary role of the Ministry of Education, University and Research, space now is object of attention and interest by more than half of the Italian government.

The repercussions of this new law were primarily made apparent in 2019, as the year 2018 saw a transformation in government and also ASI governance. However, in 2019, a general process of renovation of the national approach to space took place: the government released two strategic documents and appointed the new President of ASI in April; the Parliament re-established the Interparliamentary Group for Aerospace Policy in June.

Two strategic documents were adopted by the COMINT: the "Government Guidelines on Space and Aerospace"[128] in March 2019 and the "National Security Strategy for Space"[129] in July 2019. The first document identifies the strategic sectors related to impacts and applications of space activities, generally emphasising the importance of space diplomacy; the Guidelines prioritise the formulation of an industrial policy, an economic and financial programme to attract capital – also to support SMEs and start-ups – considering as well the formulation of new regulatory instruments, and a development programme for the upstream, midstream and downstream sectors.

Giorgio Saccoccia, President of the Italian Space Agency as of 10 April 2019 (Credit: ASI)

[127] Presidency of the Republic of Italy. "Legge 11 gennaio 2018, n. 7: Misure per il coordinamento della politica spaziale e aerospaziale e disposizioni concernenti l'organizzazione e il funzionamento dell'Agenzia spaziale italiana" (January 2018): https://www.gazzettaufficiale.it/eli/id/2018/02/10/18G00025/sg

[128] Prime Minister's Office. *Government guidelines on space and aerospace* (March 2019): http://presidenza.governo.it/AmministrazioneTrasparente/Organizzazione/ArticolazioneUffici/UfficiDirettaPresidente/UfficiDiretta_CONTE/COMINT/DEL_20190325_aerospazio-EN.pdf

[129] Presidency of the Council of Ministers of Italy, *National Security Strategy for Space* (July 2019): http://presidenza.governo.it/AmministrazioneTrasparente/Organizzazione/ArticolazioneUffici/UfficiDirettaPresidente/UfficiDiretta_CONTE/COMINT/NationalSecurityStrategySpace.pdf

French-German reinforce cooperation through Treaty of Aachen and Declaration of Toulouse

The year 2019 started with the signing of the Treaty of Aachen – a Franco-German treaty on Cooperation and Integration – signed "56 years after Chancellor Konrad Adenauer and President Charles de Gaulle signed the Elysee Treaty in Paris"[130]. The treaty broadly consists of a renewal of the alliance between the two countries on matters of security, diplomacy, economic relations and cooperation on the matter of international challenges. However, the German Federal Ministry of Finance in particular highlighted the priority projects for the implementation of the treaty in a press release a few days later and notably included the following statement: *"Cooperation in the space industry, in three core areas: support for a joint strategy for more European innovation in the space industry; cooperation to increase the competitiveness of the space industry, particularly by means of optimal industrial framework conditions; consolidation of independent European access to space through investment in research and development, rationalisation in the industry, and priority for European launchers."*[131]

Signing of the Aachen Treaty (Credit: AFP/Ludovic Marin)

Following these commitments made through the Treaty of Aachen, on 16 October 2019 Germany and France signed the French-German Declaration of Toulouse, parts of which pertain to the two countries supporting a "stronger European space policy"[132].

This declaration highlights the "strategic dimension of independent European access to space" and notably, in this regard supports "the European preference principle regarding launchers (Ariane 6)"[133]. They call on the industry to improve Europe's international competitiveness and cost-effectiveness. Furthermore, they support the creation of the new European Commission Directorate-General "devoted, inter alia, to space, taking into account the civilian character of the EU space programmes".[134] Furthermore, they highlight the importance of the ESA Ministerial Council Space19+ for the consolidation of "ESA's role in international space exploration efforts" including the ISS.

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[130] Jane McIntosh, "What's in the Franco-German Treaty of Aachen?". Deutsche Welle (January 2019): https://www.dw.com/en/whats-in-the-franco-german-treaty-of-aachen/a-47178247
[131] "The Treaty of Aachen: A new Franco-German agenda". Federal Ministry of Finance of Germany (January 2019): https://www.bundesfinanzministerium.de/Content/EN/Standardartikel/Topics/Europe/Articles/2019-01-24-treaty-aachen.html
[132] "French-German Declaration of Toulouse (16 October 2019)". Ministry of Foreign Affairs of France (October 2019): https://www.diplomatie.gouv.fr/en/country-files/germany/events/article/french-german-declaration-of-toulouse-16-oct-19
[133] *Ibid.*
[134] *Ibid.*

United Kingdom prepares for post-Brexit

For the United Kingdom, 2019 has been a year of major political changes, particularly concerning Brexit which has repercussions for the space sector. Before the general elections held in December, the trade association of UK space industries, UKSpace, released a "2020 Manifesto" recommending five policy guidelines to secure the role of the UK in space in a post-Brexit context:[135]

- Increase contributions to ESA: Noting the need to uphold the UK's space sector's "ability to compete on a global stage" and maintain an effective and sustainable space industry, the document underlines the importance of the assurance and stability ESA funding provides. Thus, according to the 2020 Manifesto, the UK government "must commit to increasing space funding from all current sources", in particular spending through ESA.
- Establish a National Space Programme with identified priorities: The 2020 Manifesto advocates for the UK Government to establish a National Space Programme including a £150m-a-year Innovation Fund. The identified priority areas of this space programme include the commercialization of R&D, as well as 5 specific space sector priority: "sovereign geospatial data"; "Ubiquitous, resilient and secure connectivity"; "resilient position, navigation and timing security solution"; "In-orbit assembly, servicing and debris removal"; and "Food security".
- Develop a new navigation satellite system: According to UK Space, "the UK's post-Brexit participation in a new global satellite navigation system must be secured, whether through ESA or a sovereign capability" - noting the £191m funding commitment of the 2019 Spending Review in support of Brexit-related activities, amongst others the creation of a UK GNSS, the cost of which is estimated at £5b.
- Strongly support the Copernicus programme: Aware of the importance of Earth observation satellite monitoring for climate change and carbon emission reduction, the 2020 Manifesto advocates for finding a solution regarding the UK's participation in the Copernicus program, "through either ESA and a post-Brexit agreement with the EU to remain as a partner on the programme".
- Empower a new National Space Council: The 2020 Manifesto advocates for the new National Space Council to receive the mandate and funding to implement a comprehensive space strategy, support the allocation of public money for space and bridge connections with industry and academia.

Portugal, new space agency for new space ambitions

In 2019, Portugal has made significant progress in terms of space policy and governance. With the approval of a national space strategy at the beginning of 2018, this year Portugal began a process of implementation and reinforcement of the space sector through the establishment of a space agency within a supporting juridical framework.

In this context, Portugal increased its subscriptions to ESA programmes at the Space 19+ Ministerial Council – co-chaired by the re-appointed Minister of Science, Technology and Higher Education, Manuel Heitor. Moreover, the newly created agency started to establish connections in the space sector, balancing its European nature with a wider Atlantic vocation. Indeed, this vocation is exemplified by different facts: in the Azores is where the Portugal Space Agency holds its HQ and organised the Summit; where ESA already has facilities and coordinates the AIR Centre; where the Portugal Space Agency aims to develop the project of a multipurpose spaceport. Furthermore, the agency revealed during the year the project to develop a constellation of satellites to observe the Atlantic maritime activities.[136]

[135] "UKspace 2020 Manifesto". UKspace (November 2019): https://www.ukspace.org/ukspace-2020-manifesto/
[136] Caleb Henry, "Portugal mulls Atlantic-focused constellation ". SpaceNews (November 2019): https://spacenews.com/portugal-mulls-atlantic-focused-constellation/

The Agência Espacial Portuguesa – Portugal Space was established in March 2019 by the Council of Ministers and the Regional Government of the Azores with the primary task to promote and implement the Portugal Space 2030 national strategy, coordinating the efforts to affirm Portugal as a space actor on the global stage.[137]

In 2019, together with the rapid setup of the space governance came also the creation of a regulatory framework with: the approval of a National Space Act and the Azores Regional Space Act, and the accession to the UN Registration Convention (already in 2018) and the Liability Convention. Notably, the National Space Act introduced both a pre-qualification system for operators and a joint license, to optimise the process of authorisation with a national space authority, while at the same time the Regional Space Act creates a regional space authority, in charge of the authorisation process as well, even if limited to the activities taking place only in the Azores. The Portugal Space 2030[138] document identifies four strategic objectives and three strategic axes for implementation.

Strategic Objectives
• "Promote economic growth and the creation of skilled jobs in Portugal by promoting space-related markets (…)"; • "Foster the generation of satellite data through new space technologies and space-related infrastructures in Portugal (…)"; • "Contribute to the development of the country and to the strengthening of diplomatic relations and international scientific cooperation (…)"; • "Ensure the development and evolution of the legal, financial, institutional, cultural/educational internationalization frameworks capable of boosting the development of the Space sector in Portugal".
Strategic Axes
• Axis 1: "Boosting the exploitation of space data and signals through space-based services and applications, promoting new markets and highly-skilled jobs in a diversity of areas"; • Axis 2: "Fostering the development, construction and operation of space equipment, systems, infrastructure and space data generation services, with an emphasis on mini, micro and nano satellites but also opening up new areas of intervention in Portugal for launcher services, including and extending existing satellite monitoring and tracking and Earth observation activities"; • Axis 3: "Continuing to build national capacity and skills, through scientific research, innovation and education and scientific culture, allowing the long-term sustainability of infrastructures, services and space applications".

Table 3: Portugal Space strategic objectives and axes (Source: Portugal Space 2030)[139]

During the year, Portugal Space signed a MoU with the UK Space Agency,[140] a cooperation agreement with CNES[141] and an agreement with ESA[142]; in particular, the last one is focused on the development of

[137] Portugal Space. *Portugal Space: Portuguese Space Agency Business and Installation Plan* (March 2019): https://www.ptspace.pt/wp-content/uploads/2019/03/Portugal-Space-Business-Plan.pdf. See also: "Portugal Space First General Assembly". Portugal Space (March 2019): https://www.ptspace.pt/portugal-space-first-general-assembly/
[138] Government of Portugal. *Portugal Space 2030: A research, innovation and growth strategy for Portugal* (March 2018): https://www.fct.pt/documentos/PortugalSpace2030_EN.pdf
[139] *Ibid.*
[140] "Memorandum of Understanding: UK and Portugal". Portugal Space (July 2019): https://www.ptspace.pt/memorandum-of-understanding-uk-and-portugal/
[141] "PT Space and CNES sign cooperation agreement". Portugal Space (June 2019) : https://www.ptspace.pt/pt-space-and-cnes-sign-cooperation-agreement/
[142] " ESA expertise to support Portugal's launch programme". ESA (June 2019): http://www.esa.int/Enabling_Support/Space_Transportation/ESA_expertise_to_support_Portugal_s_launch_programme

a national priority, the Azores International Satellite Launch Programme (ISLP), a spaceport facility in Santa Maria island in the Azores. Overall, as part of the strategy, Portugal targets to attract €2.5B in ten years from public and private investments in space related activities[143].

Canada sets new vision and direction with a Space Strategy

In March 2019, the Canadian Minister of Innovation, Science and Economic Development – the Honourable Navdeep Singh Bains – announced the new Canadian Space Strategy on behalf of the Canadian government. Titled "Exploration, Imagination, Innovation: A New Space Strategy for Canada" this strategy sets out a vision that recognizes the space sector as "a strategic national asset"[144] and was released as Canada wants to "add to its legacy of international cooperation, science and disruptive technology development".

The Canadian government set out five main activities for its strategy.

- Canada affirmed its dedication to remaining a spacefaring nation through joining the Lunar Gateway Mission, specifically contributing with "the next-generation AI-enabled deep-space robotic system" – Canadarm3. Participation in the Lunar Gateway will continue to foster scientific opportunities for Canada, cooperative partnerships and guarantee the continuation of Canada's astronaut program – all domains of priority for the Canadian government as demonstrated by significant financial investments in the past.
- Canada set out to "inspire the next generation of Canadians to reach for the stars" through the launch of its Junior Astronauts initiative, which entails an array of activities to encourage young Canadians to pursue careers in STEM and space.
- Canadian government acknowledged that space as a strategic national asset underpins various crucial domains of Canadian life, thus contributing to national security and providing socio-economic benefits.
- The government wants to "position Canada's commercial space sector to help grow the economy and create the jobs of the future". To this end, the government will review the existing regulatory framework to create an up-to-date system conducive to the work of innovative Canadian space companies. The strategy aims to invigorate and strengthen the Canadian space sector – and firms of any size – through various investment and accelerator schemes. This was demonstrated in spring of 2019 when the Canadian Space Agency awarded a total of CA$15 million to 25 companies at various levels of Technology Readiness Levels (TLR) under the Space Technology and Development Program.[145]
- Lastly, the strategy set out to "ensure Canada's leadership in acquiring and using space-based data to support science excellence, innovation and economic growth".[146]

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[143] Portugal Space and the Office of the Minister for Science, Technology and Higher Education. *Space in Portugal and Europe with ESA* (November 2019): https://www.ptspace.pt/wp-content/uploads/2019/12/Space19plus-PT-v29nov2019.pdf
[144] Ministry of Innovation, Science and Economic Development of Canada. *Exploration, Imagination, Innovation – A New Space Strategy for Canada* (March 2019): https://www.asc-csa.gc.ca/pdf/eng/publications/space-strategy-for-canada.pdf
[145] "Contributions awarded under the STDP – AO 5". Canadian Space Agency (last updated: October 2019): http://www.asc-csa.gc.ca/eng/funding-programs/programs/stdp/contributions-ao-5.asp
[146] Ministry of Innovation, Science and Economic Development of Canada. *Exploration, Imagination, Innovation – A New Space Strategy for Canada* (March 2019)

China facilitates commercial space launch

For the first time, China has introduced regulations for commercial rocket manufacturing, testing and launches. The aim of this policy is to boost the development of the nascent commercial space industry, which emerged in when private companies were permitted to enter the sector. According to the new regulation, companies must obtain permission from State Administration of Science, Technology and Industry for National Defence prior to research and production of commercial rockets and should further establish "confidential systems and secrets management systems".[147]

Through the guidelines, the government further "encourages private rocket companies to take full advantage of national resources in terms of rich technology research, production equipment and facilities, and launch sites"[148]. According to the CEO of the Chinese commercial rocket company OneSpace Technology, the regulations clarify "the qualifications, operational boundaries and national guaranties, which will be conducive to the sector's healthy and orderly development".[149]

Australia's space sector gains sophistication: The Space Act and the Australian Space Agency

The first reform of 2019 in Australia concerned the national space law: The Space Act was already introduced in June 2018 and approved in August without amendments by the Parliament. Overall, the Act reforms a legislation dated back to 1998 and aims to accelerate the licence approval process – for instance, concerning multiple launches – and lower the insurance requirements for launches and returns, while increasing the non-compliance penalties. Interestingly, the Act requires each application for launch permit to include a debris mitigation strategy based on "internationally recognised" guidelines, that has to describe the measures planned both in the operational and decommissioning phase to assess, minimise and mitigate the risks associated with debris.[150] On the mandatory or informative nature of this requirement, the Explanatory Notes to the Act issued by the competent Ministry in 2019 report that the "information on the debris mitigation strategy is relevant to the Minister's consideration of whether to grant an Australian launch permit".[151] The Act also set the standards and criteria for the approval of launch permit and authorisation in terms of: competency and financial standing of the applicant, insurance requirements, risk mitigation and national security. It should also be recalled that Australia has ratified all five space treaties.

Then, the reform of governance focused on the creation of the Australian Space Agency (ASA) in July 2018, a non-statutory entity within the Ministry of Industry, Science and Technology – that maintains the Australian national registry of space objects. The ASA aims to coordinate the national space sector and promote its role on a global level through international cooperation. The governance is centred around the Head of the Agency, who reports directly to the Ministry but in a whole-of-government approach that primarily concerns: the "government agencies involved in space activities"[152], other departments in the informal Australian Government Space Coordination Committee (SCC), and also the industrial actors in the Space Industry Leaders Forum.

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[147] Zhang Hongpei, "China rolls out rules for commercial space sector". Global Times (June 2019): http://www.globaltimes.cn/content/1153918.shtml
[148] *Ibid.*
[149] *Ibid.*
[150] Minister for Industry, Science and Technology of Australia. "Space (Launches and Returns) (General) Rules 2019". Federal Register of Legislation (August 2019): https://www.legislation.gov.au/Details/F2019L01118
[151] Minister for Industry, Science and Technology of Australia. "Space (Launches and Returns) (General) Rules 2019 – Explanatory Statement". Federal Register of Legislation (August 2019): https://www.legislation.gov.au/Details/F2019L01118/Explanatory%20Statement/Text
[152] Australian Government. *Australian Space Agency Charter* (October 2018): https://www.industry.gov.au/sites/default/files/2018-10/australian-space-agency-charter.pdf?acsf_files_redirect

The main goals of the Agency have been outlined for the first time in April 2019 in the Civil Space Strategy 2019-2028.[153] The strategy identifies seven priority areas on which to focus efforts and investments:

- Positioning, Navigation and Timing
- Earth Observation
- Telecommunication services
- SSA and space debris monitoring
- Research & Development
- Robotics and automation technologies
- Access to space

The primary purpose of the Strategy is to generate by 2030 a total amount of A$12B in the space sector and create additional 20.000 jobs. As for now, only the PNT and EO areas are *operative*, part of the implementation process provided through the Space Infrastructure Fund initiative and developed mostly in the Digital Earth Australia (DEA) and the National Positioning Infrastructure Capability (NPIC) programmes. Overall, the space budget in Australia amounts to approx. A$630M[154] ($438M at an average exchange rate), considering also: a fund A$325M managed by the Geoscience Australia Agency for the development of satellite infrastructure, and a A$150M investment in the partnership with NASA for the Moon to Mars initiative.

United Arab Emirates' space strategy and investment plan

During an eventful year for space, marked inter alia by the flight of the first person from the UAE to the space and the International Space Station, the UAE made progress in space legislation and regulation. The UAE National Space Law came into effect in December 2019, providing the regulatory framework for UAE space-related activities, including that of commercial actors and commercial space tourism flight operators.[155] Furthermore, the UAE Space Agency announced a National Space Investment Plan, that according to the government are significant pillars in enhancing the country's overall approach to space, through comprehensive objectives and initiatives. Both the Strategy and the Investment Plan build on a previous Space Policy strategic document released in 2016[156] and on an advancing legal framework composed of law and regulations.[157]

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[153] Australian Government. *Advancing Space: Australian Civil Space Strategy 2019-2028* (April 2019): https://publications.industry.gov.au/publications/advancing-space-australian-civil-space-strategy-2019-2028.pdf
[154] United Nations Committee on the Peaceful Uses of Outer Space, "International cooperation in the peaceful uses of outer space: activities of Member States – Australia, Philippines and Switzerland" (November 2019): https://www.unoosa.org/oosa/en/oosadoc/data/documents/2019/aac.105/aac.1051211add.1_0.html
[155] Sarwat Nasir, "UAE's national space law comes into effect ». The National (February 2020): https://www.thenational.ae/uae/science/uae-s-national-space-law-comes-into-effect-1.983817
[156] UAE Space Agency. *National Space Policy of the United Arab Emirates* (September 2016): https://space.gov.ae/Documents/PublicationPDFFiles/UAE_National_Space_Policy_English.pdf
[157] "UAE cabinet approves National Space Strategy 2030". UAE Cabinet: https://uaecabinet.ae/en/details/news/uae-cabinet-approves-national-space-strategy-2030

1.3 Major space programme developments in 2019

1.3.1 Navigation programmes

Galileo and EGNOS

Galileo – one of the EU's flagship programmes – reached important milestones in 2019 amidst continuous development. On 11 February, four Galileo satellites – GSAT0219, GSAT0220, GSAT0221, and GSAT0222 – entered into service after having been launched in July 2018,[158] increasing the Galileo constellation to 22 operational satellites.[159]

After completing the deployment of the necessary infrastructure, the Galileo Return Link Service "underwent a thorough System and Service validation that concluded in November 2019".[160] Set to provide free-of-charge aid to people in distress by enabling them to "receive automatic acknowledgement that their signal has been received", this service was declared operational on January 21st 2020.

Galileo users experienced a temporary interruption of service for multiple days as of July 13th due to an "equipment malfunction in the Galileo ground infrastructure, affecting the calculation of time and orbit predictions, and which are used to compute the navigation message".[161] The incident led to an interruption of the Galileo initial navigation and timing services for six days – with the exception of the Galileo Search and Rescue (SAR) service. After recovery work performed by GSA experts, industry, ESA and the European Commission, function was restored on July 18th. The GSA recalled that Galileo is still in the "initial" phase and once in the "fully operational phase", the system will function independently from other satellite navigation systems.[162] Just a few weeks after this event on 10 September, the GSA celebrated two important milestones – Galileo reaching 1 billion smartphone users[163] and the GSA's 15th anniversary.[164]

	In operation	In testing	In commissioning	In maintenance	In decommissioning
Satellites	22	2	0	0	0

Table 4: Status of Galileo satellite constellation (Source: GSA)[165]

The year 2019 also saw progress on the EGNOS program. Most importantly, the EUTELSAT 5 West B satellite was launched from Kazakhstan on 9 October 2019. According to the GSA, "hosting the GEO-3 payload of the European Geostationary Navigation Overlay System (EGNOS), the satellite will support EGNOS V3 – the next generation of the EGNOS programme".[166]

158 "Latest batch of Galileo satellites enters service". European GNSS Agency (February 2019): https://www.gsa.europa.eu/newsroom/news/latest-batch-galileo-satellites-enters-service
159 Information on the Galileo constellation. Available at: https://www.gsc-europa.eu/system-service-status/constellation-information
160 "Galileo Return Link Service declared at European Space Conference". European GNSS Agency (January 2020): https://www.gsa.europa.eu/newsroom/news/galileo-return-link-service-declared-european-space-conference
161 "Galileo Initial Services have now been restored". European GNSS Agency (July 2019): https://www.gsa.europa.eu/newsroom/news/galileo-initial-services-have-now-been-restored
162 *Ibid.* https://www.gsa.europa.eu/newsroom/news/galileo-initial-services-have-now-been-restored
163 "Space: EU's satellite navigation system Galileo reaches 1 billion smartphone users". European Commission (September 2019): https://ec.europa.eu/commission/presscorner/detail/en/ip_19_5529
164 "GSA celebrates 15 years". European GNSS Agency (September 2019): https://www.gsa.europa.eu/newsroom/news/gsa-celebrates-15-years
165 Information on the Galileo constellation. Available at: https://www.gsc-europa.eu/system-service-status/constellation-information
166 "EUTELSAT 5 West B successfully launched with EGNOS payload". European GNSS Agency (October 2019): https://www.gsa.europa.eu/newsroom/news/eutelsat-5-west-b-successfully-launched-egnos-payload

EGNOSV3 will be used for augmentation of both "GPS and Galileo in the L1 and L5 bands" and "provide additional satellite-based augmentation system (SBAS) service capabilities through a new SBAS channel on L5".[167]

GPS

2019 saw the second launch of a GPS III (third generation) satellite on 22 August.[168] This generation of GPS satellites has a 15-year design lifespan and will provide "enhanced signal reliability, accuracy and integrity",[169] through "improved anti-jamming capabilities".[170] According to Lockheed Martin, the manufacturer, this generation's "new L1C civil signal will also make it the first GPS satellite broadcasting a compatible signal with other international global navigation satellite systems, like Galileo, improving connectivity for civilian users". Lockheed Martin's contract includes building up to 32 GPS III satellites and the GPS III Follow on (GPSIIIF) satellites[171].

	In operation	In testing	In commissioning	In maintenance	In decommissioning
Satellites	31	0	0	2	1

Table 5: Status of GPS satellite constellation

Glonass

On 27 May, the Soyuz-2.1b successfully launched the Glonass-M navigation satellite from Plesetsk cosmodrome into orbit, according to the Russian Defence Ministry[172] as well as another in December 2019.[173] As of March 2020, the Glonass constellation consists of 29 satellites – of which 24 are currently operational, three in maintenance, one acts as a spare and one is in its flight test phase.[174] The newly launched satellites belong to the Glonass-M series of satellites, which was first launched in 2003 and is the modernised version of the Glonass satellite. The Glonass-M satellites have a designated lifespan of 7 years (although many Glonass satellites currently in operation have outlasted their designated lifespan).[175]

Russia has further expanded on its cooperation with China by ratifying a cooperation agreement on the use of "Russia's GLONASS and China's BeiDou satellite navigation systems for peaceful purposes", which was signed in 2018 during a meeting between the heads of governments of both countries.[176] According to Roscosmos, the cooperation agreement "creates the organizational and legal basis for the cooperation in developing and manufacturing civil navigation equipment using GLONASS and BeiDou systems as well as developing Russo-Chinese standards on implementing navigation technologies using both systems including standards on controlling and managing transport flows crossing the Russo-Chinese border".

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[167] *Ibid.*
[168] SMC Public Affairs, "First GPS III satellite successfully launched". Los Angeles Air Force Base (December 2018): https://www.losangeles.af.mil/News/Article-Display/Article/1720821/first-gps-iii-satellite-successfully-launched/
[169] Presentation of the GPS constellation space segment. Available at: https://www.gps.gov/systems/gps/space/
[170] "GPS III launch success". Lockheed Martin (August 2019): https://www.lockheedmartin.com/en-us/products/gps.html
[171] *Ibid.*
[172] "Soyuz-2.1b booster with Glonass-M satellite blasts off from Plesetsk". TASS (May 2019): https://tass.com/science/1060161
[173] Stephen Clark, "Russia adds new satellite to Glonass navigation fleet". Spaceflight Now (December 2019): https://spaceflightnow.com/2019/12/11/russia-adds-new-satellite-to-glonass-navigation-fleet/
[174] Glonass constellation status. Available at: https://glonass-iac.ru/en/GLONASS/
[175] "Glonass-M – a chapter in the history of satellite navigation". ISS Reshetnev (July 2015): http://www.iss-reshetnev.com/media/news/news-300715
[176] "Russia ratifies agreement with China on cooperation in GLONASS and BeiDou usage". Roscosmos (July 2019): http://en.roscosmos.ru/20834/

	In operation	In testing	In commissioning	In maintenance	In decommissioning
Satellites	24	1	1	2	0

Table 6: Status of Glonass satellite constellation[177]

BeiDou

In April 2019, China achieved the launch of its newest version of a satellite of the BeiDou Navigation Satellite System (BDS) with the launch of a BDS-3 satellite by a Long March-3B rocket from Xichang Satellite Launch Centre located in the Sichuan Province. This satellite is the first BDS-3 satellite in inclined geosynchronous Earth orbit and "will work with 18 other BDS-3 satellites in intermediate circular orbit and one in geosynchronous Earth orbit".[178] In the same month, officials from China and Arab countries as well as experts and industry stakeholders attended the second China-Arab States BDS Cooperation Forum in Tunisia. This year's forum on the theme of *Cooperation, Application and Service* "focused on increasing BDS application in the Middle East" and offered the opportunity for several cooperation agreements to be signed on the BDS as well[179].

	In operation	In testing	In commissioning	In maintenance	In decommissioning
Satellites	43	4	2	0	0

Table 7: Status of BeiDou satellite constellation[180, 181]

[177] Glonass constellation status. Available at: https://glonass-iac.ru/en/GLONASS/
[178] "Newly-launched BeiDou satellite enters orbit". Xinhua (April 2019): http://www.xinhuanet.com/english/2019-04/26/c_138013253.htm
[179] "Why BeiDou Navigation Satellite System Centre in Tunisia is the gateway for China/Arab space cooperation". Space in Africa (April 2019): https://africanews.space/why-beidou-navigation-satellite-system-centre-in-tunisia-is-the-gateway-for-china-arab-space-cooperation/
[180] Beidou constellation status. Available at: https://www.glonass-iac.ru/en/BEIDOU/index.php
[181] Xiaohong Zhang, Mingkui Wu, Wanke Liu & al. "Initial assessment of the COMPASS/BeiDou-3: new-generation navigation signals", *Journal of Geodesy*, vol. 91, issue 1 (April 2017): https://www.researchgate.net/publication/316055961_Initial_assessment_of_the_COMPASSBeiDou-3_new-generation_navigation_signals

1.3.2 Earth Observation and telecommunication programmes

Copernicus programs steadily increase user base and successfully launch new products and services

The Copernicus programme relies on a fleet of EO satellites named Sentinels. Currently Sentinel 1A-1B, 2A-2B, 3A-3B and Sentinel 5P have been deployed in orbit. On March 20th 2019, Sentinel 3 mission reached full operational capacity with its second Ocean monitoring satellite, Sentinel 3B. Sentinel 4, 5, 6 are planned to be launched early 2020. The fleet of Copernicus satellites display a variety of capabilities and address various applications, from land monitoring to sea level rise study. Copernicus services progressed, expanded and reached interesting milestones in 2019. [182]

- The Copernicus Atmosphere Monitoring Service (CAMS) provided valuable “accurate and timely information on global wildfires, their development and the transportation of the pollution they produce”, in particular the Australian, Arctic and Amazon wildfires. The service was upgraded in July 2019, leading to “improved particulate matter predictions and emissions forecasts”.
- As for the Copernicus Climate Change Service (C3S), it celebrated unprecedented use of its Climate Data Storage (CDS) with “users from 171 countries, and over 31 million data requests since its launch” – celebrating the achievement of having “truly become a global service”. C3S expanded their services through launching the reanalysis dataset ERA 5 in January 2019, allowing insight into meteorological conditions dating back to 1979, adding the ERA5-Land high resolution land component to the dataset in July 2019.
- The Copernicus Marine Environment Monitoring Service (CMEMS) released multiple new and updated products in 2019, including a catalogue that for the first time in history includes “wind, wave, ocean current and biogeochemical variables”[183] and an update to CMEMS’ Ocean Monitoring Indicators. CMEMS further published reports and publications, such as the 3rd edition of the Ocean State Report in June 2019. According to CMEMS, its data “was also used as a reference in the high-level IPCC Special Report on the Ocean and Cryosphere (SROCC), continuing to position the service as a high-level source of maritime monitoring information.
- Aside from many updates to existing products, the Copernicus Land Monitoring Service (CLMS) released new products, such as the European Ground Motion Service (EGMS), High Resolution Vegetation Phenology and Productivity, High Resolution Snow & Ice and Coastal Zones, and the “first Global Land Cover product – the Dynamic Land Cover product”. This product provides 100m resolution Dynamic land cover maps “including transitions of land cover classes over time”. The CLMS further released the Global Mosaic website, which “provides Sentinel-2 ‘analysis ready’ data” with the aim of increasing user uptake by allowing their users to create their own products.
- The Copernicus Emergency Management Service (CEMS) contributed to the response to the various wildfire crises in 2019 and also improved its Risk and Recovery Mapping module, which provides on-demand geospatial information and “supports emergency management activities that are not related to the immediate response phase”. At the first joint meeting of Copernicus Emergency Management Service users in May 2019,[184] stakeholders of the “different communities from within Europe shared their experience using the service, as well as their requirements for its future evolution”.
- Lastly, the Copernicus Security Services (CSS) continued to serve its users in the area of border surveillance (EBCGA/Frontex), maritime surveillance (EMSA) and to support external action (SatCen) with the continued provision of its services, launching new services and increasing its user base.

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[182] “OBSERVER: A look back at 2019 before looking forward to 2020!”. Copernicus (January 2020): https://www.copernicus.eu/en/news/news/observer-look-back-2019-looking-forward-2020

[183] “New catalogue release: wind, wave, ocean current and biogeochemical variables”. Copernicus (April 2019): https://marine.copernicus.eu/ocean-wind-wave-current-biogeochemical-variables/

[184] “Evolution of the Copernicus Emergency Management Service based on user requirements”. EU Joint Research Centre (May 2019): https://ec.europa.eu/jrc/en/science-update/copernicus-emergency-management-service-evolution

Space Climate Observatory, space in support of the Paris Agreement

International developments in 2019 related to Earth Observation notably include the Space Climate Observatory (SCO). Originally conceptualised by the signatories of the Paris Agreement in 2017, the French-led SCO held its first international meeting on 1 February 2019 in Paris, in attendance of representatives from 25 space agencies as well as four international organisations. The meeting served to "specify its objectives and to discuss its joint implementation". The beginning of the year was also marked by several cooperation agreements signed between French delegations and the African Union[185], Senegal[186], South Africa[187], Kenya[188] and Ethiopia[189], and Australia[190] some of which covered the opportunities of cooperation through the Space Climate Observatory.

A significant show of support for the SCO was exhibited by the international community on the side-lines of the Paris Air Show on 17 June 2019 with the signing of a joint declaration of interest by "22 space agencies and international organisations".[191] Signatories included (in alphabetical order): Austria, Azerbaijan, Brazil, China, Ethiopia, France, Germany, Greece, India, Israel, Italy, Mexico, Portugal, Romania, Sweden, Thailand, Ukraine, United Arab Emirates, United Kingdom, UNDP, UNOOSA.

At the 70th International Astronautical Congress (IAC) in Washington D.C. on 22-23 October 2019, the first International Steering Committee of the Space Climate Observatory convened.

France kickstarts new EO programme and furthers international cooperation

On the side-lines of the Paris Air Show in June 2019, a trilateral agreement was signed between CNES, the China National Space Administration (CNSA) and Eumetsat regarding CFOSat – "a France-China programme to study the interactions between winds and waves at the ocean surface", the data of which is used in marine weather forecasting and climate science[192]. The trilateral agreement pertains to Eumetsat's "use and distribution of CFOSat data".

In March 2019, France further kickstarted the C03D Earth Observation Programme, which comprises the creation of a "constellation of optical minisatellites [...] set to come on stream in 2022"[193]. This constellation is aimed to "provide sub-metre imagery for production of digital surface models (DSMs) of any point on the globe with an elevation accuracy of one metre", meant to be used for both civil and military purposes[194].

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[185] "France and the African Union Commission to cooperate on space, education, science and technology". GMES4Africa (March 2019): http://gmes4africa.blogspot.com/2019/03/france-and-african-union-commission-to.html
[186] "France-Senegal space cooperation, CNES and Senegal's Ministry for Higher Education, Research and Innovation sign agreement". CNES (January 2019): https://presse.cnes.fr/en/france-senegal-space-cooperation-cnes-and-senegals-ministry-higher-education-research-and-innovation
[187] "SANSA and CNES Sign a Memorandum of Understanding (MoU)". South African National Space Agency (February 2019): https://www.sansa.org.za/2019/03/01/sansa-and-cnes-sign-a-memorandum-of-understanding-mou/
[188] "State visits of President Emmanuel Macron to Ethiopia and Kenya – France and Africa step up cooperation". CNES (March 2019): https://presse.cnes.fr/en/state-visits-president-emmanuel-macron-ethiopia-and-kenya-france-and-africa-step-space-cooperation
[189] *Ibid.* https://presse.cnes.fr/en/state-visits-president-emmanuel-macron-ethiopia-and-kenya-france-and-africa-step-space-cooperation
[190] "France-Australia space cooperation – climate, innovation and exploration: CNES signs three partnership agreements". CNES (February 2019): https://presse.cnes.fr/en/france-australia-space-cooperation-climate-innovation-and-exploration-cnes-signs-three-partnership
[191] "SCO: a global commitment – France". Space Climate Observatory (June 2019): https://www.spaceclimateobservatory.org/sco-a-global-commitment/?lang=en
[192] "CNES at the 2019 International Paris Air Show – Cooperation key to the success of CNES". CNES (June 2019) : https://presse.cnes.fr/en/cnes-2019-international-paris-air-show-cooperation-key-success-cnes
[193] "France's CNES gives go-ahead to CO3D Earth Observation programme". SpaceWatch Global (March 2019): https://spacewatch.global/2019/03/frances-cnes-gives-go-ahead-to-co3d-earth-observation-programme/
[194] *Ibid.*

Italy strengthens EO segment: international cooperation and national capabilities

After the 2018 agreement with CONAE on SIASGE (Italian-Argentinian Satellite System for Emergency Management), ASI further expanded cooperation on EO through substantiated agreement with the Israeli Space Agency (ISA) on the joint hyperspectral satellite SHALOM[195] (Spaceborne Hyperspectral Applicative Land and Ocean Mission); in March Italy launched PRISMA[196] (Hyperspectral Precursor and Application Mission), a fully-Italian-developed project, and then in December the first satellite of the Second Generation of CosmoSkyMed[197] (CSG), the EO national flagship dual-use programme with strong participation by the Ministry of Defence. The CSG-1 presents enhanced interoperability with other systems and geometric resolution and is currently the fifth satellite of the programme in orbit since the first launch in 2007. CSG is developed by Thales Alenia Space Italia and Telespazio and will be followed by a second satellite, expected to be launched on a Vega C rocket before 2022. Overall, Italy further consolidated its expertise and vocation toward Earth Observation, strategically important because of its several applications, celebrating the new ESA EO mission FORUM with broad Italian contributions[198] as well as the 10-year anniversary of the establishment of e-Geos, the ASI-Telespazio Joint Company specialist in EO application services.[199]

Progress and Investment: U.S. environmental satellites

In May the first data of ICESat-2 was released, after the launch of the satellite in 2018. Equipped with a laser altimeter, the satellite has been equipped with several innovations compared to the first ICESat launched in 2003, especially in terms of variety of measurements and data collection capability in the polar regions. Other major developments concern the National Oceanic and Atmospheric Administration, that in 2020 will celebrate its 50th anniversary; the Congress provided $745M for the development of three Polar Weather Satellites and $304M for Geostationary Operational Environmental Satellite (GOES) programme[200] - rejecting the overall cuts proposed to the weather and climate programmes; moreover, the nomination of Barry Myers as NOAA administrator has been eventually withdrawn and the U.S. Air Force has taken-over the decommissioned GOES-13 satellite.[201]

Canada launches new RADARSAT missions and pushes forward with industry partnerships in Earth Observation

Canada achieved a significant milestone in 2019 with the launch of the RADARSAT Constellation Mission (RCM) – the new Canadian generation of Earth Observation satellites. This mission builds on the RADARSAT Programme, which has encompassed the Earth Observation satellites RADARSAT 1 (retired in 2013) and RADARSAT 2 (launched in 2007, mission ongoing).[202] The RADARSAT Constellation is comprised of three satellites of 1.400 kg each and were placed in SSO on 12 June on a Falcon 9

[195] Michella della Maggesa, “Con SHALOM Italia e Israele rafforzano la collaborazione nello spazio”. AirPress (July 2019): https://www.airpressonline.it/39848/39848/
[196] “Satellite iperspettrale, in grado di osservare da ottico a vicino infrarosso”. ASI (March 2020): https://www.asi.it/scienze-della-terra/prisma/
[197] “In orbita il primo satellite Cosmo-SkyMed di Seconda Generazione”. ASI (December 2019): https://www.asi.it/2019/12/in-orbita-il-primo-satellite-cosmo-skymed-di-seconda-generazione/
[198] “A new satellite to understand how Earth is losing its cool”. ESA (September 2019): https://www.esa.int/Applications/Observing_the_Earth/A_new_satellite_to_understand_how_Earth_is_losing_its_cool
[199] “10 anni di successi nell’Osservazione della Terra e un futuro nella space economy e nell’AI per e-GEOS”. Telespazio (December 2019): https://www.telespazio.com/it/news-and-stories-detail/-/detail/121219-10-years-of-success-in-earth-observation-and-a-future-in-the-space-economy-and-ai-for-e-geos
[200] “FY20 Appropriations Bills: National Oceanic and Atmospheric Administration”. American Institute of Physics (October 2019): https://www.aip.org/fyi/2019/fy20-appropriations-bills-national-oceanic-and-atmospheric-administration
[201] Jeff Foust, “NOAA weather satellite transferred to U.S. Air Force”. SpaceNews (September 2019): https://spacenews.com/noaa-weather-satellite-transferred-to-u-s-air-force/
[202] “RADARSAT-2”. Canadian Space Agency (last updated: December 2017): http://asc-csa.gc.ca/eng/satellites/radarsat2/default.asp

launcher[203]. Their mission is to enhance and enable maritime surveillance, disaster management and ecosystem monitoring[204] and their data will primarily serve the Government of Canada, however a portion of the RCM image products created from the data will be publicly available to non-government users.[205]

In a further step to ameliorate Canada's EO capabilities, the Canadian Space Agency has awarded two contracts toward its contribution to the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) mission – a collaborative mission with the European Space Agency and the Chinese Academy of Sciences (CAS) focused on space weather phenomena. For this mission, Honeywell and the University of Calgary were awarded contracts worth CA$11M and CA$1.5M respectively. The former will design the Ultra-Violet Imager (UVI) and the University of Calgary the UVI Science Operations and Data Centre – allowing for the observation of auroras over the northern hemisphere.

Moreover, the Canadian Space Agency signed a Memorandum of Intent with ESA and the Canadian EO company GHGSat. Based on a shared concern for the climate crisis and the need for improved understanding of chemical and physical atmospheric processes, the collaboration entails the "provision of free data from the GHGSat constellation to the scientific community"[206] and the support of global efforts and initiatives monitoring greenhouse gases.

Along the lines of the third tenet of the space strategy, Canada has demonstrated a focus on space for security through the award of two contracts to Raytheon Canada Limited and the University of Toronto Institute for Aerospace Studies' Space Flight Lab by the Department of National Defence for the development of microsatellites and radar technology to improve surveillance capabilities, particularly for Canada's North.[207]

Russia announces new Sovereign's Eye remote sensing constellation and federal database

In January 2019, the head of Roscosmos, Dmitry Rogozin, announced the creation of a constellation of remote sensing satellites called the Sovereign's Eye ("Gosudarevo Oko"). By 2025, Russia's planned Earth Observation constellation is expected to include at least 15 satellites, including six Canopus-Vs, which are capable of highly accurate remote sensing through a multi-spectral camera. The latter are "jointly developed by the Russian Scientific Research Institute of Electromechanics and Surrey Satellite Technology" and will use both GPS and GLONASS to navigate in SSO[208]. Dmitri Rogozin qualified this constellation as important for Russian digital economy, agriculture and cybersecurity. Moreover, the constellation is expected to aid civilian agencies in meeting their monitoring needs, such as the Ministry of Emergency Situations, whose response capabilities will be improved through the Sovereign's Eye satellite network.[209]

Roscosmos announced in September 2019 that the "Government of the Russian Federation approved the regulation to create and maintain the Earth's remote sensing federal database"[210]. The new regulation

[203] "What is the RCM?". Canadian Space Agency (last updated: December 2019): http://asc-csa.gc.ca/eng/satellites/radarsat/what-is-rcm.asp
[204] *Ibid.*
[205] "Frequently Asked Questions - RADARSAT Constellation Mission (RCM)". Canadian Space Agency (last updated: December 2019): http://asc-csa.gc.ca/eng/satellites/radarsat/faq.asp
[206] "ESA's ɸ-week 2019 opens with a flourish". ESA (September 2019): http://www.esa.int/Applications/Observing_the_Earth/ESA_s_-week_2019_opens_with_a_flourish
[207] "Government of Canada announces contract awards for research and development in support of Arctic surveillance". Department of National Defence of Canada (February 2019): https://www.canada.ca/en/department-national-defence/news/2019/02/government-of-canada-announces-contract-awards-for-research-and-development-in-support-of-arctic-surveillance.html
[208] "Russia announces Sovereign's Eye remote sensing constellation". SpaceWatch Global (January 2019): https://spacewatch.global/2019/01/russia-announces-sovereigns-eye-remote-sensing-constellation/
[209] *Ibid.*
[210] "Regulative documents on Earth's remote sensing database signed". Roscosmos (September 2019): http://en.roscosmos.ru/20917/

establishes "the contents and ways of data transmission, as well as the time period of sending the data to the database"[211]. Moreover, the database creation and maintenance as well as the cooperation with other countries (e.g. data sharing, interaction with other databases) is regulated.

China expands on fleet of EO satellites with multiple launches

In 2019, China has put considerable efforts toward expanding on its fleet of Gaofen satellites belonging to the China High-Resolution Earth Observation System (CHEOS). Gaofen-5 and Gaofen-6 (launched in 2018) were put into service in March 2019. China also launched Gaofen 7 and Gaofen 10R – the latter being supposed replacement for the Gaofen 10 satellite that failed to reach orbit upon its launch in 2016. Moreover, Gaofen 12 was launched in November 2019. According to Chinese officials, the "CHEOS satellite fleet is a civilian-operated programme comprising optical and radar imaging spacecraft".[212].

Further strides were made in Chinese Earth Observation through the launch of an additional five satellites belonging to the commercial remote sensing constellation Zhuhai-1 in September 2019. This constellation – produced by the Harbin Institute of Technology and operated by the Zhuai Orbital Aerospace Science and Technology – encompasses "34 micro-nano satellites, including video, hyperspectral and high-resolution optical satellites, as well as radar and infrared satellites".[213] The new satellites comprise 4 hyperspectral satellites and one video satellites and according to the operator will contribute to the "analysis of vegetation, water and crops, and will provide services for building smart cities", with the goal of cooperating with government entities and other private actors[214].

China seeks international partners in meteorology, remote sensing and disaster prevention

In the realm of meteorology, remote sensing and disaster prevention, China has pushed forward with international cooperation. On the side-lines of the 18th World Meteorological Congress in June 2019, the China Meteorological Administration (CMA) "signed FengYun satellite application cooperative agreements with meteorological departments of Mozambique and Oman respectively" as well as "consulted on deepening cooperation" with meteorological departments of Namibia and South Africa[215]. Both agreements focused on natural and meteorological disaster monitoring and risk mitigation.

In a similar fashion, China has signed a cooperative agreement titled *Agreement between the China Meteorological Administration and the Ministry of Emergency Situation of the Kyrgyz Republic on Cooperation in Fengyun Meteorological Satellite Services* on the side-lines of President Xi Jinping's visit to Kyrgyzstan. According to the China Meteorological Administration, this agreement represents "a new chapter for the bilateral meteorological cooperation". The agreement "aims to promote bilateral meteorological scientific cooperation to new heights, elevate FY satellites application level, improve disaster preparedness" as well as "provide support for security and well-being of people from the two countries and the socio-economic development".[216]

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[211] *Ibid.*
[212] Stephen Clark, "China launches new Gaofen Earth-imaging satellite". Spaceflight Now (October 2019): https://spaceflightnow.com/2019/10/06/china-launches-new-gaofen-earth-imaging-satellite/
[213] Annamarie Nyirady, "China Launches 5 Remote Sensing Satellites". Via Satellite (September 2019): https://www.satellitetoday.com/imagery-and-sensing/2019/09/20/china-launches-5-remote-sensing-satellites/
[214] *Ibid.*
[215] China Meteorological News Press, "China Meteorological Administration promotes "Belt and Road" meteorological cooperation with several countries". China Meteorological Administration (June 2019): http://www.cma.gov.cn/en2014/news/News/201906/t20190614_527259.html
[216] China Meteorological News Press, "China and Kyrgyzstan signs cooperative agreement in FY satellite services to provide support for scientific cooperation and disaster preparedness". China Meteorological Administration (June 2019): http://www.cma.gov.cn/en2014/news/News/201906/t20190614_527257.html

DLR collaborates on innovation in optical transmission methods

On 3 April 2019, DLR and the University of Stuttgart tested the "transmission of Earth observation data using laser communications"[217]. The Optical Space Infrared Downlink System (OSIRIS) laser communication terminal developed by DLR has completed its first transmission tests. The purpose of this experiment is to progress in optical transmission methods capable of sending large amounts of data at higher rates. The OSIRIS is compact and at 1.3 kg relatively light and thus able to be deployed on board the so called "Flying Laptop" – "a small satellite developed by the University of Stuttgart". The data was received using "DLR's optical ground station in Oberpfaffenhofen as part of a programme of experiments that has been ongoing since the summer of 2018". To further improve the process, the DLR Institute of Communications and Navigation in Oberpfaffenhofen "is developing optical communication systems that are particularly suited to direct downlink from small satellites".[218] Further transmission tests regarding the reception of data are planned for the future.

Italy kickstarts development of ITAL-GovSatCom

With an agreement between ASI, Thales Alenia Space and Telespazio in July, Italy launched the development of ITAL-GovSatCom,[219] the innovative telecommunications system mirror programme of the European GovSatCom. In September, the newly formed government approved a decree to provide €100M of additional funds to expand the pool of industrial actors and SMEs participating in the project.[220]

UK announces development of new generation of defence communication satellites SKYNET 6

Related to the developments fostered by the Ministry of Defence is also the announcement to develop a new generation of defence communication satellites "SKYNET 6", fifty years since the launch of the first satellite SKYNET-1A.[221] Furthermore, Airbus won a five-year contract with the Ministry of Defence for approximately €25M to manage the "Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR)" capability for an integrated communication network.[222]

Canadian government invests in connectivity in remote regions of country through investment in Telesat

In line with its strategy towards providing socio-economic benefits to its citizens through space, the Canadian government is taking steps to address the needs of citizens living in the vast rural and remote areas of Canada – particularly in the North. The Canadian government made an important step towards honouring its commitment to connect remote citizens of Canada by announcing an investment of CA$85M in the Canadian satellite company Telesat to "build and test innovative technologies for its low-earth-orbit (LEO) satellite constellation".[223] This agreement was further complemented by a Memorandum of Understanding with Telesat to provide broadband Internet capacity covering the entirety of Canada through the planned satellite constellation in LEO in return for a commitment of up to CA$600M from the Canadian government over the first 10 years of constellation's operation (subject to terms of a contribution agreement).[224]

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[217] "DLR and the University of Stuttgart test the transmission of Earth observation data using laser communications". DLR (April 2019): https://www.dlr.de/content/en/articles/news/2019/02/20190403_osiris-transmission-of-earth-observation-data.html;jsessionid=251379655FBB5A4FD470C181DC5CC661.delivery-replication1

[218] *Ibid.*

[219] "Thales Alenia Space and Telespazio win contract from Italian Space Agency". Thales Alenia Space (July 2019)

[220] "Space Economy: 100 milioni di euro in favore di progetti di ricerca e sviluppo presentati dalle imprese". Ministry of Economic Development of Italy (September 2019): https://www.mise.gov.it/index.php/it/per-i-media/notizie/2040249-space-economy-100-milioni-di-euro-in-favore-di-progetti-di-ricerca-e-sviluppo-presentati-dalle-imprese

[221] "Defence Secretary announces boost for multi-billion-pound SKYNET 6 programme". UK Ministry of Defence and Joint Forces Command (September 2019)

[222] "Airbus to run UK MOD's land C4ISR test centre". Airbus (July 2019): https://www.airbus.com/newsroom/press-releases/en/2019/07/airbus-to-run-uk-mods-land-c4isr-test-centre.html

[223] "Minister Bains announces major investment in the future of connectivity for Canadians living in rural and remote communities". Ministry of Innovation, Science and Economic Development of Canada (July 2019)

[224] *Ibid.*

1.3.3 Science and exploration programmes

ESA announcement of HERA mission – part of NASA cooperation on Asteroid impact deflection

At the ESA Ministerial Council 2019, ESA announced the approval of the Hera mission[225] as part of its new Space Safety Programme – which will be part of a joint NASA-ESA endeavour called Asteroid Impact Deflection Assessment (AIDA). This mission's "purpose is to deflect the orbit of the smaller body of the double Didymos asteroids between Earth and Mars through an impact by one spacecraft. Then a second spacecraft will survey the crash site and gather the maximum possible data on the effect of this collision".[226] While the impact test currently scheduled for 2022 will be performed by NASA's DART spacecraft (Double Asteroid Impact Test), ESA's Hera mission will perform the close-up surveying of the crash site and additionally deploy CubeSats for closer inspection of the site.[227]

BepiColombo poised to start journey to Mercury

In April, the European Space Agency announced that the ESA-JAXA BepiColombo mission, launched in October 2018 on an Ariane 5 rocket from French Guiana, has "successfully completed its near-Earth commissioning phase and is now ready for the operations that will take place during the cruise and, eventually, for its scientific investigations at Mercury"[228]. After confirmation of the correct functioning of BepiColombo's spacecraft, propulsion and scientific instruments, the mission enters into its operational phase. The mission comprises two orbiters – i.e. ESA's Mercury Planetary Orbiter (MPO) and JAXA's Mercury Magnetospheric Orbiter (MMO) – which will be brought to Mercury by ESA's Mercury Transfer Module (MTM) and perform orbit insertions.

BepiColombo is scheduled to arrive at Mercury towards the end of 2025[229].

Airbus progresses in production of JUICE satellite

In July 2019, Airbus DS announced that the first construction phase of ESA's JUICE satellite has been completed and is now ready for further construction and eventual final integration at various Airbus sites in Europe. ESA's JUICE (Jupiter Icy moons Explorer) aims to "investigate the potential for Jupiter's icy moons Europa, Callisto and Ganymede to harbour habitable environments such as subsurface oceans"[230]. The JUICE mission is scheduled to commence its 7-year journey of more than 600 million kilometres to Jupiter in 2022.

JUICE propulsion system integration (Credit: Airbus and Arianegroup)

[225] "ESA ministers commit to biggest ever budget". ESA (November 2019): http://www.esa.int/About_Us/Corporate_news/ESA_ministers_commit_to_biggest_ever_budget
[226] "Europe and US teaming up for asteroid deflection". ESA (September 2019): https://www.esa.int/Safety_Security/Hera/Europe_and_US_teaming_up_for_asteroid_deflection
[227] *Ibid.*
[228] "BepiColombo is ready for its long cruise". ESA (April 2019): http://www.esa.int/Science_Exploration/Space_Science/BepiColombo/BepiColombo_is_ready_for_its_long_cruise
[229] *Ibid.*
[230] "JUICE starts its journey… on Earth". Airbus (July 2019): https://www.airbus.com/newsroom/press-releases/en/2019/07/juice-starts-its-journey-on-earth.html

ESA space exploration satellite "CHEOPS" launched

ESA announced in July 2019 that the Characterising Exoplanet Satellite (CHEOPS) passed its final review before being transported to Europe's Spaceport in French Guiana for its launch on a Soyuz rocket, which occurred on 18 December. According to ESA, the mission will provide information on "stars hosting planets in the Earth-to-Neptune size range", providing information on the size of the planet which combined with the known information on their mass can give insights into their density. This, in turn "provides vital clues about its composition and structure, indicating for example if its predominantly rocky or gassy, or perhaps harbours significant oceans".[231]

Postponement of ExoMars mission announced

On 12 March 2020, ESA and Roscosmos decided to postpone the ExoMars mission to the launch window between August and October 2022, in order to complete the necessary tests and considering possible interruptions caused by the health situation in Europe.[232] After launch, the landing on Mars will be now expected to occur between April and July 2023. The decision follows delays on the parachute tests and an announced review of the entire mission schedule. Already in 2016, ESA and Roscosmos had to agree on postponing the launch date of 2018 to 2020. The first part of the ExoMars programme, the Trace Gas Orbiter, was launched in 2016 and "is already both delivering important scientific results of its own and relaying data from NASA's Curiosity Mars rover and Insight lander" and was planned to also "relay the data from the ExoMars 2020 mission once it arrives at Mars".[233] For the ExoMars mission, the European Space Agency and Roscosmos aim to launch the Mars rover named after the British scientist Rosalind Franklin to Mars on a Russian Proton-M launch vehicle. As of August 2019, the rover is equipped with all necessary scientific instruments (including cameras, a drill and an onboard laboratory) and after undergoing further testing will be integrated with the lander platform Kazachok as well as the descent module and carrier module.[234] Primary task of the rover will be to conduct several scientific operations in search for life.[235]

NASA and ESA progress on Mars Sample Return Mission

In 2019, ESA also revealed more information on the Mars Sample Return campaign currently planned in cooperation with NASA. ESA DG Wörner stated that the decision on ExoMars should not affect the schedule of the Mars Sample Return mission. According to ESA, the "campaign foresees three launches from Earth and one from Mars, two Martian rovers and an autonomous rendezvous and docking in Mars orbit – over 50 million km away from ground control".[236] The aim is to return samples from Mars that originate from the so called Jezero crater. As the crater "once held a lake and contains an ancient preserved river delta", the samples will expand humankind's knowledge on Mars' geology and climate history[237]. The campaign is scheduled for the timeframe 2020-2030 and entails three launches. NASA's Mars 2020 mission aims to explore the Red Planet's surface, collect data and samples, which then will be

[231] "Cheops passes final review before shipment to launch site". ESA (July 2019): https://www.esa.int/Science_Exploration/Space_Science/Cheops/Cheops_passes_final_review_before_shipment_to_launch_site
[232] "ExoMars to take off for the Red Planet in 2022". ESA (March 2020): http://www.esa.int/Newsroom/Press_Releases/ExoMars_to_take_off_for_the_Red_Planet_in_2022
[233] "ExoMars rover ready for environment testing". ESA Exploration (August 2019): https://exploration.esa.int/web/mars/-/61528-exomars-rover-ready-for-environment-testing
[234] "All instruments onboard Rosalind Franklin rover". ESA (August 2019): http://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/All_instruments_onboard_Rosalind_Franklin_rover
[235] "ESA's Mars rover has a name – Rosalind Franklin". ESA (February 2019): http://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/ESA_s_Mars_rover_has_a_name_Rosalind_Franklin. See also: "All instruments onboard Rosalind Franklin rover". ESA (August 2019)
[236] "Mars on Earth – what next?". ESA (May 2019): https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Mars_on_Earth_what_next
[237] *Ibid.*

placed in specific areas for later retrieval. The second launch by NASA will "send the Sample Retrieval Lander mission to land a platform near the Mars 2020 site" from which an ESA rover (Sample Fetch Rover) will retrieve the samples. Returning to the landing platform, the samples will be loaded onto the Mars Ascent Vehicle which will lift-off and rendezvous with ESA's Earth Return Orbiter, the next mission. This spacecraft will return the samples to Earth. As mentioned in the third resolution of the Ministerial Council 2019, the Mars Sample Return campaign awaits formalisation with NASA.[238]

Europe and China cooperation on SMILE mission

China will cooperate with Europe on a mission called the Solar wind Magnetosphere Link Explorer (SMILE). This project was given the green light in March 2019 and builds on successful cooperation between ESA and China on the Double Star/ Tan Ce mission (2003-2008). While the latter was a mission catalysed by China, the SMILE mission is a joint ESA-China project. The project aims to launch a 2200 kg spacecraft via European Vega-C or Ariane 62 rocket in 2023 and "subsequently [place it] in a highly inclined elliptical orbit around Earth". According to ESA, "every 51 hours, SMILE will fly out to 121 000 km – almost one third of the distance to the Moon – giving it a prolonged view of Earth's northern polar regions", after which it will return closer to Earth and enable the download of its collected data.[239] The mission will last for three years and use four instruments which will be provided from China, Europe and Canada.

Italy signs several cooperation agreements

Italy reinforced cooperation with China and the United States in the field of space science and exploration. During the visit of Xi Jinping in Rome in March, ASI and CNSA signed a MoU to continue the cooperation on the China Seismo-Electromagnetic Satellite (CSES) programme.[240] Italy already participated in the CSES-01 project with "Limadou", the High Energy Particle Detector (HEPD) instrument onboard the satellite launched in 2018 that also studies the electromagnetic variations in the ionosphere.[241] With this new MoU, Italy will develop a second HEPD and the Electric Field Detector (EFD) as well.

After a long negotiation, ASI also signed in October a Joint Statement for Cooperation in Space Exploration with NASA.[242] Italy became the first European country to sign a bilateral agreement with NASA related to the participation in Artemis and the Lunar Gateway programmes.

Italy also signed a new agreement with Virgin Galactic[243] following the framework agreement signed in 2018 between ASI, Italian companies and the U.S.-based company to explore the feasibility of suborbital research flights from the Taranto-Grottaglie Spaceport, in the Apulia region,[244] for which Italy started to develop a regulatory framework for the suborbital activities. Italy plans to fly three Italian researchers and a set of payloads from the Air Force and the National Research Centre (CNR) to conduct experiments in microgravity on a SpaceShipTwo flight expected for 2020. With this new agreement the Italian Air Force became the first governmental actor to sign a human flight commercial contract.

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[238] "Resolution on ESA programmes: addressing the challenges ahead" (Resolution 3), adopted by ESA Ministerial Council on 28 November 2019. Available at: https://esamultimedia.esa.int/docs/corporate/Resolution_3_Space19+Final-28Nov-12h30.pdf
[239] "ESA gives go-ahead for SMILE mission with China". ESA Science (March 2019): https://sci.esa.int/web/smile/-/61191-esa-gives-go-ahead-for-smile-mission-with-china
[240] "Continua la collaborazione Italia-Cina sui satelliti cinesi della serie CSES". ASI (March 2019): https://www.asi.it/2019/03/727/
[241] "Missione CSES – Contributo Italiano Limadou". ASI: https://www.asi.it/scienze-della-terra/missione-cses-contributo-italiano-limadou/
[242] "Artemis: Accordo NASA-ASI". ASI (October 2019): https://www.asi.it/2019/10/artemis-accordo-nasa-asi/
[243] Ufficio Pubblica Informazione, "Spazio: Accordo tra aeronautica militare e Virgin Galactic per volo sperimentale suborbitale". Ministry of Defence of Italy (October 2019): http://www.aeronautica.difesa.it/comunicazione/notizie/Pagine/accordo-virgin-galactic.aspx
[244] Jeff Foust, "Virgin space companies sign new agreements with Italy". SpaceNews (July 2018): https://spacenews.com/virgin-space-companies-sign-new-agreements-with-italy/

Hayabusa-2 performs successful touch-down and starts return to Earth

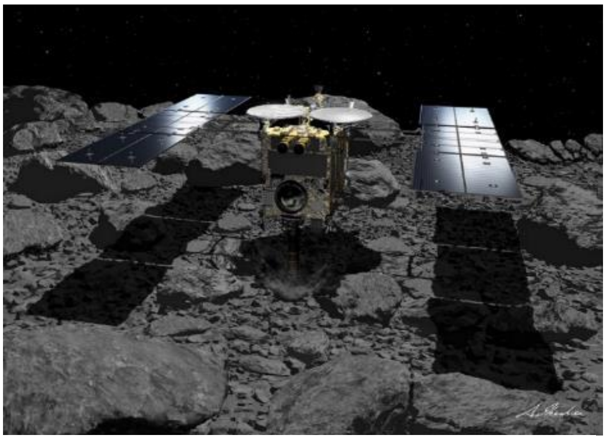

Illustration of Hayabusa2 (Credit: Akihiro Ikeshita)

An important milestone for Japanese space exploration occurred in February 2019 when the asteroid explorer Hayabusa-2 touched down on the asteroid Ryugu to collect samples, a mission that started in 2014, when Hayabusa2 was launched. On 15 April, the Institute of Space and Astronautical Science (ISAS) confirmed that the second part of the mission was successful. It entailed the separation of a Small Carry-on Impactor from Hayabusa, which impacted Ryugu and created a crater[245]. On 11 June, Hayabusa2 touched down a second time and collected the soil samples after the creation of the crater[246]. Hayabusa2 is scheduled to return to Earth in 2020 and this mission aims to "elucidate the origin and evolution of the solar system and primordial materials that would have led to emergence of life"[247].

Japan signs cooperation agreements on Martian Moon exploration and Hayabusa 2

Artist concept of MMX (Credit: JAXA/NASA)

Further international cooperation was fostered in the domain of the exploration of Mars. JAXA has signed cooperation agreements with both CNES and DLR regarding the study-phase activities of the Martian Moons eXploration (MMX) mission. The mission consists of the observation of Mars' moons (Phobos and Deimos) and the collection of surface material samples from one of the moons as well as their return to Earth – with "aims to clarify the origin of the Martian moons and the process of evolution for Mars region and to improve technologies required for future exploration"[248]. DLR's contribution includes the studies on the rover, which is equipped on MMX in cooperation with CNES, as well as the provision of experiment opportunities using the Drop Tower in Bremen, Germany. CNES will provide the "near infrared spectrometer (MacrOmega) and the knowledge and expertise of the Flight Dynamics" as well as the rover studies in cooperation with DLR[249]. The second agreement between JAXA and CNES pertained to the Hayabusa2 mission – "to which CNES is already

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245 "Successful Operation of Asteroid Explorer Hayabusa2's SCI". JAXA Institute of Space and Astronautical Science (April 2019): http://www.isas.jaxa.jp/en/topics/002146.html

246 "Success of the Second Touchdown of Asteroid Explorer "Hayabusa 2"". JAXA Institute of Space and Astronautical Science (July 2019): http://www.isas.jaxa.jp/en/topics/002203.html

247 Hiroshi Sasaki, "JAXA's Lunar Exploration Activities", presentation at the 62nd Session of the United Nations Committee on the Peaceful Uses of Outer Space (June 2019)

248 "JAXA and DLR Make and Sign Implementing Arrangement on Martian Moons eXploration (MMX)". JAXA Institute of Space and Astronautical Science (June 2019): http://www.isas.jaxa.jp/en/topics/002187.html

249 "JAXA and CNES Sign Implementing Arrangement on Martian Moons eXploration (MMX) and Hayabusa2". JAXA Institute of Space and Astronautical Science (June 2019): http://www.isas.jaxa.jp/en/topics/002188.html

contributing with the MASCOT lander" which enabled Hayabusa2 spacecraft to land on the asteroid Ryugu. The new agreement specifically covers the analysis of the samples which will be returned to Earth in 2020.[250].

In terms of space science, Japan was able to further deepen its cooperation with the European Space Agency through signing a cooperation agreement on the X-Ray Imaging and Spectroscopy Mission: XRISM. Hiroshi Yamakawa (President of JAXA) and Johann-Dietrich Wörner (Director General of ESA) signed the agreement in Darmstadt, Germany on 14 June and it entails European cooperation in "the development of one of XRISM's most important instruments, the Soft X-ray Spectrometer" as well as European scientists' participation in the project generally[251]. The projected launch of the XRISM is FY2021.

China reveals details on Mars explorer

China's space exploration ambitions also extend to Mars: in October 2019, the first picture of the Chinese Mars explorer was unveiled. According to Chief Scientist of Space Science and Deep Space Exploration at the Chinese Space Technology Academy, the launch will occur in 2020[252] – an important launch window as the "orbits of Mars and Earth are closest to each other, 'which occurs every 26 months and lasts about one month'"[253]. The launch vehicle will be the heavy-lift Long March 5. The mission is an ambitious endeavour as it sets out to orbit, land on and "to examine the Red Planet's atmosphere, landscape, geological and magnetic characteristics, which could provide clues to the origin and evolution of Mars and the solar system"[254].

German scientists present promising experiment results on production of food in space and life support for ISS

A scientific mission to benefit future Mars and Moon missions presented its first results in August 2019: the EDEN ISS project. Paul Zabel, DLR researcher and member of the crew at the Alfred Wegener Institute's Neumayer II Antarctic research station, spent one year on the perpetual ice researching the production of food in inhospitable conditions, such as future space missions on the Moon or Mars. Over nine and a half months, the team succeeded in growing 268 kg of food in an area of 12.5 m^2 while only reaching half of the projected power consumption for greenhouses in space. Eden ISS scientists have drafted a design concept for a space greenhouse to be launched using a Falcon 9 rocket and this research project on how to cultivate locally grown food in space will continue[255].

A further experimental technology project was developed for use on the ISS by the University of Stuttgart and manufactured by Airbus on the behalf of DLR is the photobioreactor (PBR). It is "designed to convert part of the CO_2 extracted by the 'LSR' Life Support Rack on board the ISS into oxygen and biomass, which could help to save valuable resources during future long-term missions into space"[256]. This is particularly pertinent for potential missions to Moon and Mars.

[250]"France-Japan space cooperation, signature of two agreements on Mars exploration and asteroid Ryugu". CNES (June 2019): https://presse.cnes.fr/en/france-japan-space-cooperation-signature-two-agreements-mars-exploration-and-asteroid-ryugu
[251] "Agreement with European Space Agency (ESA) for cooperation on the X-Ray Imaging and Spectroscopy Mission: XRISM". JAXA (June 2019): https://global.jaxa.jp/projects/sas/x-ray_imaging_and_spectroscopy_mission_xrism/topics.html#topics14766
[252] Leonard David, "This is the 1st Photo of China's Mars Explorer Launching in 2020". Space.com (October 2019): https://www.space.com/china-moon-lander-rover-first-picture.html
[253] Li Yan, "China's Mars rover to launch in 2020". ECNS (July 2019): http://www.ecns.cn/news/2019-07-08/detail-ifzkvtrv5568863.shtml
[254] Leonard David, "This is the 1st Photo of China's Mars Explorer Launching in 2020". Space.com (October 2019): https://www.space.com/china-moon-lander-rover-first-picture.html
[255] "EDEN ISS project presents results of a new greenhouse concept for future space missions". DLR (August 2019): https://www.dlr.de/content/en/articles/news/2019/03/20190823_project-eden-iss-presents-results.html?nn=bad75799-8317-4d4c-958d-3120224bc1ea
[256] "Photobioreactor: oxygen and a source of nutrition for astronauts". Airbus (April 2019): https://www.airbus.com/newsroom/press-releases/en/2019/04/photobioreactor-oxygen-and-a-source-of-nutrition-for-astronauts.html

Robotic astronaut assistant CIMON-2 launches to ISS

In August 2019, the robotic astronaut assistant called Crew Interactive Mobile Companion (CIMON) returned from its 14-month long deployment on the ISS.[257] Developed and built in Germany and equipped with Artificial Intelligence (AI), it served as a technology demonstration for cooperation between humans and intelligent machines. According to the CIMON Project Manager at DLR, Christian Karrasch, CIMON's first mission allowed to "lay the foundation for human assistance systems in space to support astronauts in their tasks and perhaps, in the future, to take over some of their work."[258] On 5 December 2019, CIMON-2 was launched to the ISS and will likely remain for up to three years. The successor to the CIMON-1 prototype is built to have more sensitive microphone equipment as well as more advanced AI capabilities.[259]

DLR progresses with radiation protection technology

ESA announced in 2019 that it will deploy two 'dummies' to investigate "the amount of radiation astronauts could be exposed to in future missions"[260] on NASA's Exploration Mission-1 – the un-crewed flight to the vicinity of the Moon. Developed by DLR, the MatroshkaAstroRad Radiation Experiment (MARE) consists of two dummies made up of "tissue-equivalent plastics that mimic the varying density of bones, soft tissue and lungs". In particular the effect of galactic cosmic radiation and virulent solar particle events are to be measured on this 'tissue' in the areas that are most sensitive to radiation, such as the lungs, the uterus, the stomach and the bone marrow. One of the dummies will wear a radiation protection vest for scientific comparison[261].

Tiangong-2 space station deorbits and re-enters atmosphere

On July 19th, the Tiangong-2 space station deorbited and re-entered the atmosphere after completing its mission which started with its launch in September 2016. As China's first space laboratory, Tiangong-2 served to master and verify the technologies required to assemble the much bigger China's Space Station (CSS) in the early 2020s.[262]

India announces the start of series of ambitious space science programmes – "mega missions"

According to ISRO Chairman Dr. K Sivan, a roadmap for the next 30 years of India's civil space programme has been prepared and includes the study, development and execution of seven "mega missions".[263] Of these missions, only two have been outlined so far – the X-ray Polarimeter Satellite (XPoSat) and Aditya-L1 missions (other than the Chandrayaan-2, which is already in operation). XPoSat will study "the degree and angle of polarization of bright X-ray sources in the energy range 5-30", whereas Aditya-L1 will study the solar corona[264]. The four remaining missions are undefined and will presumably be announced with the new roadmap on India's civil space programme.

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[257] "CIMON back on Earth after 14 months on the ISS". DLR (August 2019): https://www.dlr.de/content/en/articles/news/2019/03/20190828_cimon-back-on-earth-after-14-months.html
[258] *Ibid.*
[259] "CIMON-2 is on its way to the ISS". DLR (December 2019): https://www.dlr.de/content/en/articles/news/2019/04/20191205_cimon2-on-its-way-to-the-iss.html
[260] "Photobioreactor: oxygen and a source of nutrition for astronauts". Airbus (April 2019)
[261] "Radiation for dummies". ESA (January 2019): https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Orion/Radiation_for_dummies
[262] Andrew Jones, "China's Tiangong-2 space lab reenters over South Pacific". SpaceNews (July 2019): https://spacenews.com/chinas-tiangong-2-space-lab-reenters-over-south-pacific/
[263] SV Khrishna Chaitanya, "ISRO plans to conduct seven mega missions over next 10 years". The New Indian Express (May 2019): https://www.newindianexpress.com/nation/2019/may/18/isro-plans-to-conduct-seven-mega-missions-over-next-10-years-1978338.html
[264] *Ibid.*

2 Industry & Innovation

2.1 2019 in a nutshell

2019 has been a consolidation year for various space industry trends observed in the sector for the past few years, paving the way for a new decade that will certainly also see profound changes in the structure of the global space industry.

Mega-constellations, Microlaunchers or In-Orbit Servicing are equally important trends for the sector that have seen key achievements, as well as significant setbacks during the year. With the launch of 120 Starlink satellites and the first 6 satellites of OneWeb constellation (whose future is now difficult to predict), mega-constellations are closer to becoming a reality and to becoming confronted to the actual viability of their business model. Constellation projects alone, counted for a third of commercial satcom launches in 2019. Major progress can also be reported on the development of microlaunchers and in-orbit servicing solutions, with a few leaders emerging with major technical and commercial successes. In this field, Rocket Lab (Electron rocket) and Northrop Grumman (MEV-1 servicing spacecraft) certainly marked the year but many other outstanding developments, including in Europe, took place in 2019, shaping the progress of both trends.

In the space transportation industry, 2019 has also been marked by major milestones for important industrial programmes. In Europe, next-generation launchers Ariane 6 and Vega-C successfully passed their respective Critical Design Review and are now on the last step before their maiden flights expected to take place in 2020. Their backlog also filled up with a variety of payloads both governmental and commercial including for non-European customers. Other transportation programmes across the World also made important steps: the United States is increasingly close to recover its Human spaceflight capacity and several American, Russian, Chinese or Japanese rockets, in particular in the super-heavy segment (e.g. SLS, Yenisei, Long March 5, H3), will soon enter the market after important steps forward in 2019.

The satellite industry also faces turmoil in traditional segments such as the GEO satcom market which experienced a slowdown since 2016, with a stark decrease in satellite orders and a reduction of the associated launch activity. Telecommunication and media sectors experienced a rapid evolution across all market parameters and this transformation has profoundly impacted satcom operators that are currently facing uncertainties which may affect their businesses. This wait-and-see attitude can in turn negatively affect satellite manufacturers; this would lead to business reorganisations but also drive promising developments in the fields of reconfigurable payloads, small platforms and shared payloads.

Finally, industry involvement in renewed Moon ambitions, in particular for the Artemis programme, became much clearer both for space transportation and system developments. Major contracts were signed for various components of the programme including the Lunar Gateway, Orion spacecraft and Space Launch System but also for logistical services, Human landing system and commercial lunar payload services. These announcements are triggering a great momentum for the industry in the space exploration domain with interesting developments for the future.

This is only the tip of the iceberg and the space industry saw many other noteworthy advances in 2019 that will certainly shape new trends for the future. Some examples are the multiple projects involving the use of Artificial Intelligence or the emergence of new commercial solutions for the Internet of Things or Space Situational Awareness.

2.2 Space transportation industry highlights and trends in 2019

2.2.1 Progress of next-generation European launcher programmes

Ariane 6 (manufactured by ArianeGroup) and Vega-C (manufactured by Avio) are the next-generation European launchers, whose first flight is planned for 2020.

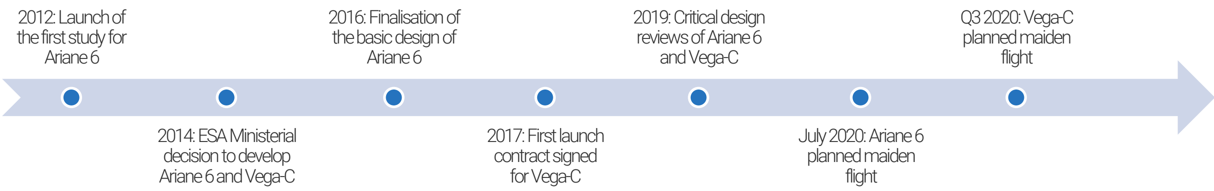

Figure 8: Major Ariane 6 and Vega-C milestones

Signature of protocols between ESA, Arianespace, ArianeGroup (Credit: ESA)

ArianeGroup and ESA planned fourteen missions for Ariane 6 during the transition period with Ariane 5 (2020-2023), including seven governmental missions. However, only three launches had been booked early 2019, not enough to start the full-scale production of Ariane 6.[265] An arrangement was found with ESA in April 2019 and ArianeGroup got the guaranteed equivalent that expenses would be covered if orders do not materialize in a reasonable time.[266] The serial production of the first fourteen Ariane 6 eventually began without any further delays. The same agreement also covers eight missions for the transition period between Vega and Vega-C, expected to last from 2020 to 2023. Later in the year, as part of the restructuring of the future European institutional commitments, ESA, Arianespace, ArianeGroup and Avio signed several protocols on the exploitation phase of the two future launchers. These protocols govern the long-lasting exploitation of Ariane 6 and Vega-C, by sharing the technical and industrial responsibilities in several domains, such as compliance with requirements, maintenance, launch authorisation, etc.

At the end of 2019, a number of payloads from various public and private customers had already been secured for the two launchers. The first flight of Vega-C in 2020 will carry a science satellite from the Italian Space Agency and the French CO3D and Pléiades Neo constellations are expected to be launched on this rocket. Overall, around six to seven launch contracts were already signed for Vega-C at the end of 2019. Regarding Ariane 6, OneWeb signed a contract in 2019 to launch 30 of its satellites on the maiden flight of Ariane 62 (2020 update: consequences of OneWeb bankruptcy still unknown) and ESA chose an

[265] Caleb Henry, “Arianespace says full Ariane 6 production held up by missing government contracts”. SpaceNews (January 2019): https://spacenews.com/arianespace-says-full-ariane-6-production-held-up-by-missing-government-contracts/
[266] Caleb Henry, “ArianeGroup starting Ariane 6 production after new ESA agreement”. SpaceNews (April 2019): https://spacenews.com/arianegroup-starting-ariane-6-production-after-new-esa-agreement/

Ariane 64 to launch the future JUICE mission.[267] In addition, by modifying the contract that it had for an Ariane 5, ViaSat became the first commercial customer to commit to launch on an Ariane 64. Finally, early 2020, ESA preordered four more launches of Ariane 62 on behalf of the European Commission, in order to launch Galileo satellites.[268]

A non-exhaustive list of the launches planned for the two future European launchers is provided below:

Year	Launcher	Payload	Customer	Orbit	Comments
2020	Ariane 6	30 OneWeb sats	OneWeb	LEO	Inaugural launch of Ariane 62, status unknown
	Vega C	LARES_2	ASI	LEO	Inaugural launch of Vega-C
		CSG-2	ASI	LEO	Or 2021
		Pléiades-Neo 1 & 2	Airbus DS	SSO	
2021	Ariane 6	ViaSat 3	ViaSat	GEO	First commercial launch for Ariane 64
		CSO 3	French DGA	SSO	
		Hotbird 13F & 13G	Eutelsat	GEO	
		Galileo 25 & 26	European Commission	MEO	
	Vega-C	CERES 1,2,3	French DGA	SSO	
		THEOS-2 HR	GISTDA (Thailand)	SSO	
		KOMPSAT-7	KARI (South Korea)	SSO	Or 2022
2022	Ariane 6	Galileo 27 & 28	European Commission	MEO	
		Galileo 29 & 30	European Commission	MEO	
		Euclid	ESA	Escape	Or onboard Soyuz
		JUICE	ESA	Escape	Or onboard Ariane 5
	Vega-C	NAOS	OHB (for Luxembourg DoD)	LEO	Or onboard Vega
		Pléiades-Neo 3 & 4	Airbus DS	SSO	
		Space Rider	ESA	LEO	
2025	Vega-C	e.Deorbit	ESA	LEO	

Table 8: Ariane 6 and Vega-C announced payloads

[267] The JUICE mission could also be launched onboard an Ariane 5 if it is needed to meet its schedule. Debra Werner, "Arianespace reveals manifest, notes launch market variety". SpaceNews (September 2019): https://spacenews.com/arianespace-wsbw-2019/
[268] "ESA and the European Commission preorder four more Ariane 6 launches". Arianespace (March 2020): https://www.arianespace.com/press-release/european-commission-preorder-ariane-6/

From a technical standpoint, the two launcher programmes reached several milestones in 2019. Various successful tests on the engines of the two launchers have been performed, in particular:

- The P210C, a solid rocket booster made of carbon composite and built in one piece, and which will constitute the strap-on boosters of Ariane 6 and the first stage of Vega-C, managed to pass a static fire test in January. During the test, the engine met expectations and no anomaly occurred.[269]
- The Vulcain 2.1, the liquid-fuelled engine of the first stage of Ariane 6, passed its final qualification test in July, after 15 months of test. The engine was fired 655 seconds (almost 11 minutes), thus reaching a total test duration of almost four hours.[270]

These successes open the way for combined testing, which will use a representative full main stage, in order to qualify the full Ariane 6 core stage for flight.[271] Moreover, providing that the motor that will propel the upper stage, Vinci, finished its qualification campaign in October 2018, all engines of Ariane 6 are now on track for the first launch of the rocket in 2020.

Both Ariane 6 (in September) and Vega-C (in February) passed their respective Critical Design Review, meaning that the design and means used to produce the rockets have been validated. Integration of the various components of the launchers is already underway; and a new factory to proceed with the integration of Ariane 6 upper stages was inaugurated in October in Bremen.

Ariane 6 will also allow to demonstrate European innovation. For instance, the new product line of RUAG, thermal insulation for launchers, will be used on the rocket. In addition, ESA and ArianeGroup are already thinking about potential ameliorations: for instance, the two entities signed a contract for the development of the prototype of a highly-optimised black upper stage (PHOEBUS). This upper stage will be built of carbon composite materials for several of its elements in order to reduce the cost and weight of the rocket. Up to two supplementary tons of payload could be launched, with a potential application to Ariane 6 planned for 2025.[272]

Progress on Europe's future launchers was also achieved through the selection of the start-up MyCTO by ArianeWorks (an acceleration platform launched by CNES and ArianeGroup in February 2019) to build the prototype of one of the recovery concepts under study for the development of THEMIS, a low-cost reusable first-stage demonstrator.[273] In addition, ArianeGroup, with the support of ESA, CNES and DLR, finalised the Definition Review of the Prometheus engine demonstrator, which aims at developing a very low-cost and potentially reusable engine for European launchers.[274]

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[269] "P120C solid rocket motor tested for use on Vega-C". ESA (January 2019): https://www.esa.int/Enabling_Support/Space_Transportation/P120C_solid_rocket_motor_tested_for_use_on_Vega-C
[270] "Ariane 6 Vulcain engine: successful qualification testing". ArianeGroup (July 2019): https://www.ariane.group/en/news/ariane-6-vulcain-engine-successful-qualification-testing/
[271] "Ariane 6's core engine completes qualification tests". ESA (September 2019): http://www.esa.int/Enabling_Support/Space_Transportation/Ariane_6_s_core_engine_completes_qualification_tests
[272] "Contracts signed for prototype of a highly-optimised black upper stage". ESA (may 2019): http://www.esa.int/Enabling_Support/Space_Transportation/Contracts_signed_for_prototype_of_a_highly-optimised_black_upper_stage
[273] "ArianeWorks selects MyCTO to prototype stage-recovery concept for Themis". CNES (May 2019): https://presse.cnes.fr/sites/default/files/drupal/201905/default/cp074-2019_-_arianeworks_va.pdf
[274] "Prometheus: demonstrator of future engine passed its definition review". ArianeGroup (February 2019): https://www.ariane.group/en/news/prometheus-demonstrator-of-future-engine-passed-its-definition-review/

2.2.2 Microlaunchers frenzy continues, tangible progress by leading firms

The launch market has quickly evolved in recent years and the number of small satellites (under 500 kg) launched every year has skyrocketed since 2012. Even though these light spacecraft still represent a very small share of the total mass launched (small satellites represented 80.2% of all payloads launched in 2019 but only 11.2% of the mass put in orbit), several companies are developing "microlaunchers" specifically designed to address this potential new market.

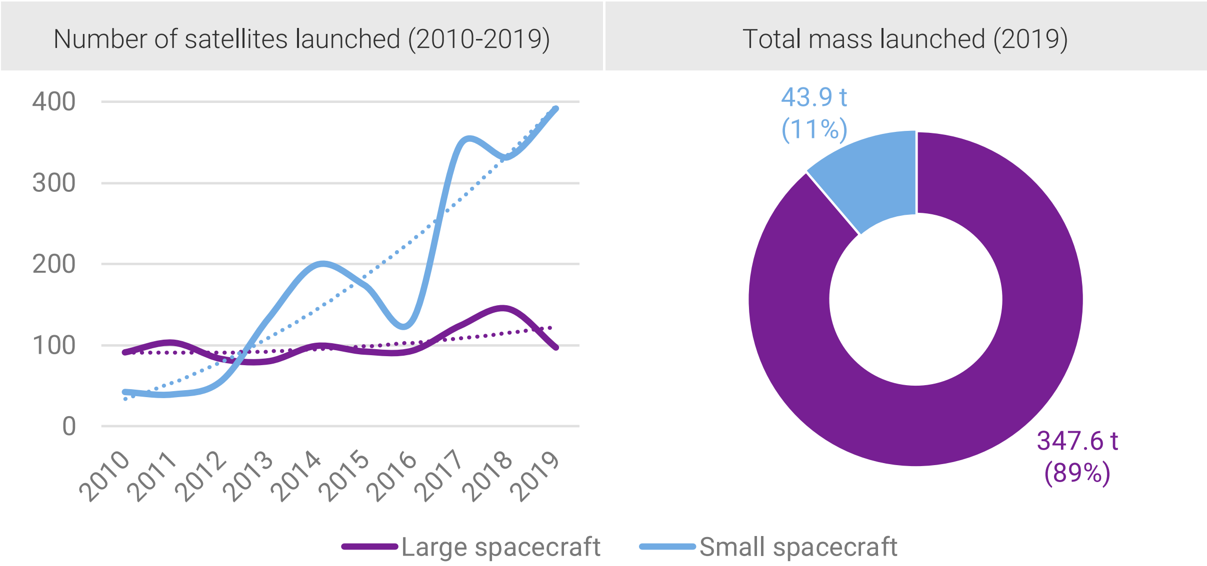

Figure 9: Key statistics on small and large spacecraft launched

A study by Carlos G. Niederstrasser, master systems engineer at Northrop Grumman, at the International Astronautical Congress in October 2019 suggested that more than 100 microlaunchers projects (defined in the study as able to launch satellites under 1000 kg) were under development in 2019.[275] The author also estimated that around $2 billion have been spent globally in the development of such small launch vehicles in recent years. The paper points out that the high number of actors creates a fierce competition which has already led to business casualties.[276] A recent example is the company Vector Launch, which was forced to suspend its operations and ultimately declared bankruptcy in 2019 because of financial difficulties, even though it was engaged in programmes of U.S. governmental organisations such as DARPA.

Today, the most advanced microlauncher business is Rocket Lab. The private American-New Zealand company performed its tenth launch in 2019 and set a new record of altitude for its Electron launcher (around 1000 km). The company also committed to increase the production rate of its rockets. To reach this objective, it invested in a new manufacturing robot able to produce an upper stage in 12 hours instead of more than 400 hours and announced that it intends to recover and reuse the first stage of these rockets (data were already gathered during two 2019 launches). Rocket Lab also unveiled a satellite platform, Photon, allowing its customers to focus exclusively on payload development. Photon can carry 170 kg to LEO but the company also announced its wish to use the spacecraft in order to provide, in the future, services for smaller payloads (around 30 kg) in lunar orbit. Finally, Rocket Lab started the construction of a second launch pad in its New Zealand launch complex and inaugurated its second launch site, located

[275] Carlos Niederstrasser, *A 2019 Update On The Impending Small Launch Vehicle Boom*, IAC 2019. Abstract available at: https://iafastro.directory/iac/paper/id/52324/abstract-pdf/IAC-19,B4,5,1,x52324.brief.pdf?2019-04-05.15:28:21
[276] Debra Werner, "How many small launch vehicles are being developed? Too many to track!". SpaceNews (October 2019): https://spacenews.com/carlos-launch-vehicle-update-iac/. Based on the study: Carlos Niederstrasser, *A 2019 Update On The Impending Small Launch Vehicle Boom*, Paper for the 70th IAC (October 2019)

in the United States. The first launch from the American soil is expected to take place in the second quarter of 2020, with a U.S. Air Force experimental satellite.

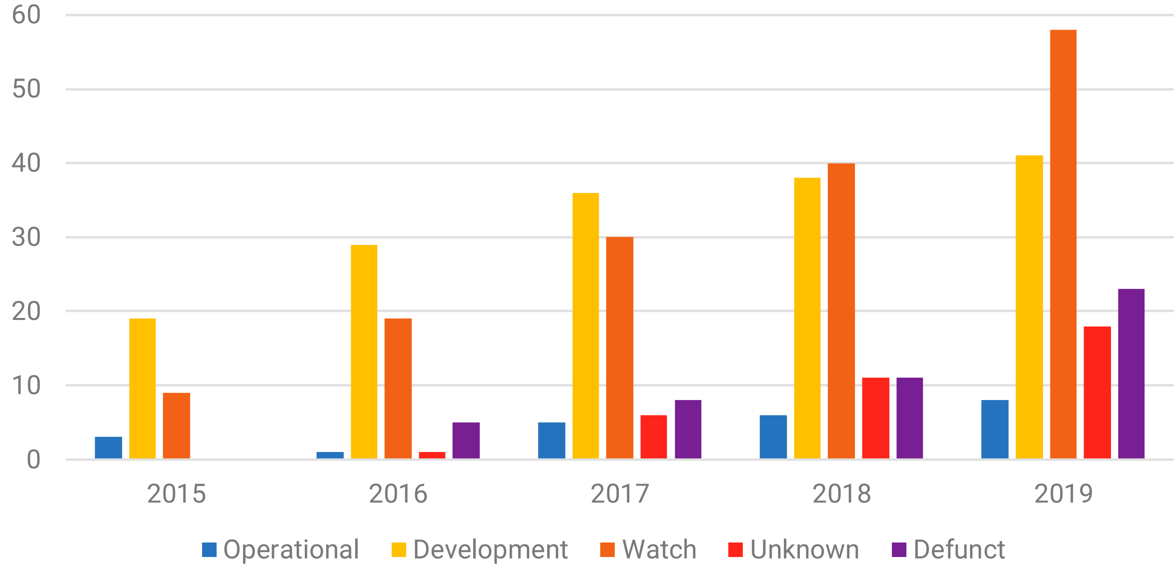

Figure 10: Worldwide small launch vehicles (<1000 kg) (adapted from: Carlos G. Niederstrasser "A 2019 Update on the Impending Small Launch Vehicle Boom")

In Europe, OHB announced that it is designing a small launch vehicle (three-stage liquid propulsion), able to carry 200 kg to LEO; the company expects a first launch for 2021.[277] The rocket will be self-funded by OHB, without government support. Targets of this initiative are satellite operators seeking a flexible and customized launch solution satisfying their specific needs (e.g. a more precise launch schedule or a more accurate orbital insertion).[278] Other companies in Europe are actively developing microlaunchers:

- Orbex unveiled for the first time its Prime rocket in February 2019; the launcher will transport the world's largest 3D-printed engine, manufactured in a single piece without joins and using bio-propane, an eco-friendly propellant. New headquarters and technical facilities were also built and inaugurated in Scotland.[279] The company announced that Surrey Satellite Technology Ltd. will fly an experimental payload on the maiden launch of the Prime rocket in 2021. Finally, Orbex signed a Cooperation Agreement with Innovative Space Logistics for launch manifest cooperation, payload integration and other technical services as well as the procurement by ISL of orbital space launches from Orbex.[280]
- In 2019, PLD Space, a company supported by the Future Launchers Preparatory Programme (FLPP) of ESA, unveiled its Propulsion facilities at the Teruel Airport and successfully completed a drop test of a demonstrator of the first stage of MIURA 5, its future orbital reusable launcher.[281] After a failure in May 2019, PLD Space achieved in February 2020 a full-duration rocket engine test for its MIURA 1

[277] Caleb Henry, "European spaceport boom could benefit industry". SpaceNews (November 2019): https://spacenews.com/european-spaceport-boom-could-benefit-industry/
[278] Caleb Henry, "OHB defends self-funded launcher effort". SpaceNews (November 2019): https://spacenews.com/ohb-defends-self-funded-launcher-effort/
[279] "Orbex unveils Prime rocket at new facility in Scotland". Orbex (February 2019): https://orbex.space/news/orbex-unveils-prime-rocket-at-new-facility-in-scotland
[280] "Orbex and Innovative Space Logistics Sign European Space Launch Agreement". Orbex (August 2019): https://orbex.space/news/orbex-and-innovative-space-logistics-sign-european-space-launch-agreement
[281] "Successful drop test of the demonstrator of the first stage of MIURA 5". PLD Space (April 2019): http://pldspace.com/new/2019/04/11/successful-drop-test-of-the-demonstrator-of-the-first-stage-of-miura-5/

mission, a suborbital rocket. Finally, it signed an agreement with Hispasat to define the technical features of satellites and analysing compatibility to launch services on board the MIURA 5 launcher.[282]

- In June 2019, the British company Skyrora opened a new manufacturing facility in Scotland. One month later, a test-firing was undertaken for the "LEO", the precursor of the engine which will be used for the operational rocket of the company. In November, the assembly and pressure testing of the suborbital vehicle Skylark L, a suborbital vehicle that is the second largest in the Skyrora family, took place.[283] In January 2020, the company successfully tested an 3D-printed engine powered through recycled plastic waste.

ESA is actively supporting European projects as part of ESA's Future Launchers Preparatory Programme (FLPP). The Agency organised a workshop where five companies presented the results of studies funded by the programme, which will be used to select the technologies that the Agency will further support with the FLPP programme: "PLD Space presented a service based on its Miura launcher. Deimos and Orbex presented AZµL, a service from the Azores islands using the Orbex Prime vehicle. Avio presented a service derived from their Vega workhorse and the upcoming Vega-C. MT Aerospace presented the results of a trade of analysis including different concepts and launch locations. ArianeGroup presented Q@TS – a "Quick @ccess To Space" ecosystem including a microlauncher concept based on Nammo's hybrid propulsion technology".[284]

China is also very proactive in the microlaunchers sector, in particular for the development of private and semi-private solutions. In one year, four Chinese microlaunchers have been launched with mixed results:

- LandSpace launched its Zhuque-1 in October 2018, but failed to put the payload in orbit; in November 2019, the company performed a successful full system test on the engine to be used on Zhuque-2 (a rocket with more capacity, able to lift four tons to 200 km and two tons to a 500 km SSO orbit)
- OneSpace failed to launch its OS-M1 in March 2019;
- In July 2019, i-Space launched its Hyperbola-1 rocket, and became the first Chinese private company to perform a successful orbital launch;
- A month later, in August 2019, China Rocket (a spin-off of the CASC) also managed to put payloads in orbit with its Jielong-1 rocket.

Hyperbola-1 (Credit: CNS)

These companies are quite advanced and already plan to launch next generations of their rockets in the years to come (e.g. Hyperbola-2, which is designed to have a higher lift capacity and to be reusable). In addition, several others Chinese firms are also entering the market, even if they have still not tried to launch. Galactic Energy proceeded with a hot-fire test of the second and third stages of Ceres-1, its first launch vehicle (whose first flight is planned for 2020); the first and second stages of the rocket also passed a separation test, an achievement that was completed as well by the rocket of S-Motor, another company. In parallel, Space Trek performed a test flight of a suborbital rocket, Tansuo-1, from the Jiuquan Satellite Launch Centre in northwest China

[282] Rachel Jewett, "Hispasat to Help Validate PLD Space As a Launch Services Provider". Via Satellite (March 2020): https://www.satellitetoday.com/launch/2020/03/03/hispasat-to-help-validate-pld-space-as-a-launch-services-provider/
[283] "Skyrora 2019: a year in review". Skyrora (December 2019): https://www.skyrora.com/post/skyrora-2019-a-year-in-review
[284] "Microlaunchers to grow Europe's economy". ESA (March 2019): https://www.esa.int/Enabling_Support/Space_Transportation/Microlaunchers_to_grow_Europe_s_economy

in December.[285] It also received an undisclosed amount of money from two funding groups, in part to support the development of the Xingtu-1 orbital launcher.[286] Finally, Beijing Deep Blue Aerospace Technology carried out tests of the thrust chambers of its Nebula-1 and Nebula-2, respectively a light and medium launcher.[287]

The microlauncher frenzy, which contributes to making access to space more accessible also led several countries to reflect on the installation of a spaceport on their territory. For instance, in Europe, several projects are under consideration: in Portugal's Azores, where a consortium should be chosen in 2020 to set up a spaceport and equip it with a launch vehicle while work with ESA is underway to make this spaceport a landing zone for the Space Rider,[288] in Cornwall (for Virgin Orbit's horizontal launches); in the Shetlands; in Italy; Sweden (Kiruna); Germany; and Norway.

Finally, the rise of small satellites and microlaunchers led more traditional launch operators to offer new services in order to face this competition. SpaceX unveiled the SmallSat Rideshare Programme in August 2019, which aims at reducing prices and increasing flight opportunities for this kind of satellite. Small satellites (up to 200 kg) will get a dedicated launch at regular and fixed dates and will therefore not be linked to a primary spacecraft and suffer from the constraints that it creates, especially in terms of schedule. The price would start at $1 million per launch; a first contract with Kepler Communications was announced in December, for 400 kg of payload capacity.[289] Similarly, Arianespace unveiled a new service dedicated to launch small satellites to geostationary orbit, on a rideshare launch. The launch will follow a planned schedule without depending on a lead customer. The first mission, GO-1, is planned for 2022, onboard an Ariane 64 flight.[290]

[285] "Commercial suborbital carrier rocket launched in China". Xinhua (December 2019): http://www.xinhuanet.com/english/2019-12/25/c_138657406.htm
[286] Andrew Jones, "New Chinese commercial rocket firms move toward maiden launches". SpaceNews (October 2019): https://spacenews.com/new-chinese-commercial-rocket-firms-move-toward-maiden-launches/
[287] Andrew Jones, "Chinese commercial launch companies are preparing second-generation rockets". SpaceNews (October 2019): https://spacenews.com/chinese-commercial-launch-companies-are-preparing-second-generation-rockets/
[288] Caleb Henry, "Portugal mulls Atlantic-focused constellation". SpaceNews (November 2019): https://spacenews.com/portugal-mulls-atlantic-focused-constellation/
[289] "Smallsat Rideshare Program Monthly Missions As Low As $1M". SpaceX: https://www.spacex.com/smallsat
[290] "Arianespace's "GO-1" mission will provide small satellites with a direct flight to geostationary orbit". Arianespace (August 2019): https://www.arianespace.com/press-release/arianespaces-go-1-mission-will-provide-small-satellites-with-a-direct-flight-to-geostationary-orbit/

2.2.3 Super-heavy launchers and deep space transport under the spotlight

On the other side of the spectrum, super-heavy launchers are also under the spotlight, in particular as result of the renewed interest of public and private actors for deep space transport to the Moon and beyond.

United States committed to SLS despite new delays

The Space Launch System (SLS), which has been developed by Boeing since 2011 for NASA deep space plans and which has encountered serious delays and cost overruns, was still at the heart of discussions in 2019. The issue became even more salient with the White House ambitioning to send astronauts back to the Moon in 2024.

Officials at NASA announced that the first launch, already delayed and expected to take place in June 2020, would probably be still postponed by six to twelve months. Early 2020, a new schedule was once again mentioned: the second half of 2021. These delays kept discussions about alternatives to the SLS going, in particular with regards to the first launch of the Orion spacecraft. Jim Bridenstine, NASA Administrator, raised the idea of using a commercial rocket for this launch in order to meet the proposed schedule of the Artemis programme. However, due to the political and industrial stakes of the SLS programme, which has already cost several billions of dollars (app. $14-15B to date), Mr. Bridenstine quickly changed his mind and voiced its full commitment to the use of an SLS. NASA even started negotiations with Boeing to extend the contract beyond the Artemis I and II missions. Under this new contract, the manufacturer would produce up to ten core stages of SLS to support future Artemis missions; in addition, the proposition includes the construction of up to eight Exploration Upper Stages, a second stage which aims at sending payloads to the Moon, Mars and deep space. Key aspects of the document still have to be worked in 2020 (e.g. the level of funding by NASA), but the objective of NASA is to secure a core stage in time for Artemis III in 2024 (comeback of astronauts to the Moon) as well as to save money on production costs by relying on lessons drawn from the design, development, test and evaluation phase of the launcher[291] and by benefitting of economies of scale.

Despite difficulties and delays, the development of the rocket has made steady progress: the flight software which will be used in the core stage during its first launch was developed and went through a “run for record” testing, during which the software flew many simulated launches according to different scenarios.[292] The tank for liquid hydrogen was also tested and declared “safe for flight”; the tank for liquid oxygen was prepared for testing. More crucially, the core stage of the rocket that will be used for the Artemis I mission was completed, and the four Aerojet Rocketdyne RS-25 engines attached to it. Because of existing delays in the programme, NASA thought about skipping a “green run” static fire test planned for 2020. The test consists of firing the core stage of the rocket and its four main engines for eight minutes to validate that all systems are working as they should. Renouncing the test would have enabled NASA to save several months up in order to launch the first SLS before the end of 2020. However, it was finally decided to maintain it, as a matter of safety.

SLS core stage (Credit: NASA/Jude Guidry)

[291] “NASA Commits to Future Artemis Missions With More SLS Rocket Stages”. NASA (October 2019): https://www.nasa.gov/feature/nasa-commits-to-future-artemis-missions-with-more-sls-rocket-stages
[292] Philip Sloss, “SLS flight software and avionics in “run for record” testing”. NASA Spaceflight (April 2019): https://www.nasaspaceflight.com/2019/04/sls-flight-software-avionics-run-record-testing/

NASA seeking commercial providers for cislunar transportation services

In parallel of the development of the SLS, NASA is exploring options to deliver cargo and other payloads to the Lunar Gateway and to the lunar surface. To this end, two programmes have been created: the Gateway Logistics Services, to send cargo to the Lunar Gateway (update 2020: first contract has been granted to SpaceX); and the Commercial Lunar Payload Services, enabling private companies to develop landers able to bring payloads to the Moon. These two programmes are addressed in the Policy & Programme section of this Yearbook.

SpaceX presents its Starship spacecraft

SpaceX Starship (Credit: SpaceX)

SpaceX is also developing its own super-heavy rocket to lead missions to the Moon and, ultimately, to Mars. In September 2019, Elon Musk made a presentation of SpaceX's interplanetary transportation system, called Starship. The presentation was made in front of the first prototype of the spacecraft, Starship Mk 1, while another model, Mk 2, was under production in Florida. Facing criticisms from NASA Administrator, who underlined that SpaceX was still suffering major delays in delivering the commercial manned capsule Crew Dragon, Musk explained that the funds dedicated to Starship represent only 5% of the resources of SpaceX.

Starship will measure 50 meters, and is expected to lift at least 100 tons to orbit. It should be launched by a big booster, Super Heavy, which would complement the company's portfolio. Both Starship and Super Heavy should be reusable and, put together, would measure 118 meters (higher than the 110.6 meters of Saturn V and similar to the expected 117 meters of the most powerful version of the SLS). Starship will be powered by six Raptor engines, the new engine under development by SpaceX; in-orbit refuelling is planned. The spacecraft is made of stainless steel, which allows to resist very high temperatures and reduces the requirements for the heat shield. Moreover, stainless steel is much less expensive than carbon fiber (around 2% of its cost), a material which had been explored for Starship. SpaceX expects to be able to land Starship on the Moon in 2022.

The Starhopper, a spacecraft used as a limited prototype for Starship, successfully passed several tests: first, a static fire test; and, then, two flight tests at an altitude of 20 meters and 150 meters. The first firing of the Raptor flight engine was successfully completed. Moreover, a pressurization test of the Mk 1 prototype took place in November, but led to the blow-up of the top of the spacecraft. According to SpaceX, the anomaly did not create any substantial damage and will not slow down development plans. Work on Mk 2, the second spacecraft, had also been paused to focus on Mk 3, the version which was expected to undertake the first flight.[293] Yet, two other tests early 2020 led to the destruction of the prototypes used for them, until a successful one in April 2020. Finally, Starship was selected as a potential provider for NASA under the Commercial Lunar Payloads Services contract, meaning that SpaceX is now able to bid for the delivery of payloads to the lunar surface with its Starship and Super Heavy spacecraft.

Man-rated Ariane 6 to support Moon plans?

At the 70th International Astronautical Congress in October 2019, Stéphane Israel, CEO of Arianespace, announced that his company was planning a rideshare mission to the Moon in 2023. The mission would

[293] Marcia Smith, "Today's Tidbits: December 3, 2019". SpacePolicyOnline (December 2019): https://spacepolicyonline.com/news/todays-tidbits-december-3-2019/

use Ariane 6 to deliver 8500 kg into a lunar transfer orbit, for public or private customers. Israel also revealed that Arianespace is in favour of a European crewed spaceflight programme. Therefore, the company will lobby for the adoption of such a programme at the European Space Agency's 2022 Ministerial Council, in order to send European astronauts in orbit with a European launcher.[294]

Long March 5 returns to flight

At the end of 2019, China accomplished a successful return-to-flight of the Long March-5 rocket, the Chinese super-heavy launcher. The rocket was used to launch a demonstration satellite to geostationary orbit, while it had not flown since 2017, when a previous Long March-5 suffered technical problems leading to the failure of the mission. The rocket is able to lift 25 tons in LEO, 14 tons in GEO and 8.2 tons in translunar injection.[295] The December launch an important step for China, as Long March-5 is a key element for the ambitious Chinese space programme. Indeed, it is expected to be used to build the future large modular space station of the country (to be operational from 2022), and to contribute to its deep space missions. For instance, the rocket will launch the first Chinese probe to Mars in 2020 as well as Chang'e-5, a sample return mission to the Moon, that same year.[296]

Russia introduces its new heavy and extra-heavy carriers

Information on a new Russian super-heavy launcher, the Yenisei, was delivered. Russia's Scientific and Technical Council approved the conceptual design of the rocket. Each part of the launcher will be an independent flight element, and they will form, together, a technological "building kit". The rocket should be able to deliver more than 70 tons of cargo in LEO, and its first flight is expected to take place in 2028. Russia intends to use the new rocket for missions to the Moon, including the landing of Russian cosmonauts on the surface of the Earth's natural satellite. According to Roscosmos, the Yenisei will be able to deliver a 27-ton payload to the Moon's orbit.[297] The launch pad of the rocket will be located in Vostochny spaceport, with preparatory work planned to start in 2022.[298]

Moreover, Roscosmos plans to use a new version of its Angara rocket, the Angara-A5P, to put Oryol, Russia's next manned spacecraft, into orbit. The design of this rocket was presented in November 2019;[299] yet, the actual development of the vehicle is only at its initial stage due to the work needed to ensure its "greater redundancy potential, reliability and safety"[300] compared to Angara-A5. Moreover, it will be less expensive than the upcoming Soyuz-5 thanks to serial production. The Angara-A5P will be ready by 2024, while the expendable version of the Oryol spacecraft will first lift off in 2023. A reusable model will be sent in orbit in 2024 and its crewed modification in 2025.[301] According to the head of Roscosmos, the Omsk-based Polyot production enterprise will build ten Angara rockets per year (eight heavy-weight and two light-weight rockets a year) starting from 2024.[302]

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[294] Caleb Henry, "Arianespace targets 2023 for lunar Ariane 6 rideshare mission". SpaceNews (October 2019): https://spacenews.com/arianespace-targets-2023-for-lunar-ariane-6-rideshare-mission/
[295] Andrew Jones, "Successful Long March 5 launch opens way for China's major space plans". SpaceNews (December 2019): https://spacenews.com/successful-long-march-5-launch-opens-way-for-chinas-major-space-plans/
[296] Jing Xuan Teng, "China launches powerful rocket in boost for 2020 Mars mission". Digital Journal (December 2019): http://www.digitaljournal.com/news/world/china-launches-powerful-rocket-in-boost-for-2020-mars-mission/article/564275
[297] "Russia approves conceptual design of super-heavy carrier rocket". TASS (October 2019): https://tass.com/science/1084537
[298] "Work on launch complex for super-heavy carrier rocket at Vostochny to start in 2022". TASS (December 2019): https://tass.com/science/1099611
[299] "Russia Plans Scientific Projects for Super Heavy Rocket Apart From Moon Landing – Sources". Sputnik News (November 2019): https://sputniknews.com/science/201911281077422540-russia-plans-scientific-projects-for-super-heavy-rocket-apart-from-moon-landing---sources/
[300] "Russia to create Angara-A5P rocket for manned space launches by 2024". TASS (November 2019): https://tass.com/science/1087207
[301] *Ibid.*
[302] "Roscosmos plans to make 10 Angara rockets annually from 2024 – Rogozin". Interfax (October 2019): http://www.interfax.com/newsinf.asp?y=2019&m=10&d=3&pg=7&id=929688

2.2.4 Other outstanding developments in the space transportation industry

ISS servicing: the United States close to recovering its Human spaceflight capabilities

U.S. companies pursued their effort as part of the Commercial Crew Development (CCDev) programme started in 2010 to develop spacecraft capable of sending astronauts to the ISS and recover U.S. independent capabilities in this domain, lost with the retirement of the Space Shuttle. The two companies selected by NASA to achieve this goal, Boeing and SpaceX, have both proceeded with tests of their capsules.

SpaceX reached an important milestone in March, when its Crew Dragon capsule launched, docked to the ISS and returned safely to Earth without any difficulty. A launch abort test was then planned for July, in order to start operation of the spacecraft as soon as possible. However, during a test of the SuperDraco thrusters in April, a failure led to the explosion of the same capsule that had performed the successful mission of March. This failure was due to a leaky valve in the abort propulsion system. Another tentative took place in November and was successful.[303] In parallel, work on parachutes were conducted after one of them failed during a test in April,[304] and SpaceX announced in November and December that it had completed thirteen successful tests of the Mark 3 parachutes as well as ten multi-parachute tests; Elon Musk lauded the Mark 3 as the best parachutes ever built.[305]

The other company, Boeing, continued to develop the CST-100 Starliner capsule. Technical progress was made during the year: in May, the entire propulsion system was successfully tested on the ground, simulating in-space maneuvers and abort situations.[306] In November, an actual pad abort test took place, which was considered a success by Boeing despite the failure of one parachute to be deployed;[307] finally, an Orbital Flight Test (un-crewed test) was undertaken in December, but did not run according to the plan. Due to a timing problem, the capsule consumed too much fuel, preventing it from reaching orbit and from docking to the ISS. The mission was therefore reduced to two days instead of the eight initially planned. Despite this setback, the team completed as many mission objectives as possible (e.g. test of the docking mechanism, of the stellar navigation cameras, etc.) and the Starliner safely de-orbited, re-entered and landed on Earth.[308] Yet, an inquiry revealed later that the spacecraft suffered another major software issue during the reentry, which was corrected during the flight.

In light of this progress, SpaceX plans to launch crewed tests from May 2020 while Boeing, supported by NASA, decided to perform a second unmanned test of its CST-100 Starliner (update 2020: additional delays are likely to occur).

Space tourism: toward the final step?

In addition to the development of manned spaceflight on behalf of public agencies, private actors are also entering the domain of space tourism. Despite interest by Roscosmos (which signed a partnership with

303 Marie Lewis, "SpaceX Completes Crew Dragon Static Fire Tests". NASA (November 2019): https://blogs.nasa.gov/commercialcrew/2019/11/13/spacex-completes-crew-dragon-static-fire-tests/
304 Jeff Foust, "Crew Dragon parachutes failed in recent test". SpaceNews (May 2019): https://spacenews.com/crew-dragon-parachutes-failed-in-recent-test/
305 Jeff Foust, "SpaceX trumpets progress on commercial crew parachute testing". SpaceNews (November 2019): https://spacenews.com/spacex-trumpets-progress-on-commercial-crew-parachute-testing/
306 "Boeing's Starliner completes service module hot fire testing". Boeing (May 2019): https://boeing.mediaroom.com/2019-05-24-Boeings-Starliner-completes-service-module-hot-fire-testing
307 Stephen Clark, "Boeing identifies cause of chute malfunction, preps for Starliner launch". Spaceflight Now (November 2019): https://spaceflightnow.com/2019/11/07/boeing-identifies-cause-of-chute-malfunction-continues-preps-for-first-starliner-launch/
308 Stephen Clark, "Boeing's Starliner capsule lands after missing rendezvous with space station". Spaceflight Now (December 2019): https://spaceflightnow.com/2019/12/22/boeings-starliner-capsule-safely-lands-after-missing-rendezvous-with-space-station/. For the full list of achieved mission objectives, see "NASA, Boeing Complete Successful Landing of Starliner Flight Test". NASA (December 2019): https://www.nasa.gov/press-release/nasa-boeing-complete-successful-landing-of-starliner-flight-test

the U.S. company Space Adventures to launch two tourists to the ISS in 2021) and the Russian company Kosmokurs,[309] the company which displayed the most progress in 2019 is Virgin Galactic. From mid-2020, the firm, founded by Richard Branson, expects to launch private individuals in suborbital flights for a ticket costing around $250 000.

Virgin Galactic's VSS Unity (Credit: Virgin Galactic)

The company progressed on the development and testing programme of its spaceship (the VSS Unity). A test flight with a crew member of the company was successfully conducted in February, with the winged craft carrying people to the edge of space while reaching three times the speed of sound.[310] In parallel, work on the construction of a second spaceship has been underway. Given its progress, Virgin Galactic attracted the interest of other actors. The company signed an agreement with the Italian Air Force to fly several research payloads and three people on one of its spaceflights.[311] It also received an investment of $20 million from Boeing, which started a mutually beneficial partnership between the two companies, as it would enable Boeing to gain a foothold in the potential future market of high-speed point-to-point transportation on Earth.[312]

The most significant transformation for Virgin Galactic stems from its merger with the special-purpose acquisition company Social Capital Hedosophia (SCH). Through this merger, Virgin Galactic was provided with $450 million in capital and rose to an estimated value of $1.5 billion. Due to this operation, the company could make its entry on the stock market, and listed to the New York Stock Exchange in October. It became the first publicly traded company with human spaceflight as its core activity.

However, the perspectives presented by Virgin Galactic raise the skepticism of several analysts, as its expectations for the space tourism market seem fairly overestimated.[313] Moreover, the company's main competitor, Blue Origin, also marked progress this year. Its reusable suborbital vehicle, the New Shepard, which launches vertically like a rocket and not like a plane from under a carrier aircraft, passed its 10th test in January (with 8 payloads), its 11th test in May (with 38 research payloads)[314] and a 12th flight in December (the first time a New Shepard flew six times). Until now, all flights have yet been unmanned, contrary to those of Virgin Galactic (two crewed tests in December 2018 and February 2019).

[309] "Russia Customising Soyuz Spaceship for Tourist Trips – Roscosmos". Sputnik News (October 2019): https://sputniknews.com/science/201910231077123665-russia-customising-soyuz-spaceship-for-tourist-trips/
[310] Morgan Lee, "Virgin Galactic moves to New Mexico, entering 'home stretch' toward commercial flight". USA Today (May 2019): https://eu.usatoday.com/story/money/2019/05/12/virgin-galactic-moves-new-mexico-another-step-commercial-flight/1183547001/
[311] Jeff Foust, "Virgin Galactic to fly Italian Air Force research mission". SpaceNews (October 2019): https://spacenews.com/virgin-galactic-to-fly-italian-air-force-research-mission/
[312] Bethan Staton, "Boeing to invest $20m in Virgin Galactic". Financial Times (October 2019): https://www.ft.com/content/3695a158-e9d8-11e9-85f4-d00e5018f061
[313] Doug Messier, "Richard Branson's Virgin Galactic Goes Public With Extravagant Promises to Keep". Parabolic Arc (October 2019): http://www.parabolicarc.com/2019/10/27/richard-bransons-virgin-galactic-goes-public-with-extravagant-promises-to-keep/
[314] Loren Grush, "Blue Origin successfully launches and lands its New Shepard rocket during 11th test flight". The Verge (May 2019): https://www.theverge.com/2019/5/2/18525850/blue-origin-new-shepard-rocket-test-flight-nasa-how-to-watch

A future revival of the air-launch market?

While Northrop Grumman's Pegasus XL, which has been the only commercial player for the past 20 years, performed its last planned launch, another company, Virgin Orbit, made steps towards the implementation of an operational service.

The company made technical progress on Launcher One, the rocket that it is being developed to be launched under the wing of a modified Boeing 747 aircraft. A successful full duration, full scale, and full thrust test firing of the main stage was completed in May 2019.[315] A few months later, a successful drop test took place: the rocket was filled with water and antifreeze to simulate its weight when filled with fuel, and dropped to the ground. This test allowed the company to ensure that the rocket and the aircraft could separate without difficulties, and to analyse the rocket's fall through the air.[316] In regards to these advancements, other entities from various fields decided to collaborate with Virgin Orbit. The UK Royal Air Force (RAF) expressed interest in the responsive launch capabilities provided by the company and partnered with it, while the UK Space Agency and the Cornwall Council provided financial help to establish a spaceport in the Cornwall Newquay Airport, from which Virgin Orbit could launch.

Another company, Stratolaunch Systems Corporation, underwent more difficulties in 2019. While its carrier aircraft flew for the first and single time in April 2019 for an initial test flight, financial difficulties led Stratolaunch's owner to sell it to a private equity firm, Cerberus Capital Management.[317] A change of activity was announced early 2020, with Stratolaunch withdrawing from the launch sector (at least temporarily) and focusing on supporting technology development, especially in the domain of hypersonic systems, through an air-launch platform which will enable to collect data.[318]

Stratolaunch (Credit: Robert Sullivan)

Other major developments in the space transportation industry and launcher programmes across the World

United States

The development of new rockets in the United States takes place in a context marked by the second phase of the U.S. Air Force's Launch Service Procurement process. Indeed, this competition has encouraged companies to propose new launchers that will be available from the start of the 2020s. Contenders and their proposed rockets are Blue Origin (New Glenn), ULA (Vulcan Centaur), and Northrop Grumman (OmegA). In addition, SpaceX is running the competition with already-developed launchers (Falcon 9 and Falcon Heavy). The specific framework of the Launch Service Procurement facilitated the development of these new launchers. In October 2018, the three aforementioned companies received contracts from the Air Force to help them develop their rockets and related launch pads: ULA obtained $967 million, Northrop Grumman received $792 million, and Blue Origin was awarded $500 million. The two winners of

[315] "Main stage hotfire: our biggest test yet". Virgin Orbit (May 2019): https://virginorbit.com/main-stage-hotfire-our-biggest-test-yet/
[316] "Virgin Orbit's epic drop test". Virgin Group (July 2019): https://www.virgin.com/richard-branson/virgin-orbits-epic-drop-test
[317] Mark Harris, "Exclusive: Buyer of Paul Allen's Stratolaunch space venture is secretive Trump ally". GeekWire (December 2019): https://www.geekwire.com/2019/exclusive-buyer-paul-allens-stratolaunch-space-venture-secretive-trump-ally/
[318] Jeff Foust, "Stratolaunch gets mystery new owner". SpaceNews (October 2019): https://spacenews.com/stratolaunch-gets-mystery-new-owner/

the competition will be announced in 2020, with a distribution of 60%/40% of the several dozens of defence satellites launches planned for the period 2022-2027.

Major evolutions for the New Glenn were more related to the industrial set-up than to technological development of the rocket itself. Blue Origin continued works undertaken on the launch complex and related facilities that it leases at Cape Canaveral (LC-36). Similarly, it has started to install a factory to refurbish the first stage of its rocket directly on the launch complex.[319] In addition, the company began the construction of a factory in Huntsville to manufacture the BE-4 engines, which will power the first stage of the New Glenn, but also ULA's Vulcan. Blue Origin signed a Commercial Space Launch Act agreement with NASA to use the 4670 test stand at the Marshall Space Flight Center in order to test its BE-3U (two of them will be used for the second stage of the New Glenn) and BE-4 engines.[320] The BE-4 was also tested at full power in August, in Texas. Finally, the New Glenn attracted new customers: in January, Telesat, which expects to send a mega-constellation in LEO, signed a contract with Blue Origin to launch an undisclosed number of satellites on this rocket.[321] In addition, this vehicle could be used to launch the Power and Propulsion Element of the Lunar Gateway, as this element will be developed by Maxar, in partnership with Blue Origin and Draper.[322]

United Launch Alliance (ULA) is developing the Vulcan rocket, which will replace all Delta launchers and the Atlas V. Vulcan will use BE-4 engines developed by Blue Origin as well as solid rocket boosters developed by Northrop Grumman for its own rocket, OmegA. It also already flies specific technology on current Atlas and Delta vehicles, so that the hardware has flight heritage before the first launch of Vulcan.[323] The liquid propellant tank and thrust structure was certified in 2019, and the Critical Design Review of the rocket was completed in May. This milestone has paved the way for the rocket's hardware qualification. Finally, ULA gained its first two customers contracts for the rocket. The first is Astrobotic, which will launch its commercial lunar lander, Peregrine, in 2021, on the first certification flight of Vulcan. The second customer is Sierra Nevada Corporation, whose first Dream Chaser, used to resupply the ISS through the CRS-2, will be launched on the second certification flight of the rocket. Sierra Nevada even expanded the agreement and decided to launch all of its six CRS-2 missions with the Vulcan rocket.[324]

Finally, OmegA, which is developed by Northrop Grumman, will consist of two solid-fuelled boosters and a liquid-fuelled third stage; an Aerojet Rocketdyne RL-10 engine will be used for the upper stage (as for Vulcan). OmegA's hardware and avionics also come from other Northrop Grumman vehicles.[325] The rocket is expected to deliver 5250 to 7800 kg to GEO. The first mission is planned for 2021 and full certification for 2022 (a schedule comparable to Vulcan's and New Glenn's), while the heavy variant should fly in 2024. A static test fire of the first stage of OmegA was undertaken in May 2019. The test lasted 122 seconds and was considered a success despite an anomaly with the nozzle. Indeed, it allowed to verify the performance of the motor's ballistics, insulation and joints, and to control the nozzle position. Yet, a second test which was planned for 2019 was postponed to 2020 in order to investigate the anomaly in greater detail. Moreover, in order to fulfill the requirements of the U.S. Air Force, which asks contenders

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[319] Ian Atkinson, "Blue Origin continuing work on New Glenn launch complex, support facilities". NASA Spaceflight (September 2019): https://www.nasaspaceflight.com/2019/09/blue-origin-work-new-glenn-launch-facilities/
[320] Chris Bergin, "Blue Origin sign up historic test stand for engine testing". NASA Spaceflight (April 2019): https://www.nasaspaceflight.com/2019/04/blue-historic-test-stand-engine-testing/
[321] Caleb Henry, "Telesat signs New Glenn multi-launch agreement with Blue Origin for LEO missions". SpaceNews (January 2019): https://spacenews.com/telesat-signs-new-glenn-multi-launch-agreement-with-blue-origin-for-leo-missions/
[322] Doug Messier, "Maxar Teams with Blue Origin, Draper on Lunar Gateway Power & Propulsion Element". Parabolic Arc (May 2019): http://www.parabolicarc.com/2019/05/23/maxar-teams-blue-origin-draper-lunar-gateway-power-propulsion-element/
[323] Caleb Henry, "ULA to fly Vulcan technology on Atlas 5 to gain flight heritage". SpaceNews (April 2019): https://spacenews.com/ula-to-fly-vulcan-technology-on-atlas-5-to-gain-flight-heritage/
[324] Chris Bergin, "Cargo Dream Chaser solidifies ULA deal by securing six Vulcan Centaur flights". NASA Spaceflight (August 2019): https://www.nasaspaceflight.com/2019/08/cargo-dream-chaser-solidifies-ula-deal-vulcan/
[325] Sandra Erwin, "Air Force insists launch competition must stay on schedule". SpaceNews (April 2019): https://spacenews.com/air-force-insists-launch-competition-must-stay-on-schedule/).

to be able to launch from both East and West Coasts, Northrop Grumman is building a new facility on the Eastern Range. Finally, OmegA also received its first commercial contract: Saturn Satellite Networks will fly one or two of its NationSat small geostationary satellites on the first certification flight of the rocket in 2021.

Russia

In Russia, progress on new launchers was also underway in 2019, in addition to the Yenisei and Angara-A5P. Indeed, Russia is developing a new version of Soyuz: Soyuz-5. The sales director of GK Launch Services, a subsidiary of Glavkosmos operating Soyuz-2 commercial launches from Russian spaceports, announced that flight tests for the new Soyuz-5 rocket will not start before 2023 and commercial launches will not occur before 2026. A critical design review is planned for 2021. The Soyuz-5 is a medium-class rocket, capable in its current design of placing 17.3 tons into LEO and five tons into GTO. It will be launched from both Baikonour and Vostochny.[326]

China

In China, the Long March-8 rocket, maiden flight of which is planned for 2020, successfully passed a test for its second stage engine. The Long March-8 relies on proved technology as its first stage is similar to the one of the Long March-7 and its second stage is the same as the third stage of the Long March-3A. With this rocket, China Aerospace Science and Technology Corporation (CASC) wants to use module design and to create a launcher which can be prepared in short time, in order to make it competitive on the commercial market. The objective is to carry out between 10 and 20 launches per year.[327] Finally, Long March-8 will be the first Chinese reusable launcher, with vertical landing capabilities.[328]

Japan

In October 2019, during the IAC, a representative of Mitsubishi Heavy Industries presented the plans of the company for the future. MHI is preparing the next generation of its rockets, the H3, for a maiden launch in 2020. The H3 will launch the HTV-X, a new Japanese cargo vessel, to the ISS, from 2021. Moreover, MHI is also considering the development of two upgraded variants in order to support the Lunar Gateway from 2025. The most powerful version of these variants would be in development by 2030.

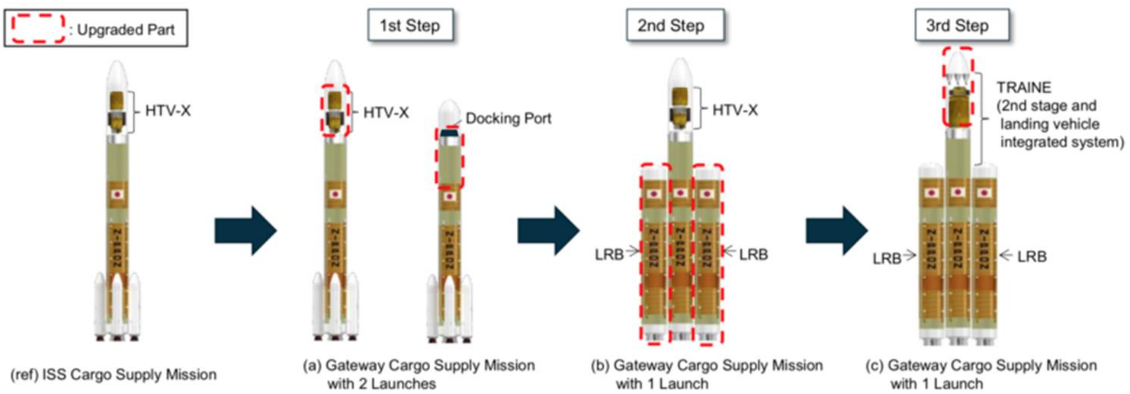

Figure 11: Contemplated evolutions of Mitsubishi Heavy Industries' H3 rocket (Credit: MHI)

326 Jeff Foust, "Soyuz-5 rocket to enter service in mid-2020s". SpaceNews (November 2019): https://spacenews.com/soyuz-5-rocket-to-enter-service-in-mid-2020s/
327 "China's Long March-8 rocket successfully passes engine test". Xinhua (December 2019): http://www.xinhuanet.com/english/2019-12/02/c_138600162.htm
328 Andrew Jones, "China to continue world-leading launch rate in 2020". SpaceNews (December 2019): https://spacenews.com/china-to-continue-world-leading-launch-rate-in-2020/

India

In February 2019, the public company New Space India Limited (NSIL) was created, under the administrative control of the Department of Space. One of its missions is to develop the Small Satellite Launch Vehicle (SSLV) in partnership with the private sector. SSLV is a new Indian launcher designed to send 500 kg to LEO and 300 kg to SSO. Its first demonstration flight is expected for 2020. The first commercial launch was already purchased by Spaceflight from NSIL in August 2019, but the customer was not disclosed.[329]

[329] Alan Boyle, "Spaceflight gets first crack at India's new SSLV rocket – and puts up a 'sold out' sign". GeekWire (August 2019): https://www.geekwire.com/2019/spaceflight-gets-first-crack-indias-new-sslv-rocket-puts-sold-sign/

2.3 Satellite industry highlights and trends in 2019

2.3.1 Industry involvement in Moon plans taking shape

The year 2019 was marked by a strong revival of the interest in Moon missions by major space powers. The subsequent efforts are mostly undertaken under the scope of public programmes. In the United States, the Trump administration decided to advance the deadline to send an astronaut to the Moon by 2024 (instead of 2028, the date previously planned by NASA), and called its new programme Artemis. This decision sparked reactions from old and new partners of the United States, including Russia, Japan, Europe but also Australia, which expressed a wish to collaborate.

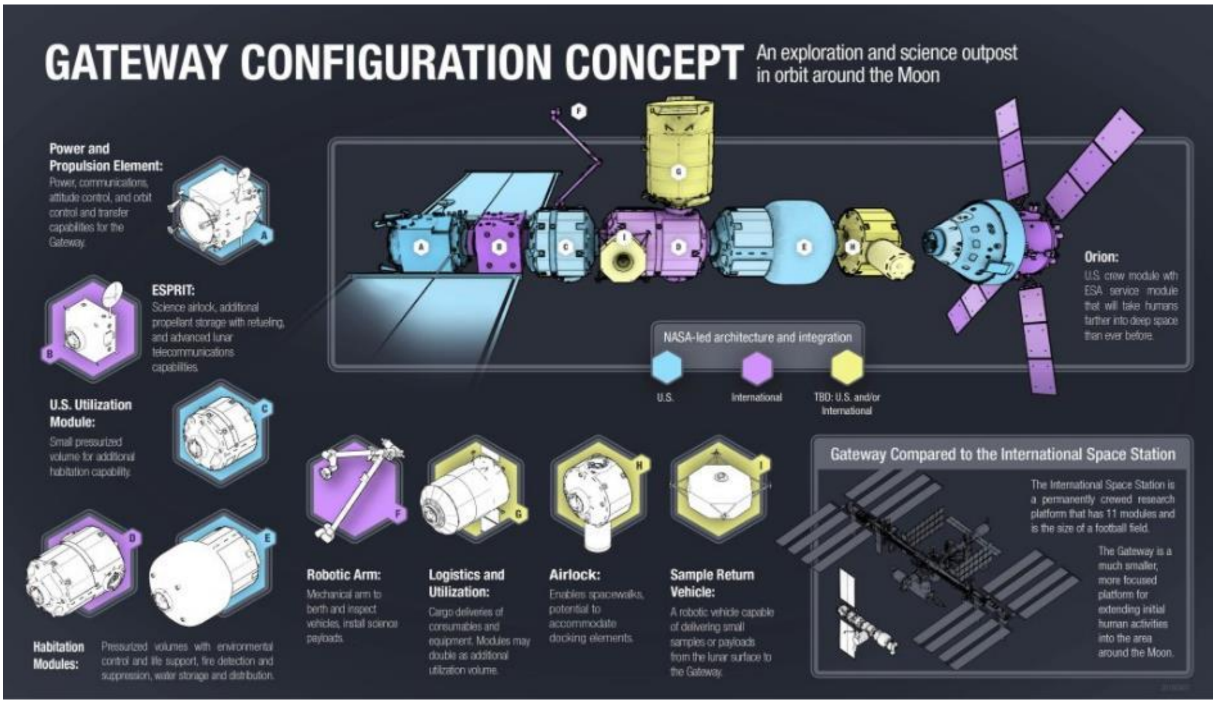

Figure 12: Lunar Gateway elements (likely to evolve)

Industry involvement in the Lunar Gateway

The U.S. decision also accelerated progress regarding the Lunar Gateway, the space station that would orbit the Moon and facilitate trips to and back from the celestial body. Three announcements have already been made for this project:

- Maxar received a fixed-price contract of $375 million in May 2019 to develop the Power and Propulsion Element (PPE), which will provide power, manoeuvring, attitude control, communications systems and initial docking capabilities. It will be based on the 1300-class platform of Maxar and use solar electric propulsion means. Maxar will be joined by Blue Origin and Draper for the design, building and operation of the system.[330] The PPE will be propelled by an Advanced Electric Propulsion System (AEPS), a thruster developed by NASA and Aerojet Rocketdyne, of which a successful demonstration

[330] "Maxar Selected to Build, Fly First Element of NASA's Lunar Gateway". Maxar Technologies (May 2019): http://investor.maxar.com/investor-news/press-release-details/2019/Maxar-Selected-to-Build-Fly-First-Element-of-NASAs-Lunar-Gateway/default.aspx

at full power took place in November.[331] Finally, Maxar subcontracted the manufacturing of solar arrays to Deployable Space Systems[332] and the design and manufacture of Solar Power Modules to SolAero Technologies.[333] Maxar will fully own and operate the PPE during its flight demonstration period; after one year, NASA will have the option to acquire the spacecraft.[334]

- Northrop Grumman Innovation Systems (NGIS) will be responsible for the construction of the Habitation and Logistics Outpost (HALO). The contract was not open to competition; NASA awarded it to Northrop Grumman because the Agency thought that it was the only company able to build a minimal module in the requested timeframe. Intended to be used by the first Artemis crewed mission to the Moon in 2024, the module will have to be completed and delivered by mid-2023. Yet, an open competition would have created delays and risks that the module would not be ready on time. However, it is to be noted that a contract has not been signed yet: it will be done once NGIS submits a concrete proposal to NASA, the price of which is considered fair and reasonable. The design proposed by NGIS is still not clear but will be based on the Cygnus spacecraft used to supply the ISS.[335] However, the company was given limited authority to start working on urgent HALO-related requirements.
- Canada awarded two contracts to MDA for the development of the Canadarm-3, which will provide extra-vehicular robotics services to the Gateway.[336] Thus, MDA will develop concept and technology for robotic interfaces of the two main components of Canadarm, the "exploration large arm" (XLA) and the "exploration dexterous arm" (XDA). Jointly considered, the contracts are worth CA$7 million.[337]

In August 2019, NASA also issued a call for proposals regarding the Gateway Logistics Services programme, which aims at providing cargo transportation services to the Lunar Gateway (at least 3400 kg of pressurised cargo and 1000 kg of unpressurised cargo). The vehicles would dock for missions up to one year, with possibility to extend this period. The full budget for contracts under the programme is $7 billion. In March 2020, it was announced that SpaceX won the first contract in the framework of the Gateway Logistics Services programme. The company is expected to use a new spacecraft, the Dragon XL, launched onboard a Falcon Heavy rocket.[338]

The formalisation of the participation of ESA in the Lunar Gateway that occurred at Space19+ will have consequences for the European industry, which will be involved in the development of the European module, ESPRIT (European System Providing Refuelling, Infrastructure and Telecommunications) and possibly other elements.

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331 "Advanced Electric Propulsion Thruster For Nasa's Gateway Achieves Full Power Demonstration". Aerojet Rocketdyne (November 2019): https://www.rocket.com/article/advanced-electric-propulsion-thruster-nasa%E2%80%99s-gateway-achieves-full-power-demonstration
332 Debra Werner, "Maxar selects Deployable Space Systems to build solar arrays for Gateway's Power and Propulsion Element". SpaceNews (October 2019): https://spacenews.com/maxar-dss-rosa-ppe/
333 Annamarie Nyirady, "Maxar Selects SolAero for Power and Propulsion Element of NASA Gateway". Via Satellite (August 2019): https://www.satellitetoday.com/launch/2019/08/20/maxar-selects-solaero-for-power-and-propulsion-element-of-nasa-gateway/
334 "NASA Awards Artemis Contract for Lunar Gateway Power, Propulsion". NASA (May 2019): https://www.nasa.gov/press-release/nasa-awards-artemis-contract-for-lunar-gateway-power-propulsion
335 Jeff Foust, "NASA Taps Northrop Grumman to Build Lunar Gateway Habitation Module". Space.com (July 2019): https://www.space.com/nasa-taps-northrop-grumman-lunar-gateway-habitat.html
336 "MDA Selected to Build Robotic Interfaces for Canadarm3 on NASA-led Gateway". MDA (August 2019): https://mdacorporation.com/corporate/news-archive
337 "Two contracts awarded in preparation for Canadarm3, Canada's contribution to the Lunar Gateway". Canadian Space Agency (August 2019): http://www.asc-csa.gc.ca/eng/astronomy/moon-exploration/news.asp?utm_source=website&utm_medium=news&utm_campaign=moon-exploration&utm_content=contracts-canadarm3&utm_term=home-page#20190819
338 Jeff Foust, "SpaceX wins NASA commercial cargo contract for lunar Gateway". SpaceNews (March 2020): https://spacenews.com/spacex-wins-nasa-commercial-cargo-contract-for-lunar-gateway/

Industry involvement in the Orion spacecraft

Orion spacecraft (Credit: NASA)

The push for a quick return to the Moon also led to advancement regarding the Orion spacecraft, developed by Lockheed Martin to send astronauts to deep space. The launch abort system of the capsule was successfully tested in flight, reinforcing the safety for astronauts[339] and the Altitude Control Motor of the launch abort system successfully passed its second qualification test.[340] In addition, the capsule which will be used for the Artemis I mission was completed and unveiled in July by U.S. VP Mike Pence, during commemorations of the 50th anniversary of Apollo 11's Moon landing. Final tests will be required but development is well on track.

In 2019, NASA awarded a contract to Lockheed Martin for twelve Orion spacecraft. The initial order for the first three Orion is worth $2.7 billion (for missions Artemis III through V) while three more should be bought in 2022 (for Artemis VI through VIII) for $1.9 billion. Ordering the spacecraft in groups of three allows NASA to benefit from production efficiencies and cost savings that become available in the supply chain over time. Six additional spacecraft will be ordered by 2030 under a fixed-price contract, whose value will depend on the costs of the six previous systems. Finally, in order to reduce costs over the long term, reusability is considered by NASA: some elements of Orion used for the first Artemis missions could be reused for later ones. For example, internal computers and electronics, as well as crew seats and switch panels, from the Artemis II mission's Orion spacecraft, should be re-flown on Artemis V and the entire Artemis III crew module should be reused on Artemis VI.[341]

Industry involvement in the Human landing system

Another important component of the Artemis programme is the lander that will enable astronauts to reach and leave the Moon. NASA organised the Human Landing System competition in September in order to select two companies to design and build this lander: one company would fly its system in the Artemis III mission (2024), while the second would be used for Artemis IV (2025). NASA will then transition into a lunar lander services contract similar to those existing for commercial cargo and crew services for the International Space Station.[342] Several companies have expressed their interest, for instance Boeing which proposed a lander launchable on its SLS and minimising the number of mission critical events required.[343] Blue Origin, which had unveiled its own lander design, called Blue Moon, in May,[344] announced in October that it was creating a "national team" with three other major companies (Lockheed Martin, Northrop Grumman and Draper) to compete. At the core of the proposal is the Blue Moon and its descent module, both developed by Blue Origin, but its partners will take charge of other important parts of the

[339] "Successful Orion Test Brings NASA Closer to Moon, Mars Missions". NASA (July 2019): https://www.nasa.gov/press-release/successful-orion-test-brings-nasa-closer-to-moon-mars-missions
[340] "Milestone demonstrates motor's reliability to enhance astronaut safety". Northrop Grumman (August 2019): https://news.northropgrumman.com/news/releases/northrop-grumman-successfully-completes-qualification-motor-test-for-nasas-orion-launch-abort-system-attitude-control-motor
[341] "NASA Commits to Long-term Artemis Missions with Orion Production Contract". NASA (September 2019): https://www.nasa.gov/press-release/nasa-commits-to-long-term-artemis-missions-with-orion-production-contract
[342] "Fast-Track to the Moon: NASA Opens Call for Artemis Lunar Landers". NASA (September 2019): https://www.nasa.gov/feature/fast-track-to-the-moon-nasa-opens-call-for-artemis-lunar-landers
[343] Jeff Foust, "Boeing offers SLS-launched lunar lander to NASA". SpaceNews (November 2019): https://spacenews.com/boeing-offers-sls-launched-lunar-lander-to-nasa/
[344] Jeff Foust, "Blue Origin unveils lunar lander". SpaceNews (May 2019): https://spacenews.com/blue-origin-unveils-lunar-lander/

mission: Northrop Grumman will build the transfer element which will move the lander from the Lunar Gateway to an optimal altitude; Draper will provide the flight software for navigation; and Lockheed Martin will build the ascent module, to allow astronauts to leave the Moon.[345] Similarly, it was revealed in January 2020 that Dynetics, Sierra Nevada Corporation and other companies associated to take part in the competition.[346] In April 2020, NASA awarded 10-month study contracts, allowing to deeply design the landers, to three companies: Blue Origin ($579 million); Dynetics ($253 million) and SpaceX ($135 million), which had also made a proposal for the competition but had not announced it officially.[347]

Industry involvement in payload delivery to the Moon

In parallel, NASA launched in 2018 a commercial programme to deliver payloads to the Moon: the Commercial Lunar Payload Services programme. It selected 14 companies (nine in November 2018 and five in November 2019) that are entitled to bid for missions proposed by the agency. In May 2019, NASA awarded two task orders: one to Astrobotic ($79.5 million), which will launch its Peregrine lander in 2021; and one to Intuitive Machines ($77 million). Another company, OrbitBeyond, also won a contract but eventually abandoned it because of internal issues. Finally, a first version of the task order to deliver the lander of the Volatiles Investigating Polar Exploration Rover (VIPER), which will investigate the presence of water on the Moon, was also transmitted to the companies. The selection of the winner of this contract should occur in 2020. Finally, NASA announced that it was also interested in developing in partnership with industry the rover that will be used by astronauts.[348]

In addition to the public programmes previously described, the Moon is also a source of interest for start-ups willing to develop space technologies. Yet, 2019 was not a positive year for some of these endeavours:

- The Beresheet lander, developed by the Israeli company SpaceIL (a former contender of the Lunar X Prize), managed to reach lunar orbit but suffered a hard landing because of difficulties with the engine and loss of communication with the spacecraft. Beresheet was declared lost in April. If successful, the lander would have been the first private system to land on Earth's satellite.[349]
- PTScientists, another former participant in the Lunar X Prize, agreed with ArianeGroup for a far-reaching cooperation on lunar missions and received support from ESA. However, the company announced in July its insolvency. It was then bought by Zeitfracht Group and rebranded Planetary Transportation Systems. However, it still plans to launch its lunar lander and rover in a few years.[350]

Despite these setbacks, the excitement of private start-ups for the Moon is poised to continue in years to come. The company SpaceBit announced that it will launch the first UK lunar rover in 2021; it will be the smallest rover ever produced and will be equipped with legs instead of wheels, enabling it to explore lunar caves.[351] Similarly, Dymon will launch the first Japanese lunar rover that same year. Both rovers will ride on the first launch of the Peregrine lander, developed by the U.S. company Astrobotic (also a former Lunar X Prize competitor), and which will be the first lunar lander launched from the American soil since Apollo.[352]

[345] Leah Crane, "Blue Origin assembles space industry dream team to build moon lander". New Scientist (October 2019): https://www.newscientist.com/article/2220765-blue-origin-assembles-space-industry-dream-team-to-build-moon-lander/
[346] Stephen Clark, "Dynetics, Sierra Nevada partnering on human-rated lunar lander proposal". Spaceflight Now (January 2020)
[347] Jeff Foust, "NASA selects three companies for human landing system awards". SpaceNews (April 2020): https://spacenews.com/nasa-selects-three-companies-for-human-landing-system-awards/
[348] Jeff Foust, "NASA to seek ideas for an Artemis lunar rover". SpaceNews (November 2019): https://spacenews.com/nasa-to-seek-ideas-for-an-artemis-lunar-rover/
[349] Kenneth Chang, "Moon Landing by Israel's Beresheet Spacecraft Ends in Crash". The New York Times (April 2019)
[350] "Berliner Zeitfracht Group invests in German lunar mission". PT Scientists (September 2019)
[351] Leah Crane, "Plans for UK's first moon rover announced at New Scientist Live". New Scientist (October 2019)
[352] "Astrobotic and Dymon Announce Agreement to Bring the First Japanese Lunar Rover to the Moon". SpaceWatch Global

The status of industry involvement in Moon plans is provided in the table below:

Programme	Description	Main current contractors
Lunar Gateway	Construction of a permanent station orbiting the Moon	• Power and Propulsion Element: Maxar • Habitation and Logistics Outpost: Northrop Grumman • Canadarm-3 (studies): MDA
Space Launch System	Super-heavy rocket for crewed lunar flights	• Boeing
Orion	Transportation capsule for astronauts to, and from, the Lunar Gateway and the Moon	• Lockheed Martin • Airbus DS (European Service Module)
Gateway Logistics Services	Delivery of cargo to the Lunar Gateway	• SpaceX
Human Landing System	Landers carrying astronauts to the Moon surface	• "National Team": Blue Origin, Northrop Grumman, Lockheed Martin, Draper • Other team: Dynetics, Sierra Nevada Corporation, Thales Alenia Space, Astrobotics and others • SpaceX
Commercial Lunar Payload Services	Transportation of small systems to the Moon surface, through end-to-end commercial payload delivery services contracts	• Astrobotics • Intuitive Machines

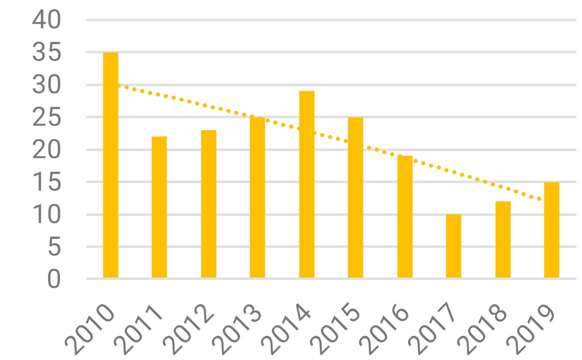
Table 9: Major programmes related to NASA's Moon endeavours

2.3.2 Turmoil in GEO satcom markets

GEO satcom, a major commercial space market facing uncertainties

Since 2016, the GEO satellite communications (satcom) market slowed down, with a stark decrease in GEO satcom orders and a reduction of the mass of this kind of satellites launched over the past few years, to the benefit of LEO/MEO constellations.

Number of GEO satcom contracts signed per year (2010-2019)



Source: Gunter's Space Page

Evolution of the mass (in tons) of satcom launched per orbit (2010-2019)

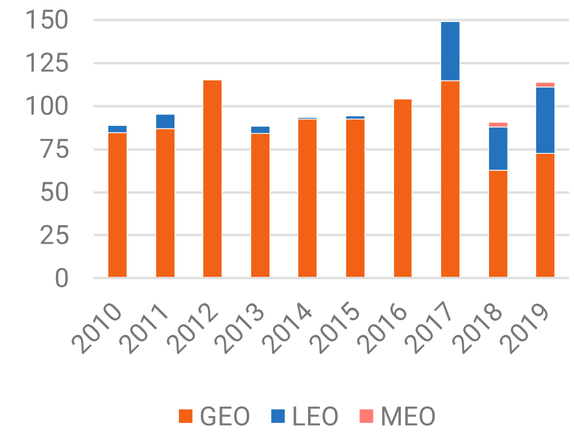


Figure 13: Statistics on commercial telecommunications satellites (2010-2019)

Telecommunication and media sectors experienced a rapid evolution across all market parameters. This transformation has profoundly impacted the traditional GEO satcom operators that are currently facing uncertainties affecting, in turn, new GEO satcom orders. This wait-and-see attitude in turn negatively affects satellite manufacturers, leading to business reorganisations.

In 2019, the former leader on the market, Maxar, sold its Canadian subsidiary MDA and almost closed its U.S. subsidiary Space Systems Loral. Maxar finally decided to keep ownership of the company (under the new name of Maxar Space Solutions) but plans to reduce its reliance on commercial markets by seeking government contracts and developing smaller satellites. Similarly, Thales Group announced its intent to restructure its space activities because of the global slowdown in GEO satellite commercial orders according to Pascal Bouchiat, Thales Chief Financial Officer.[353] As a consequence, Thales Alenia Space planned to reduce its workforce by 500 employees, who should be deployed to other business lines of Thales Group. Finally, Airbus DS started discussions with employees to engage a restructuration because of negative results caused by low order intakes marked by three consecutive years of falling orders in the space segment,[354, 355] lower performance in a competitive Space environment and efforts to support sales campaigns.[356] Difficulties also stem from other Airbus DS business lines such as the military plane A400M. In 2020, the company announced that it will lay off 2300 people.

[353] Caleb Henry, "Thales Group to restructure space business as order gap drives losses". SpaceNews (September 2019): https://spacenews.com/thales-group-to-restructure-space-business-as-order-gap-drives-losses/
[354] Guillaume Faury, Airbus CEO, during the annual press conference of Airbus (February 2020). Available at: https://www.youtube.com/watch?v=HMabagzn9lQ&feature=youtu.be
[355] Benjamin Katz, "Airbus to Restructure Defense, Space Unit". The Wall Street Journal (December 2019): https://www.wsj.com/articles/airbus-to-restructure-defense-space-unit-11576612768
[356] "Airbus reports Full-Year (FY) 2019 results, delivers on guidance". Airbus (February 2020): https://www.airbus.com/investors/financial-results-and-annual-reports.html

Some analysts foresee a rebound of the GEO satcom market in the coming years. Indeed, as shown in the left figure above, the number of GEO satcom contracts has been slowly increasing in 2017 and 2018, although still far from the level of order prior to 2016. Manufacturers are more confident for 2020, anticipating that the number of orders will be stable or slightly increase compared to 2019.[357]

Major decisions for space at the World Radiocommunication Conference 2019

The GEO satcom market takes place in an international environment strongly marked by the issue of frequency sharing. In this context, a significant development was the outcome of the ITU's World Radiocommunication Conference (WRC-19), which took place in Sharm el-Sheikh, Egypt, in November 2019. This quadrennial conference aims at updating and adjusting the global coordination of radio spectrum utilisation.

The WRC-19 occurred in a context of growing competition for space solutions with terrestrial services. Thus, its agenda extensively addressed the anticipated rollout of 5G mobile networks and, in this sense, allocated more than 17 GHz of new spectrum for cellular 5G. These new spectrum allocations have not come at the cost of drastic reduction of spectrum rights that are essential to commercial satellite operators. Satcom providers, as a matter of fact, collectively praised the WRC-19 outcomes.

More specifically, major WRC-19 decisions related to GEO satcom include:

- Protections for vital bands for the satellite industry, additional spectrum for satellite services and new orbital slots for broadcasting: WRC-19 produced encouraging outcomes for the satellite community with respect to protection of spectrum rights in bands essential for the satellite industry, namely in 3.8 - 4.2 GHz portion of the C-band[358] and in 28 GHz band.[359] In these bands, no new rights of considerations of future allocations were put forward to the IMT or HAPS. A decision was also made to protect GSO systems from interference produced by non-GSO FSS systems in several bands of the Ka and Q/V frequencies.[360] Additionally, new 51.4-52.4 GHz band was identified for fixed satellite services. WRC-19 also opened up new orbital slots for broadcasting satellites and provided developing countries with the opportunity to regain access to spectrum orbit resources thanks to a priority mechanism especially set for them.[361]
- New spectrum for the operation of Earth Stations in Motion (ESIM): As technological advances have made ESIM (connectivity, such as internet, on-board planes, ships or trains) more readily available and more practical (possibly a viable market for satcom), delegates at WRC-19 decided on the regulatory and technical conditions under which the frequency bands 17.7 - 19.7 GHz and 27.5–29.5 GHz can be used by ESIM communicating with geostationary (GSO) systems in the fixed-satellite service (FSS).[362]

Other WRC-19 decisions related to megaconstellations or space safety & sustainability are addressed in the respective chapters of this Yearbook.

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[357] Caleb Henry, "Geostationary satellite orders bouncing back". SpaceNews (February 2020): https://spacenews.com/geostationary-satellite-orders-bouncing-back/
[358] This frequency range is used for the satellite distribution of broadcast channels to Europe, the Americas, Asia, and Africa.
[359] C-Band spectrum allocations were not in the agenda for WRC-19, but since WRCs traditionally set the agenda for the next WRC 4 years later, there was pressure from the IMT community to open up more of the C-band allocated to satellite services for mobile 5G (IMT).
[360] It means the following frequencies: 37.5–39.5 GHz, 39.5–42.5 GHz, 47.2–50.2 GHz and 50.4–51.4 GHz
[361] Rutoing Chang, "ITU-R at a Glance and Accessibility Matters". Presentation available at: https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2019/Accessible%20Europe/09_Ruoting%20Chang_ITU-%20R%20glance%20and%20Accessibility%20matters%20for%20Europen%20accessibiliyty%20.pdf
[362] "Key outcomes of the World Radiocommunication Conference 2019". ITUNews Magazine (2019): https://www.itu.int/en/itunews/Documents/2019/2019-06/2019_ITUNews06-en.pdf

Traditionally, WRCs set the agenda for the for the following WRC four years later. In this context, WRC-19 delegates put several space-related a items on the agenda of the next WRC-23, especially on: the communication between ESIM and GSO and NGSO satellite networks; on the possibility to make more spectrum available for fixed and mobile satellite services to enable broadband and 5G applications; or on the study of other emerging issues, i.e. intersatellite links or suborbital vehicles.[363] WRC-19 also initiated the research on a potential use of Ku-band (specifically between 10.7 GHz and 11.7 GHz) for fixed wireless broadband IMT. This bandwidth is currently used for Direct-to-Home reception around the world. While it will not be up for official discussion until at least 2027, it suggests continuation of competition between space and terrestrial means of communication at spectrum allocation forums.[364]

Development of new solutions: reconfigurable payloads, small GEO satcom and shared satellites

To withstand the difficult context that they are facing, satellite manufacturers are actively developing new technologies to provide new, more flexible, solutions to satcom operators.

Reconfigurable payloads

Firstly, a large share of satellites ordered in 2019, whatever their dimensions, were equipped with digital reconfigurable payloads. Thus, instead of being limited to pre-set coverage areas, power levels and beam sizes, operators now have the possibility to adapt more easily to customers' needs and to increase the lifetime of their spacecraft.[365]

If needed, a satellite can be repurposed to another region or to provide another kind of service in another frequency. These possibilities greatly improve the flexibility of satcom operators.

Small GEO satellites

Secondly, 2019 confirmed the rise of the "small GEO satellites" trend expected to provide relevant alternatives to GEO satcom operators. Due to their smaller size and mass, these satellites can only target a smaller area but they are also less expensive and are often equipped with digital payloads, thus offering greater flexibility. All major manufacturers unveiled this kind of products in 2019.

Boeing proposed the 702X family,[366] which can be used both in GEO and MEO and is based on the O3b mPower constellation that the company developed for SES.[367] The MEO version is therefore already being produced while the GEO one, which weighs around 1900 kg, should be operational by 2022. The spacecraft is equipped with a digital payload so that the customer can change the mission of the satellite and re-purpose its capacity. For instance, several governments are interested by the option to split the satellite capacity between governmental and commercial users.

One of Boeing's biggest competitor's in this market is Airbus DS, which unveiled the OneSat series, a smaller satellite fully reconfigurable in orbit (adjustment of the coverage area, capacity and frequency).[368] Airbus already received a contract for this system, as Inmarsat ordered three of them to start its seventh-

[363] Thomas Weber and René Woerfel, "A quick overview of major satellite-related decisions at WRC-19". SpaceWatch Global (November 2019): https://spacewatch.global/2019/12/a-quick-overview-of-major-satellite-related-decisions-at-wrc-19/
[364] Jeffrey Hill, "The Consequences of WRC-19: Initial Observations". Via Satellite (December 2019): https://www.satellitetoday.com/government-military/2019/12/05/the-consequences-of-wrc-19-initial-observations/
[365] Caleb Henry, "To do business, reprogrammable satellites now the requirement for manufacturers". SpaceNews (September 2019): https://spacenews.com/to-do-business-reprogrammable-satellites-now-the-requirement-for-manufacturers/?fbclid=IwAR0vBsZu6kRzEr94FJXKufvsxxRh8GTzcLWNACLIGWfjYv1QAM_lJeIwDCs
[366] "New Boeing 702X Satellites Offer Unique Multi-Mission Flexibility". Boeing (September 2019): https://boeing.mediaroom.com/2019-09-09-New-Boeing-702X-Satellites-Offer-Unique-Multi-Mission-Flexibility#assets_20295_130499-117
[367] Sandra Erwin, "Boeing marketing its small GEO satellite to international governments". SpaceNews (October 2019): https://spacenews.com/boeing-marketing-its-small-geo-satellite-to-national-governments/
[368] "Flexible Payloads". Airbus: https://www.airbus.com/space/telecommunications-satellites/flexible-payloads.html

generation constellation.[369] A serial production method will be used so that, after the first three satellites are manufactured, the others are produced more quickly. The ultimate goal of Inmarsat is to get an order-to-launch timeframe of 18 months. The operator chose this spacecraft as it provides it with a satellite which is reprogrammable and has a greater capacity than all Global Xpress satellites that it currently holds in orbit.[370]

Thales Alenia Space and Maxar are also active on the small GEO satcom segment. TAS proposed a product named Space Inspire (standing for "INstant SPace In-orbit REconfiguration"), meant to be a reprogrammable satellite,[371] and which will be a low-cost solution due to its serial production; indeed, the company expects to build six satellites a year. Both OneSat and Inspire can be launched by groups of three on the same rocket, thus reducing the cost of the launch. Inspire will weigh around 2000 kg and offer a throughput of 100-200 gigabits per second. Its digital payload enables greater flexibility, which also appears in the spacecraft itself, as it can be used by both GEO and MEO operators. The satellite can only operate in Ku- and Ka-band, but can nevertheless carry payloads designed for other frequencies. As previously noted, part of the restructuration strategy of Maxar is to turn to the market of smaller satellites. This strategy has already met some success with a contract signed in July with Ovzon for a satellite based on the middle-class Legion bus. The production started the same month.[372]

Satellite Characteristics	Boeing	Airbus Defence & Space	Thales Alenia Space	Maxar	GEOShare (Lockheed Martin)
Name	702X	OneSat	Inspire	Based on Legion bus	MondoCondo
Weight	1900 kg (GEO version)	-	2000 kg	1500 kg	2000 kg
Reprogrammable	Yes	Yes	Yes	-	-
Orbit	MEO/GEO	GEO	MEO/GEO	GEO	GEO

Table 10: Small GEO satellites by main manufacturers

Besides major companies, other firms started to be active in the sector of small GEO satellites. At the end of 2018, the China Great Wall Industry Corporation unveiled the APSTAR SMALL GEO Communication Satellites System, based on the Dong Fang Hong-4 full-electric SMALL GEO platform, with the objective of embarking small-size payloads and being compatible with medium launchers. In 2019, Astranis, a U.S. company, picked up SpaceX to launch its first satellite, called MicroGEO (around 350 kg) in 2020.[373] The satellite will be used for a contract that Astranis has with Pacific Dataport to provide Alaskans with

[369] "Airbus wins three satellite deal from Inmarsat for revolutionary spacecraft". Airbus (May 2019): https://www.airbus.com/newsroom/press-releases/en/2019/05/airbus-wins-three-satellite-deal-from-inmarsat-for-revolutionary-spacecraft.html
[370] Caleb Henry, "Inmarsat details GX expansion, OneSat satellite orders". SpaceNews (July 2019): https://spacenews.com/inmarsat-details-gx-expansion-onesat-satellite-orders/
[371] "Thales Alenia Space Releases Fully Digital Satellite To Address Fast Moving Market Needs", Thales Group (September 2019): https://www.thalesgroup.com/en/worldwide/space/press-release/thales-alenia-space-releases-fully-digital-satellite-address-fast
[372] "Maxar Begins Production on Legion-class Satellite for Ovzon". Maxar Technologies (July 2019): http://investor.maxar.com/investor-news/press-release-details/2019/Maxar-Begins-Production-on-Legion-class-Satellite-for-Ovzon/default.aspx
[373] Alex Knapp, "Internet Startup Astranis Selects SpaceX To Launch Its First Commercial Satellite". Forbes (August 2019): https://www.forbes.com/sites/alexknapp/2019/08/26/internet-startup-astranis-selects-spacex-to-launch-its-first-commercial-satellite/#43c739aa1399

Internet. This kind of satellite offers operators the possibility of having highly-tailored capacity over a very specific area. Another company, Saturn Satellite Networks, has been working on the NationSat satellite, another small GEO satellite, since 2017. The company will either lease the satellite's capacity over its lifetime to a customer or provide full ownership, depending on the customer's preference. In 2019, the entire system design was completed while the Critical Design Review started in December. In July, the company selected Seakr to build digital radio-frequency processors for NationSat.[374]

Shared satellites

Finally, another solution proposed by prime manufacturers to mitigate the reduction of GEO satcom orders is to offer satellites that can be shared among operators. This is the case of GEOshare, a subsidiary of Lockheed Martin, which unveiled the Mondo Condo satellite in October 2019.[375] The company's satellite could be exploited by up to five operators on the same bus, in order to reduce the price of the gigabit per second for each customer. It especially targets the African and Asian-Pacific markets, as the operators of these regions do not always have the financial capacity to buy their own satellites. The proposal of GEOShare does not impact the weight of the spacecraft, as the bus used for Mondo Condo also weighs around 2000 kg.

[374] Mark Holmes, "Choi Explains NovaWurks Acquisition, Talks LEO Future". Via Satellite (November 2019): https://www.satellitetoday.com/innovation/2019/11/27/choi-explains-novawurks-acquisition-talks-leo-future/
[375] Caleb Henry, "GEOshare says 'Mondo Condo' satellite drawing interest from prospective tenants ". SpaceNews (October 2019): https://spacenews.com/geoshare-says-mondo-condo-satellite-drawing-interest-from-prospective-tenants/

2.3.3 LEO satcom constellations: steady progress and growing concerns

Important milestones for LEO satcom constellations in 2019

Recent years have been marked by the rise of so-called "mega-constellation" projects aiming to provide satellite communication services, usually broadband connectivity, through large constellations of hundreds or even thousands of small LEO satellites. These ambitious projects often rely on a vertically integrated business model where the activity of the company spans along the whole value chain, from the manufacturing of the satellite to the provision of services to end-users. Mega-constellation projects have been in the pipeline for several years already, passing some important milestones including fund raising, contractual arrangements, industrial setup, fillings for spectrum allocation, tests and demonstration.

Current/Planned satcom constellation projects	# of satellites	Satellite mass (kg)	Altitude	Project status
Amazon Kuiper	3,236	unspecified	590-630 km	Development
Boeing V-band	2,956	unspecified	1,200 km	Suspended
Globalstar 2	24	700 kg	1,410 km	In operation
Hongyan	320	unspecified	1,100 km	Demonstration
Hongyun	156	250 kg	1,000 km	Demonstration
Iridium-NEXT	72	860 kg	780 km	In operation
Kepler	140	3U CubeSats	575 km	Development
LeoSat	108	1.000 kg	1,432 km	Suspended operations
OneWeb	648	147 kg	1,200 km	Deployment
SpaceX Starlink	4,425 (init.) (+37,518)	260 kg	1,100-1,325 km 340 km (add. sats)	Deployment
Swarm	150	0.25U CubeSats	300-550 km	Demonstration
Telesat LEO	117	unspecified	1,000 km	Development
Theia	120	unspecified	800 km	Development

Table 11: Selection of current and planned large LEO satcom constellation projects (Source: ESPI compilation)

2019 has again been marked by important developments for LEO satcom constellations (selection):

- Iridium was awarded a $738.5 million contract by the U.S. Department of Defence. This seven-year, fixed-price contract will allow the U.S. Air Force Space Command (now the U.S. Space Force) unlimited access to satellite service from the company's communications constellation in LEO.
- Swarm Technologies raised €22.2 million in Series A (led by Craft Ventures and Sky Dayton, with the participation of Social Capital, 4DX Ventures and NJF Capital) for the building of a low-cost satellite network. More significantly, SpaceX and OneWeb raised more than $1 billion each from private investors[376] in order to continue the development of their businesses.
- SpaceX requested the authorisation to get radio spectrum rights for 30 000 additional satellites (leading eventually to a constellation of 42 000 satellites), to be launched in an orbit between 328 km and 580 km, and another one to reduce the altitude of its satellites.
- Amazon announced that it would launch a constellation of approximately 3000 satellites, named Project Kuiper, for communication purposes and started paperwork to get appropriate authorisations by the Federal Communications Commission in July 2019.
- Kepler Communications commissioned a 465 m^2 facility at its Toronto headquarters. It announced in January 2020 that it will build its satellites in-house, using this facility.
- Telesat postponed the selection of the manufacturer of its constellation to 2020.
- Rumours arose about the potential interest of Apple in developing a constellation. The project remains vague but Tim Cook is said to have defined it as a priority. According to Bloomberg, the company set up a secret team to work on satellite technology, maybe in order to establish a direct internet connection with its devices or to link them together, without the need to use wireless networks.
- Iridium and OneWeb, two major actors, signed a Memorandum of Understanding in order to provide a combined service offering.[377] This is the first time that LEO operators agree to deliver services in L- and Ku-band. The arrangement remains limited, is not exclusive and does not involve money, but it is a step towards the provision of complementary attributes.[378]
- Some companies suffered setbacks:
  - LeoSat, faced financial difficulties which led the company to reduce the size of its constellation (from 108 to 84 satellites), as well as the mass of its satellites (with the aim to be able to launch a full orbital plane with only one rocket), in order to reduce the overall cost. However, despite these efforts, the company suspended its operations in November 2019 due to a lack of investment from its main funders, Hispasat and Sky Perfect JSAT.[379]
  - OneWeb announced in March 2020 that it was filing for bankruptcy and laying off all its workforce. Because of the economic situation and the COVID-19 crisis, the main backer of the company, Softbank, decided to stop financing it. 2019 had been a full year for OneWeb: the joint venture between OneWeb and Airbus DS, OneWeb Satellites, had opened a factory in Florida in 2019 with an objective of producing two satellites per day and OneWeb had announced its intention to launch 30 satellites per month with the aim to provide partial service in 2020 and global coverage in 2021. OneWeb bankruptcy, a major event, is addressed in more details later.

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[376] Michael Sheetz, "Elon Musk's SpaceX raises over $1 billion this year as internet satellite production ramps up". CNBC (May 2019): https://www.cnbc.com/2019/05/24/spacex-raised-over-1-billion-this-year-as-starlink-and-starship-ramp-up.html. See also: "OneWeb Secures $1.25 Billion in New Funding After Successful Launch". OneWeb (March 2019): https://www.oneweb.world/media-center/oneweb-secures-1-25-billion-in-new-funding-after-successful-launch
[377] "Iridium and OneWeb to Collaborate on a Global Satellite Services Offering". Iridium (September 2019): http://investor.iridium.com/2019-09-17-Iridium-and-OneWeb-to-Collaborate-on-a-Global-Satellite-Services-Offering
[378] Chris Gebhardt, "Iridium inks 7-year deal with military, Memorandum of Understanding with OneWeb". NASA Spaceflight (September 2019): https://www.nasaspaceflight.com/2019/09/iridium-deal-military-oneweb/
[379] Mark Holmes, "Mark Rigolle Details Painful Demise of LeoSat Dream". Via Satellite (November 2019): https://www.satellitetoday.com/business/2019/11/13/mark-rigolle-details-painful-demise-of-leosat-dream/

Besides these important milestones, 2019 was initially going to be a turning point for LEO satcom mega-constellations efforts as the two most advanced players of the sector, OneWeb and SpaceX, kicked-off the deployment of their respective projects. OneWeb put its first six satellites in orbit in February 2019 while SpaceX launched as much as 120 Starlink satellites in May and November 2019, onboard the company's Falcon 9. In parallel, Iridium finalized the deployment of its second-generation constellation of 75 satellites in February (66 operational and nine spare satellites in orbit, as well as six spares on the ground). The deployment took almost ten years and cost the company around $3 billion. Iridium asserted that it will now become a "cash generator" thanks to new revenue streams related to broadband, Internet of Things and hosted payloads.[380]

As a result, LEO satcoms accounted for one third of the commercial satcom launch activity in 2019.

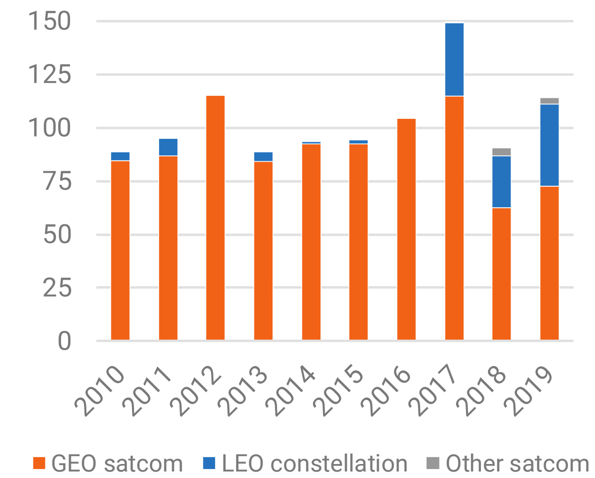
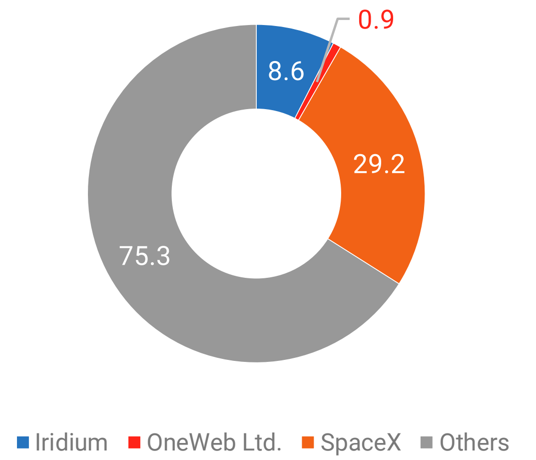
Evolution of the total mass (in tons) of commercial satcom per category (2010-2019)	Share of LEO constellations in the total commercial satcom mass (in tons) in 2019
	

Table 12: Statistics on commercial LEO satcom constellations

Concerns over the impact of LEO constellations

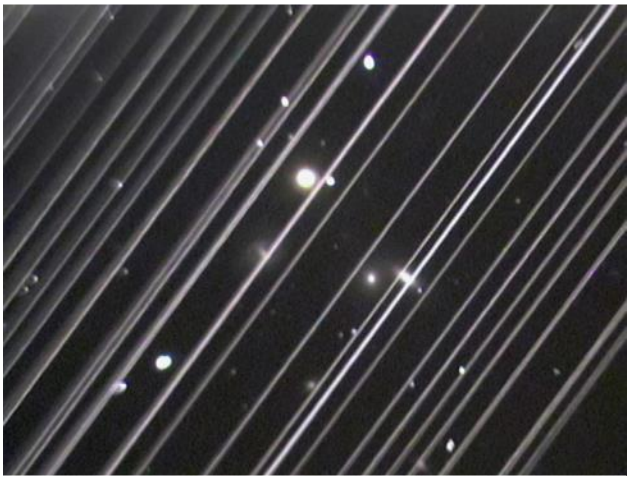
The launch and operation of these mega-constellations raise concerns over the impact they may have in some domains such as space safety and sustainability, astronomy or interferences.

The unprecedented number of satellites to be launched raises new challenges for safe operations in space. For instance, and although the company recalled at various occasions its commitment to a sustainable space environment and its intention to be an exemplary actor in this domain, SpaceX lost control of three Starlink satellites, only a few weeks after their launch. In September, a risk of collision between a Starlink satellite and Aeolus, an ESA scientific satellite launched in 2018, also raised some concerns regarding the suitability of current best practices in the management of collision avoidance in an environment populated by thousands of satellites. Even if ESA managed to perform an avoidance maneuver in order to prevent any damage,[381] communication with SpaceX proved difficult because of

[380] "Iridium Declares Victory; $3 Billion Satellite Constellation Upgrade Complete". Iridium (February 2019): http://investor.iridium.com/2019-02-06-Iridium-Declares-Victory-3-Billion-Satellite-Constellation-Upgrade-Complete
[381] "ESA spacecraft dodges large constellation". ESA (September 2019): http://www.esa.int/Safety_Security/ESA_spacecraft_dodges_large_constellation

technical problems with the operator.[382] Originally planned to be made up of 12 000 satellites, SpaceX filed new papers with the International Telecommunications Union (through the U.S. Federal Communications Commission) in order to get the authorisation to deploy 30 000 additional spacecraft. This move triggered a petition from its direct competitors OneWeb and Kepler Communications, and from the operator SES, highlighting the difficulty to deal with the high risk of collision it would create.[383] Similarly, papers filed by Amazon, which announced in 2019 its plans to put 3000 satellites in LEO to create the Kuiper constellation, showed that, if 5% of the Kuiper satellites lose their capacity to perform collision avoidance maneuvers, there is a 6% chance that one of those satellites eventually collides with a piece of space debris measuring 10 cm or larger. Despite assertions by Amazon that it wants the probability of control failure to be well below 5%, these high scores created concern from many actors.[384] LEO constellations are therefore an important driver of the rising international debate about adapted Space Traffic Management frameworks.

In addition to collision risks, the SpaceX constellation also raised major concerns from astronomers about its impact on observations. After the first launch, it indeed appeared that Starlink satellites have a high albedo, i.e they reflect the sunlight to a significant extent, thus preventing the observation of dimmer objects in distant areas of the universe.[385] The company announced that it will address the problem by testing a specific product on a few satellites to be launched to reduce their albedo.



Starlink impact on observations (Victoria Girgis / Lowell Observatory)

Moreover, the multiplication of satellites creates issues with regard to spectrum allocations, with an increasing risk of frequencies overlap between different users. The petition by Kepler and others against the request made by SpaceX to substantially increase the number of its spacecraft also underlines the major risk of interference that would stem from such a development.[386] The actual emergence of mega-constellations pushed public actors, like the ITU, to clarify their position. The final agreement of the WRC-19 sets out to “strike a balance between the prevention of radio-frequency spectrum warehousing, the proper functioning of coordination mechanisms, and the operational requirements related to the deployment of NGSO systems”.[387] More specifically, the regulatory regime – commencing on 1 January 2021 – requires mega-constellations to “deploy 10% of their constellation within two years after the end of the current regulatory period for bringing into use, 50% within five years, and complete the deployment within seven years”.[388] The objective is to avoid that some frequencies are blocked for years without any actual service being offered.

382 Jonathan O’Callaghan, “SpaceX Says A 'Bug' Prevented Its Starlink Satellite Avoiding A Collision With A European Satellite”. Forbes (September 2019): https://www.forbes.com/sites/jonathanocallaghan/2019/09/03/spacex-says-a-bug-prevented-its-starlink-satellite-avoiding-europes-aeolus-satellite-in-orbit/#726709077ff5
383 Marc Boucher, “Kepler Communications and Other NGSO Constellation Operators Oppose SpaceX Plans”. SpaceQ (October 2019): http://spaceq.ca/kepler-communications-and-other-ngso-constellation-operators-oppose-spacex-plans/
384 Mark Harris, “Amazon Reports Collision Risk for Mega-Constellation of Kuiper Internet Satellites”. IEEE Spectrum (October 2019): https://spectrum.ieee.org/tech-talk/aerospace/satellites/amazon-reports-collision-risk-for-its-megaconstellation-of-kuiper-internet-satellites
385 Alexandra Witze, “SpaceX launch highlights threat to astronomy from ‘megaconstellations’”. Nature (November 2019): https://www.nature.com/articles/d41586-019-03446-y
386 Marc Boucher, “Kepler Communications and Other NGSO Constellation Operators Oppose SpaceX Plans”.
387 “ITU Members agree to new milestones for non-geostationary satellite deployment”. ITU (November 2019): https://news.itu.int/itu-members-agree-to-new-milestones-for-non-geostationary-satellite-deployment/
388 Thomas Weber and René Woerfel, “A quick overview of major satellite-related decisions at WRC-19”. SpaceWatch.Global (November 2019): https://spacewatch.global/2019/12/a-quick-overview-of-major-satellite-related-decisions-at-wrc-19/

2020 update: OneWeb bankruptcy

On 27 March 2020, OneWeb officially filed for bankruptcy under the Chapter 11 of the United States Bankruptcy Code.

In the official press release, the company and the CEO Adrian Steckel stated that this situation is a consequence of the "financial impact and market turbulence related to the spread of COVID-19". Previously, on 19 March, Bloomberg reported rumours that OneWeb was considering bankruptcy and court protection to reorganise its debts and its overall corporate financial situation. Eventually, the decision was taken after OneWeb failed to secure additional funding and SoftBank, OneWeb's largest investor, agreed to the financial restructuring. Founded in 2012 by Greg Wyler, the London-based company raised from 2015 approx. €3B in funding rounds: overall, the Japanese investment giant SoftBank invested €2.5B in the company. Other investors include Airbus, Qualcomm Technologies, Virgin Group. The news came just after the company launched its second batch of 34 satellites on 21 March. The constellation operated by OneWeb now counts with 74 satellites but is unable to offer communication services. The company planned to launch additional satellites with a high frequency to reach 300 satellites and start a regional service by the end of 2020; subsequently, it expected to start providing a global service in 2021 with 588 satellites in orbit. Over the years, OneWeb secured more than twenty launch services contracts with Arianespace, 20 on Soyuz rockets plus the Ariane 6 maiden flight. Before officially communicating bankruptcy, OneWeb already announced reductions in its 500-staff workforce and delays in the scheduled launches, citing as main reason the virus SARS-CoV-2 outbreak and the consequent pandemic crisis. Analyses on the context leading to the bankruptcy have been diverse: according to Bryce Space and Technology, SoftBank decided to focus on its highest-priority investments – thus excluding OneWeb – while Matt Desch, Iridium's CEO, commented about the impatience of investors for returns, that on large constellation are far from being immediate. Finally, in case OneWeb might not find buyers for its assets, the entity responsible for the 74 spacecraft in orbit is the UK government.

The bankruptcy of such prominent actor of the New Space and mega-constellations trend raises questions about the future of the trends observed over the last years, especially in the context of the outbreak of the COVID-19 crisis.

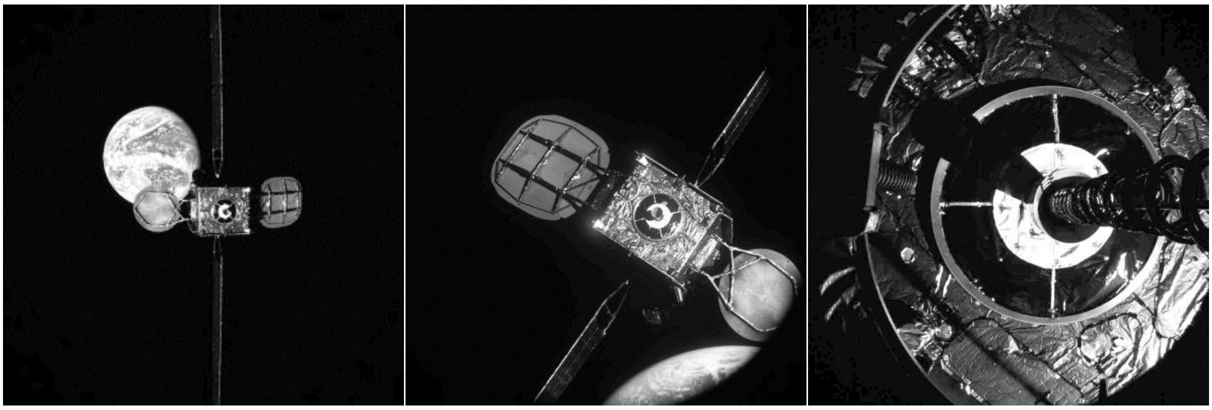
2.3.4 In-orbit servicing, the next big market?

In-Orbit Servicing (IOS) encompasses a broad range of new solutions for satellite operators based on Rendezvous and Proximity Operations (RPOs) techniques. IOS is a long-contemplated and potentially disruptive capability, that was envisioned in the first place for military applications. Today IOS aims to address a large portfolio of different applications – such as refuelling, life-extension, inspection, active debris removal, or even disruption for military missions.

Although IOS raises a variety of issues (regarding law and regulation, technology and standardisation, safety and sustainability, security and defence), it offers new interesting prospects for the space sector at large with a potentially disruptive impact on the space industrial value chain.

Life extension services

IOS developments made a big step forward recently with the launch of the Mission Extension Vehicle (MEV-1) which marked a concrete progress in both technological and business areas of servicing operations. Developed by SpaceLogistics LLC, a subsidiary of Northrop Grumman since the acquisition of Orbital ATK in 2018, the MEV-1 is based on a servicing vehicle designed to provide life-extension for up to 15 years. In 2016, Intelsat signed a contract with Orbital ATK for the first commercial IOS mission: the MEV-1 contract provides for a 5-year life-extension service of the Intelsat 901 (I-901), in operation in GEO since 2001, for a price estimated around $70M. The MEV-1 was launched in October 2019 from Baikonur on a Proton-M rocket and started the RPO phase with I-901 in February 2020 in a graveyard orbit at 300 kilometres above GEO, in order to avoid accidents with other GEO satellites. On 25 February, the MEV-1 completed RPO phase, autonomously approaching, capturing and docking to the I-901's liquid apogee engine, a device present on the vast majority of GEO satellites.



MEV-1 docking sequence with Intelsat 901 (credit: Northrop Grumman)

After docking, the MEV-1 is expected to relocate the satellite to a new orbit slot, in compliance with orbital regulations, and perform as a "combined vehicle stack" the 5-year life-extension, adding 26% to the current I-901 lifetime. At the end of the mission, the MEV-1 could either extend the service or proceed with the disposal of the satellite to the graveyard orbit, consequently becoming available for new clients. Intelsat already signed a contract for MEV-2 to provide similar servicing to its I-10-02 satcom, in operation since 2004. Northrop Grumman is reportedly developing the MEV-2 spacecraft with additional capacity to carry payloads and deploy small satellites. The company is also developing other IOS systems such as the Mission Robotic Vehicle and the Mission Extension Pods, to offer new solutions and a better life-extension service. If successful, the demonstration of the flexible and likely replicable MEV-1 mission will illustrate some of the potential impacts of IOS at industrial and economic level.

In July 2019, the company was awarded feasibility study contracts by the Space Enterprise Consortium, a U.S. Air Force organisation, to assess the servicing of four satellites used for national security activities.[389]

Besides MEV-1 launch, 2019 was marked by other major developments in the IOS domain.

Maxar completed the Critical Design Review of the satellite bus which will be used for Restore-L, a mission planned by NASA since 2016 and which aims at refuelling the U.S. Geological Survey's Landsat 7 satellite in LEO.[390] Maxar announced that the project is on track and will be sent to NASA in 2020 for integration of the payload, with a launch planned for 2022. The mission will enable to validate the "tools, technologies and techniques" used for servicing, in anticipation of future exploration missions as well as to contribute to the development of a new servicing industry.

Maxar, on the other hand, withdrew from another IOS project, organised by DARPA and called Robotic Servicing of Geosynchronous Satellites (RSGS). RSGS aims to provide four types of IOS missions: high-resolution inspection; anomaly correction; cooperative relocation; and upgrade installation. DARPA aims at servicing more than 30 customers over the lifetime of the mission.[391] The withdrawal from Maxar was mainly due to financial difficulties faced by Space Systems Loral (now Maxar Space Solutions), which was supposed to build the bus for the mission, integrate it in the launcher, operate the spacecraft, and support part of the costs of these activities. Maxar decided to redirect its resources towards other programmes (in particular, the Earth observation satellites WorldView-Legion) in order to ensure optimal returns.[392] Despite this abandon, payload packages (robotic arm, camera…) have been delivered[393] and DARPA still intends to launch its mission in 2022. In 2020, DARPA announced that it was selecting Northrop Grumman to replace Maxar in the RSGS programme, due to its experience with the MEV-1. SpaceLogistics could be joined in several years by new competitors, as systems developed in both RSGS and Restore-L frameworks will be transferred to commercial actors after a determined period of time.[394]

Active Debris Removal

A specific field falling in the IOS domain is Active Debris Removal (ADR) which encompasses a variety of technical solutions and approaches to deorbit target objects in space.

Europe made a great step in this domain: at the Space19+ Ministerial Council, ESA included ADR as a strategic goal, managing to gain support for it under the Clean Space initiative. The Agency adopted a service-oriented approach, also to encourage the development of IOS solutions at large and demonstrate the feasibility of commercial IOS missions. ESA eventually awarded a space debris removal services contract in December 2019 to the Swiss start-up ClearSpace with the objective to deorbit a 100kg Vega Secondary Payload (Vespa) upper stage in LEO. The start-up will be in charge of leading a consortium to design and build a spacecraft equipped with four robotic arms.[395]

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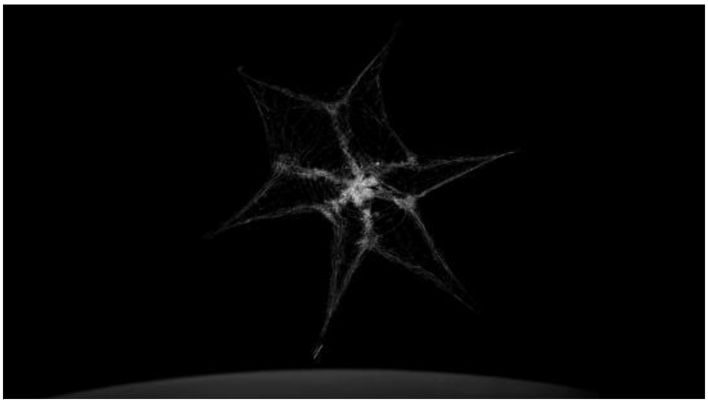
389 Theresa Hitchens, "DARPA In Talks With New Robot Sat Servicing Company". Breaking Defense (October 2019): https://breakingdefense.com/2019/10/darpa-in-talks-with-new-robot-sat-servicing-company/
390 "Maxar and NASA Successfully Complete Design Review for Restore-L On-Orbit Servicing Spacecraft Bus Innovative spacecraft on track to make history as first-ever to refuel satellite in Low Earth Orbit". Space Systems Loral (April 2019): http://sslmda.com/html/pressreleases/2019-04-08-Maxar-and-NASA-Successfully-Complete-Design-Review-for-Restore-L-On-Orbit-Servicing-Spacecraft-Bus.php
391 Mark Holmes, "Satellite Servicing Becomes an Actual Market". Via Satellite (March 2019): http://interactive.satellitetoday.com/via/march-2019/satellite-servicing-becomes-an-actual-market/
392 "Maxar Technologies' SSL Terminates its Participation in DARPA's Robotic Servicing of Geosynchronous Satellites Program". Maxar Technologies (January 2019): http://investor.maxar.com/investor-news/press-release-details/2019/Maxar-Technologies-SSL-Terminates-its-Participation-in-DARPAs-Robotic-Servicing-of-Geosynchronous-Satellites-Program/default.aspx
393 Theresa Hitchens, "DARPA In Talks With New Robot Sat Servicing Company". Breaking Defense (October 2019)
394 Nathan Strout, "DARPA wants a robotic satellite mechanic launched by 2022". C4ISR.net (October 2019): https://www.c4isrnet.com/battlefield-tech/space/2019/10/03/darpa-wants-a-robotic-satellite-mechanic-launched-by-2022/. See also: "Restore-L Factsheet". NASA: https://www.nasa.gov/sites/default/files/atoms/files/restore_l_factsheet_092717.pdf
395 Caleb Henry, "Swiss startup ClearSpace wins ESA contract to deorbit Vega rocket debris". SpaceNews (December 2019): https://spacenews.com/swiss-startup-clearspace-wins-esa-contract-to-deorbit-vega-rocket-debris/


RemoveDebris net capture (Credit: Surrey Space Centre)

ESA is not the only European organisation supporting developments in this field. In February 2019, one of the EU-funded RemoveDebris mission's experiments used lidar and camera vision-based navigation to target an object and capture it with a harpoon. Other ADR techniques were also displayed in 2019 in Europe. Surrey Satellite Technology Ltd successfully deployed an innovative "space sail", called Icarus-1 and measuring 6.7 m^2. The sail was aboard the TechDemoSat-1, a satellite launched in 2014 at an altitude of 635 km in LEO. It is intended to increase the small amount of atmospheric drag which continues to affect satellites up to orbit heights of 1000 km or more. It therefore reduces the time necessary for the spacecraft to be de-orbited. This mission marked the second time that the sail was successfully tested to de-orbit a satellite, the first test having taken place on Carbonite-1 in November 2018.[396] A sail was also deployed at the end of the RemoveDebris mission, as part of the experiments that took place.

Outside Europe, the start-up Astroscale, announced a demonstration mission for 2020 called ELSA-d. The Japanese company, which opened a U.S. office in 2019, works on a spacecraft equipped with a magnet to attract debris and move it to a lower altitude. ELSA-d will consist of two spacecraft, a Servicer, weighing 180 kg and a Client, weighing 20 kg, possessing a docking plate and acting as the dummy debris, launched stacked together. The Servicer will repeatedly release and dock the Client in a series of technical demonstrations, proving the capability to approach and dock with space debris.[397] The test will demonstrate the first semi-autonomous capture of a non-responsive, tumbling target, as well as the first identification of a target that stands outside of the field of view of the navigation sensors of the Servicer.[398] In addition, Astroscale won a contract from OneWeb in the frame of the ESA's Sunrise Project,[399] with the aim of developing a future large constellation end-of-life service. A similar contract was awarded by OneWeb to the Italian company D-Orbit.[400] In addition, OneWeb and OneWeb Satellites partnered with Altius Space Machines and Astroscale by committing to implement an advanced grappling technology on all of their spacecraft.[401]

[396] "Camera captures innovative drag sail deployment in space". Cranfield University (May 2019): https://www.cranfield.ac.uk/press/news-2019/camera-captures-innovative-drag-sail-deployment-in-space
[397] Ciaran McGrath, "Space junk: UK firm at the heart of 'critical' mission to clean up space". The Express (September 2019): https://www.express.co.uk/news/science/1184411/space-junk-warning-debris-satellites-astroscale-nasa-space-latest-news-update
[398] "SSTL Ships Target Satellite to Tokyo for Astroscale's ELSA-d Mission". SSTL (November 2019): https://www.sstl.co.uk/media-hub/latest-news/2019/sstl-ships-target-satellite-to-tokyo-for-astroscal
[399] Doug Messier, "Astroscale Advances Environmentally Sustainable Use of Space through ESA / OneWeb Sunrise Project". Parabolic Arc (July 2019): http://www.parabolicarc.com/2019/07/15/astroscale-advances-environmentally-sustainable-use-of-space-through-esa-oneweb-sunrise-project/
[400] "Italy's D-Orbit Selected By OneWeb For Active Debris Removal In ESA Project Sunrise Framework". SpaceWatch Global: https://spacewatch.global/2019/11/italys-d-orbit-selected-by-oneweb-for-active-debris-removal-in-esa-project-sunrise-framework/
[401] "OneWeb and OneWeb Satellites bolster commitment to Responsible Space with advanced grappling technology from Altius Space Machines". OneWeb (December 2019): https://www.oneweb.world/media-center/oneweb-and-oneweb-satellites-bolster-commitment-to-responsible-space-with-advanced-grappling-technology-from-altius-space-machines

2.3.5 Other outstanding developments in the satellite industry

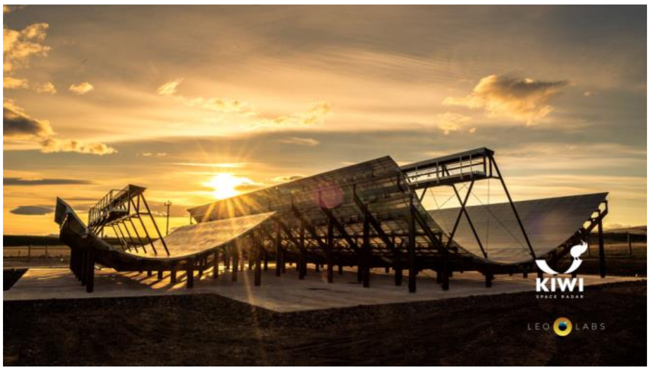
Great promises of Artificial Intelligence for space systems

Artificial intelligence is seen as a promising technology for the space sector, especially for the Earth observation domain. Indeed, this capability would enable to faster process the great amount of data that is being collected every day by remote sensing satellites, a quantity which is expected to dramatically increase given the number of satellites planned to be launched in the upcoming years. In 2019, several developments took place (selection):

- PhiSat, the first European satellite demonstrating how onboard artificial intelligence can improve Earth Observation missions will be launched early 2020. The project, supported by ESA, will involve a CubeSat with a hyperspectral camera collecting a large number of images of the Earth, some of which will not be suitable for use because of cloud cover. To avoid downlinking these unusable images back to Earth, PhiSat's onboard AI chip will filter them out so that only useful data are returned.
- ESA also launched OPS-SAT in December 2019, a nanosatellite which is the world's first orbiting software laboratory, available to test, in actual space conditions, novel methods for mission operation. The satellite harnesses more flight computing power than any previous ESA spacecraft. Artificial intelligence and autonomous planning, fault detection and recognition are some of the experiments that will be conducted. Teams exploiting the CubeSat have direct access to it by Internet.
- Planet launched an AI-based platform, called "Planet Analytics Feeds", aimed at making possible the automatic analysis of satellite imagery. The product uses machine learning and cloud computing and is able to detect road, building and vessels over the customers' areas of interests in a few minutes. Users can exploit these feeds on top of other Planet products. Planet also worked on a Change Detection feed, to help customers focus their resources on where change has recently occurred.
- Lockheed Martin announced that it is developing a satellite imagery recognition system using open-source deep learning libraries to quickly identify and classify objects or targets in large areas across the world. This technology could help saving the time of image analysts by avoiding the need to manually categorise and label items within an image.

Development of commercial solutions for Space Situational Awareness

The vitality of the LEO satcom sector described above has snowball effects on other markets, like commercial space surveillance. Indeed, this activity will gain traction as more and more (small) satellites are launched into orbit, creating the need to track them in order to avoid collision. For instance, LeoLabs, a company specialised in space surveillance and which has set a goal to provide data on mega-constellations, announced the opening of its third radar station in New Zealand in October and its intention to double the number of these stations in the next few years in order to provide global coverage.[402]



LeoLabs' Kiwi Space Radar (Credit: LeoLabs)

This is only one commercial project among many others taking place in the United States and Europe.

[402] Theresa Hitchens, "LeoLabs' New Radar Tracks Tiny Space Debris". Breaking Defense (October 2019): https://breakingdefense.com/2019/10/leolabs-new-radar-tracks-tiny-space-debris/

The Internet of Things, growing market for satcom?

According to Quilty Analytics, the satellite industry could capture 2% of the Internet of Things (IoT) market in the future, compared to less than 1% currently. To reach this goal, some barriers have to be overcome, pertaining to terminals, spectrum issues and the design of business strategies.

The IoT market is promising and some space companies, including traditional GEO satcom operators, have made some moves towards this market in 2019 (selection):

- Eutelsat unveiled its Eutelsat LEO for Objects (ELO) constellation project, which will offer a global Internet of Things coverage to enable objects to transmit data regardless of their location. 25 nanosatellites and hosted payloads are expected to be launched in 2020-2022. The first four will be built by Loft Orbital and Clyde Space and each satellite should not cost more than €1 million.[403] Moreover, Eutelsat also announced that it will offer a new connectivity service dedicated to IoT devices. Called Eutelsat IoT First, it will use the operator's geostationary satellite fleet and will complement the future ELO. The two services are complementary: while the geostationary Eutelsat IoT First service will link “large fixed assets” in Ku-band that need to move hundreds of megabits worth of data over the internet, the LEO constellation will use ISM frequencies to connect smaller devices. IoT First has already been activated over the Americas, Europe, the Middle East and Northern Africa at the end of October.[404]
- EchoStar has ordered two S-band satellites from Tyvak Nano-Satellite Systems, in order to start a constellation for IoT purposes. To this end, the company will use the spectrum rights that it gained by acquiring the start-up Helios Wire. The launch of the two satellites is also meant to secure these rights, which provide S-band spectrum for a global coverage. Once that regulatory process will be complete — by launching at least one of the S-band Tyvak satellites, operating it for 90 days and filing the requisite paperwork — EchoStar will decide on a longer-term strategy.
- The Swiss nanosatellite manufacturer Astrocast, which targets the IoT market, announced in January that it will be launching 3 new pilots of its new LEO Nanosatellite Network, dedicated to remote areas for marine, industrial and water purification devices. The Lausanne-based company further announced it will be launching ten of its nanosatellites in 2023 with the launch vehicle of Orbex. The second nanosatellite of the constellation was successfully launched at the beginning of April.

Development of new propulsion technologies for deep space travel

In parallel to the growing popularity of electric thrusters for small satellites (with start-ups like Morpheus Space[405] or Orbion Space Technology[406]), a lot of demonstrations on alternative propulsion means were carried out in 2019. Greener propellant was thus developed and tested in the United States and China. But these new technologies can also be more innovative. For instance, the LightSail-2 mission, a CubeSat designed by the Planetary Society and which deployed a sail to use photons emitted by the Sun to raise its orbit,[407] was launched in June 2019. A prototype of a wafer scale spacecraft was developed by students of the University of California in Santa Barbara and sent into the stratosphere with a balloon. The

[403] Annamarie Nyirady, “Eutelsat Reveals ELO Constellation for the IoT Market”. Via Satellite (September 2019): https://www.satellitetoday.com/launch/2019/09/24/eutelsat-reveals-elo-constellation-for-the-iot-market/
[404] Annamarie Nyirady, “Eutelsat Launches IoT Connectivity Service”. Via Satellite (October 2019): https://www.satellitetoday.com/mobility/2019/10/28/eutelsat-launches-iot-connectivity-service/
[405] Debra Werner, “Morpheus Space plans future electric propulsion tests”. SpaceNews (April 2019): https://spacenews.com/morpheus-space-plans-future-electric-propulsion-tests/
[406] Jim Vinoski, “Meet The Makers Of Small Plasma Rockets That Will Propel The Coming Space Revolution”. Forbes (November 2019): https://www.forbes.com/sites/jimvinoski/2019/11/14/meet-the-makers-of-small-plasma-rockets-that-will-propel-the-coming-space-revolution/#472f21f8fbd4
[407] Jason Davis, “LightSail 2 set to launch next month aboard SpaceX Falcon Heavy rocket”. The Planetary Society (May 2019): https://www.planetary.org/blogs/jason-davis/lightsail-2-set-to-launch.html

project aimed at building an ultra-lightweight (gram scale) silicon wafer with embedded electronics, capable of being shot into space while relaying data back to Earth. Laser propulsion will give an impulse to the spacecraft and, possibly, make it reach 20% of the speed of light. Ultimately, this technology would considerably reduce the amount of time required for interstellar travels.[408]

On the commercial side, the start-up Momentus successfully demonstrated its water plasma propulsion technology. According to its CEO, "the on-orbit testing has demonstrated for the first time that microwave electrothermal plasma technology has the potential to achieve high specific impulse using water propellant"; he considers that the technology is mature enough to be used for in-orbit missions. The goal of the company is to use these propellants for its future Vigoride and Vigoride Extended, two shuttles that will move small satellites between orbits.[409] The first Vigoride will be launched on a SpaceX dedicated rideshare mission. Finally, the French start-up ThrustMe, which develops a first-of-its-kind cold gas thruster fuelled by solid iodine, launched and tested its system for a few dozens of minutes on a Chinese CubeSat operated by Spacety. The full process from the development of the product to the gathering of data took approximately one year.[410] ThrustMe is also working on an electric propulsion system for small satellites, of which the cold gas thruster is a subsystem.

[408] Sonia Fernandez, "First Flights Experimental cosmologist Philip Lubin's group launches its first iterations of space-traveling 'wafercraft'". UC Santa Barbara (May 2019): https://www.news.ucsb.edu/2019/019460/first-flights
[409] Debra Werner, "Momentus reports success in testing water plasma propulsion". SpaceNews (September 2019): https://spacenews.com/momentus-el-camino-real-results/
[410] Debra Werner, "ThrustMe, Spacety report initial success of cold gas thruster". SpaceNews (November 2019): https://spacenews.com/spacety-thrustme-cold-gas-test/

2.4 Selected company profiles in 2019

This section provides an overview of outstanding developments including corporate developments, announcements, achievements, contracts and partnerships for the following companies:

2.4.1 Launch service providers

Country

India

Core activity

Upstream

Employees

10 – 50

Major announcements and achievements

- Announced that it will commercialise NavIC, the Indian Global Navigation Satellite System. Antrix identifies suitable device manufacturers on the one side and comprehensive integrators of NavIC-based systems on the other.
- Contributed to the development the Small Satellite Launch Vehicle, planned for launch in 2020

Major contracts

- Signed a bandwidth service agreement with Thaicom for a two-year period

Country

France

Core activity

Upstream - Launch Provider

Employees

200 – 500

Major announcements and achievements

- Presentation of a new service to launch small satellites to GEO through a rideshare launch dedicated to this kind of spacecraft. The first mission, GO-1, is planned for 2022 and will be able to carry up to 4500 kg of payload.
- Announced that it is planning a rideshare mission to the Moon in 2023 (with an Ariane 6 launcher to deliver 8500 kg to a lunar transfer orbit) and that it will push for a European manned programme at ESA's Ministerial Council in 2022
- After 13 successful launches, first failure of Vega while carrying the FalconEye1 satellite, due to a problem with the second stage
- Launches in 2019: 4 Ariane 5; 3 Soyuz; 2 Vega

Major contracts

- A contract with OneWeb was signed to launch 30 satellites on the first Ariane 62 mission in 2020
- A contract was signed with ESA to launch the JUpiter ICy moon Explorer (JUICE) aboard an Ariane 64 or an Ariane 5.
- Ovzon changed the launch provider of its satellite Ovzon-3: it left SpaceX's Falcon Heavy for Arianespace's Ariane 5
- Contract for the launch of SEOSat/Ingenio, an optical Earth observation satellite from Spain
- Two contracts with ESA to launch spacecraft studying the environment in 2022: for the launch of Earth Explorer Biomass onboard Vega; and of EarthCARE onboard Soyuz
- Received a contract from Measat to launch MEASAT-3D

Country

United States

Core activity

Upstream - Manufacturer

Employees

1000 – 5000

Corporate developments

- Construction of a $200 million rocket plant in Alabama to produce BE-4 engines
- Opened a new office close to Los Angeles to work on propulsion systems design and development

Major announcements and achievements

- Unveiled the Blue Moon lunar lander
- Officially competed for the U.S. Air Force National Security Space Launch Phase 2 Launch Service Procurement, by offering the New Glenn rocket
- First hot-fire test of the BE-7 engine, planned to be used on the Blue Moon lander

Major contracts

- Contract from Telesat to launch an undisclosed number of satellites for the upcoming Telesat LEO constellation
- As part of NASA's Tipping Point programme, Blue Origin was awarded a $10 million contract in order to develop a ground demonstration of hydrogen and oxygen liquefaction and storage, representing rocket and spacecraft propellant that could be produced on the Moon, thanks to the ice present there
- Was selected for NASA's Commercial Lunar Payload Services programme. Blue Origin will compete for future bids with its Blue Moon lander.

Partnerships

- Teamed up with Northrop Grumman, Lockheed Martin and Draper for a lunar lander. Blue Origin will provide the lander and the descent stage.
- Received three Space Act Agreement from NASA, which allows it to work with NASA centres and tap into their expertise in a range of technologies, especially to develop its lander

Country

United States

Core activity

Upstream - Launch Provider

Employees

10 – 50

Corporate developments

- Was absorbed by Glavkosmos, the Roscosmos subsidiary in charge of selling Soyuz launches. ILS has become the North American marketing unit for Glavkosmos.
- Kirk Pysher left the position of President

Major announcements and achievements

- First launch of two commercial spacecraft on a single Proton (Eutelsat 5 West B and MEV-1)
- Only one mission this year
- Launches in 2019: 1 Proton rocket

Country

United States

Core activity

Upstream – Manufacturer and Launch Provider

Employees

200 – 500

Corporate developments

- Completion of the second launch site of the company, in the United States (Wallops Island). With this launch complex, Rocket Lab aims at providing responsive launch, especially for American customers.
- Investment in a new manufacturing robot to produce first stages in 12 hours instead of 400 hours
- Started the construction of a second launch pad at is Launch Complex 1 in New Zealand

Major announcements and achievements

- Performed its 10th launch and broke its height record during its ninth launch
- Announced its will to recover and reuse the first stage of its Electron rocket, in order to increase the company's launch rate (and not to reduce launch prices)
- Unveiled the Photon small satellite platform. The spacecraft will be used for LEO but also to transport payload (around 30 kg) to lunar orbit
- Flew a fully Autonomous Flight Termination System (AFTS) for the first time on an Electron launch vehicle. It is an important step to increase launch frequency and responsiveness, while continuing to ensure safety. All future Electron missions will fly with the AFTS.
- Launches in 2019: 6 Electron rockets

Major contracts

- Rocket Lab is one of the eight companies selected by the U.S. Air Force to provide launch services in the Orbital Services Program-4. It will thus be able to bid for contracts worth a total of $986 million over nine years.

Partnerships

- Partnership with KSAT to provide ground stations as an additional service to customers of Electron launches and Photon spacecraft. The objective of Rocket Lab is to deliver a complete solutions for small satellites operators: launch, satellites, and ground services.

Country

United States

Core activity

Upstream – Manufacturer and Launch Provider

Employees

1000 – 5000

Corporate developments

- Raised $1 billion through two funding rounds
- Announced it will lay off around 10% of its workforce

Major announcements and achievements

- Launched its first 120 Starlink satellites and filed papers for 30 000 additional satellites (on top of the already agreed 12 000). The company now possesses the largest telecommunications system in space. 24 Starlink launches are planned for 2020.
- Docking of Crew Dragon Demo-1, which would send astronauts to the ISS in the future, and loss of the same capsule one month later in a ground test. This latter test was finally passed in November with another capsule.
- Presentation of Starship Mk 1, the first prototype of this deep space spacecraft.
- Announcement of a new rideshare service for small satellites, the Smallsat Rideshare Program. The price of a launch would be as low as $1 million.
- First commercial launch of the Falcon Heavy, with the Arabsat-6A satellite
- Launches in 2019: 11 Falcon 9; 2 Falcon Heavy

Major contracts

- Was awarded a contract by SES for the launch of the first seven O3b mPower satellites in 2021
- As part of NASA's Tipping Point programme, SpaceX was awarded a $3 million agreement to work on a coupler prototype for large-scale in-orbit refueling
- Was selected for NASA's Commercial Lunar Payload Services programme. SpaceX will compete for future bids with its Starship and Super Heavy systems.
- Contract with Intuitive Machines to launch a lander to the Moon
- Received a contract of $297 million from the U.S. Air Force for three missions to be launched in 2021-2022 (AFSPC-44, NROL-85, and NROL-87)

Partnerships

- Received a Space Act Agreement from NASA, which allows it to work with NASA centres and tap into their expertise in a range of technologies. The focus of this work will be on technology for landing large vehicles on the Moon, and in-space propellant transfer

Country

United States

Core activity

Upstream – Manufacturer and Launch Provider

Employees

1000 – 5000

Major announcements and achievements

- Last launch of the Delta 4 Medium rocket, which achieved a 100% success rate over its career
- Completion of the Critical Design Review of Vulcan Centaur, the next generation rocket of ULA
- Launches in 2019: 3 Delta IV; 2 Atlas V

Major contracts

- Received a contract from Sierra Nevada for six Dream Chaser launches to the ISS aboard the upcoming Vulcan rocket
- Selected by Astrobotic for the launch of its Peregrine lunar lander in 2021, with a Vulcan launcher
- Was awarded a contract by NASA ($148.3 million) to launch the Lucy mission in 2021, which will study Trojan asteroids, located close to Jupiter
- Received a $441.76 million contract from the U.S. Air Force for three missions to be launched in 2021-2022 (SBIRS GEO-5, SBIRS GEO-6 and Silent Barker)
- The U.S. Air Force Space and Missile Systems Center (SMC) awarded several contracts to ULA: a contract of $1.18 billion to cover the launch operations costs of five National Reconnaissance Office missions (NROL-44, NROL-82, NROL-91, NROL-68 and NROL-70); a contract of $98.5 million for the completion of three Atlas V missions in 2020; the SMC also awarded contract modification worth $149 million for a Delta 4 Heavy launch of the NRO mission NROL-68, and another one worth 156.7 million for the launch of NROL-70.

2.4.2 Space systems manufacturers and integrators

AIRBUS DEFENCE & SPACE

Country

France

Core activity

Upstream - Manufacturer

Employees

> 10 000

Corporate developments

- Appointment of Jean-Marc Nasr as Executive Vice President Space Systems
- Started discussions with employees to implement a restructuration of the unit
- Opening of a satellite integration and space technology centre on Airbus' Friedrichshafen site, for around €45 million

Major announcements and achievements

- Unveiling of a new GEO satellite series (OneSat), fully reconfigurable in orbit
- Announced that it will sell capacity on Syracuse IV with Telespazio
- Live demonstration of the SpaceDataHighway
- Completed the construction of Copernicus Sentinel-6A and of the CHEOPS satellite
- Presentation of ELSA+, a versatile reception antenna used for Eutelsat's Quantum satellite and allowing the spacecraft to adapt to the evolving business cases of customers

Major contracts

- Won the contract of the two SpainSAT NG for Hisdesat (with Thales Alenia Space). Airbus DS will build the platform, based on the Eurostar Neo, as well as the X-band payload
- Won a contract from Inmarsat for three satellites; they will be based on the new OneSat platform
- Contract from Measat to build the MEASAT-3d
- Contract from CNES to build an Earth observation constellation (CO3D)
- Five-year contract with the UK Ministry of Defence (approximately £22 million) to manage test and reference services to support the delivery and assured release of C4ISR capability for operations around the globe

Partnerships

- Memorandum of Understanding with the Hellenic Space Agency on Earth observation, space exploration and future growth opportunities
- Partnerships with ESA and UNOOSA on the Bartolomeo platform of the ISS
- Memorandum of Understanding with Firefly Aerospace, which is interested in launching the Arrow platform of Airbus

arianeGroup

Country

France

Core activity

Upstream - Manufacturer

Employees

5000 – 10 000

Corporate developments

- Inauguration of a new facility for the integration of Ariane 6 upper stages in Bremen

Major announcements and achievements

- Completion of the Critical Design Review of Ariane 6
- Start of the full-scale production of Ariane 6 (beyond the first rocket) thanks to an agreement with ESA guaranteeing coverage if governmental orders do not materialise in due time
- Finalisation of the Definition Review of the Prometheus engine, a future reusable and low-cost rocket engine

Major contracts

- Contract from ESA to develop, with MT Aerospace, PHOEBUS, the prototype of an upper stage made of carbon composite, a potential future amelioration of Ariane 6
- Selected by Airbus Defence & Space, prime contractor for the two new Eutelsat HOTBIRD satellites, to supply 10 Antenna reflectors

Partnerships

- Memorandum of Understanding signed with CNES to launch ArianeWorks, an acceleration platform dedicated to the preparation of future launchers
- Partnership with Shetland Space Centre: ArianeGroup will define a concept of operations and assess the range of missions for the SSC spaceport project in the frame of a three-month study

BOEING

Country

United States

Core activity

Upstream - Manufacturer

Employees

> 10 000

Corporate developments

- Change of CEO: Dennis Muilenburg resigned and was replaced by David Calhoun, who is also President of the company
- Relocation of the Space and Launch division HQ from Arlington, Virginia to Titusville, on Florida's Space Coast
- Investment of $20 million in Virgin Galactic

Major announcements and achievements

- Several successful tests of the CST-100 Starliner capsule (e.g. passing of the Environmental Qualification Testing, test of the parachutes, of the propulsion system, pad abort test considered a success) and completion of the Orbital Flight Test, which suffered timing problems and did not manage to dock to the ISS
- Completion of the core stage of the first SLS rocket
- Unveiling of a new small GEO satellite family (702X)
- Proposal for a lunar lander sent to NASA, which reduces the number of mission critical events
- New duration record for the X37-B, a reusable robotic spacecraft managed by the U.S. Air Force

Major contracts

- Opening of negotiations with NASA on a contract for up to ten Space Launch System core stages and up to eight Exploration Upper Stages to support the third through the twelfth Artemis missions (key aspects have still to be discussed)
- Was awarded a $605 million contract for the production of the Air Force's 11th Wideband Global Satellite (WGS-11) Communication Space Vehicle
- Contract from ViaSat for the manufacturing of the platform of the third ViaSat-3 satellite; the satellite will be reprogrammable and ViaSat builds itself the payloads. Boeing had already won the contracts of the first two ViaSat-3.

Partnerships

- Statement of Strategic Intent with the Australian Space Agency to support investments in R&D, innovation, STEM education and government programmes

LOCKHEED MARTIN

Country

United States

Core activity

Upstream - Manufacturer

Employees

> 10 000

Corporate developments

- Appointment of Timothy Cahill to lead Lockheed Martin International
- Appointment of former NASA Acting Administrator Robert Lightfoot as Vice President, Strategy and Business Development. Lightfoot will lead strategic planning, advanced technology concepts, and new business strategy for the corporation's Space business area
- Strategic investment of Lockheed Martin Ventures in ABL Space Systems Company, which develops the RS1 launch vehicle

Major announcements and achievements

- Progress on the Orion spacecraft (e.g. launch abort system passed) and unveiling of the first capsule
- Presentation of the Mondo Condo satellite, a small GEO satellite which can be exploited by up to five customers, by the subsidiary GEOshare
- Started to offer a new product, the global automated target recognition system. Based on AI, this system helps analysts to more easily identify objects in satellite imagery

Major contracts

- Was awarded by NASA a contract for six Orion capsules ($2.7 billion for the first three, $1.9 billion for the next three) and potentially six more later in the future
- Received a $3.3 billion contract from the U.S. Air Force for the operations, sustainment and enhancement activities of classified systems

Partnerships

- Teamed up with Blue Origin, Northrop Grumman and Draper for a lunar lander (while it had presented it own concept before). Lockheed Martin will provide the ascent module.
- Memoranda of Understanding with three Indian start-ups: Terero Mobility, Sastra Robotics and NoPo Nanotechnologies

MAXAR

Country

United States

Core activity

Upstream - Manufacturer

Employees

5000 – 10 000

Corporate developments

- Appointment of a new CEO and President: Daniel Jablonsky
- The operations of DigitalGlobe, SSL and Radiant Solutions (three subsidiaries of Maxar) were unified under the Maxar brand
- Sold MDA, its Canadian subsidiary, to a consortium of firms for $765 million
- Measures to reduce its debt (property sale, private offering of senior notes…)

Major announcements and achievements

- Announced that the WorldView Legion constellation will be made up of six satellites and will get images from a single location more than 15 times a day
- Exit from RSGS, the DARPA satellite servicing programme, but completion of the critical design review of Restore-L, an in-orbit servicing mission for NASA
- Failure of the WorldView-4 satellite, launched in November 2016
- End of the collaboration with Thales Alenia Space in the bid to manufacture the Telesat constellation; both companies are now competing on their own

Major contracts

- Won the contract ($375 million) to manufacture the Power and Propulsion Element of the Lunar Gateway
- Contract from Intelsat for a GEO communications satellite, Intelsat-40e
- Received a contract to host the NASA's TEMPO environmental hosted payload on Intelsat-40e. Maxar will provide satellite integration, launch and data transmission services.
- Multiple contracts (total value: $95 million) from the U.S. Air Force, Special Operations Command and the National Geospatial-Intelligence Agency for imagery and analytics

Partnerships

- Teaming agreement with Dynetics to collaborate on the design, building and operations of the Power and Propulsion Element. The company is also partnering with Draper and Blue Origin on the PPE.
- Signature of a Joint Statement of Strategic Intent and Cooperation with the Australian Space Agency

MITSUBISHI ELECTRIC

Country

Japan

Core activity

Upstream - Manufacturer

Employees

> 10 000

Corporate developments

- Creation of a Space and Sensing Systems division at the headquarters of the company in the United States. The new division will sell, among others, satellite on-board equipment including solar array panels, lithium-ion batteries, and Radio Frequency (RF) equipment.

Major announcements and achievements

- Selected by JAXA to build the Innovative Satellite Technology Demonstration-2, a 100 kg-satellite which will pave the way to the use of a standardised platform for future constellations
- Es'hail-2, built by Mitsubishi Electric, entered into service for customers in Middle East and North Africa

Major contracts

- Contract for a terminal Doppler lidar system by ROMATSA, the national air traffic and aviation meteorology service provider in Romania

MITSUBISHI HEAVY INDUSTRIES

Country

Japan

Core activity

Upstream – Manufacturer and Launch Provider

Employees

> 10 000

Major announcements and achievements

- Was forced to postpone a mission to the ISS because of a fire on the platform carrying a H-2B rocket. The launch took place two weeks after the planned date.
- The company prepares the first flight of the H3 launcher in 2020 and reflects on more powerful variants to support the Lunar Gateway from 2025.
- Launches in 2019: 1 H-2B rocket

NORTHROP GRUMMAN

Country

United States

Core activity

Upstream - Manufacturer

Employees

> 10 000

Corporate developments

- Establishment of a new operating structure with four operating sectors (including Space Systems).

Major announcements and achievements

- Launch of the first-ever commercial in-orbit servicing spacecraft, the Mission Extension Vehicle-1. The spacecraft will extend the life of the satellite Intelsat-901 for five years.
- Progress on the OmegA rocket, which competes for the National Security Space Launch Phase 2 Launch Service Procurement
- Successful test of a "late load" capacity on its Cygnus spacecraft: up to 20% of the cargo could be loaded only 24 hours before launch
- Completed, with NASA team, the mechanical assembly of the James Webb Space Telescope

Major contracts

- Was selected by NASA to build (and launch) the Habitation and Logistics Outpost (HALO) module of the Lunar Gateway
- Contract with Space Norway for the Arctic Satellite Broadband Mission system (two HEO satellites). Northrop Grumman will design, manufacture and integrate the spacecraft, and provide critical ground infrastructure. The satellites will be equipped with payload for Inmarsat, the Norwegian Ministry of Defence and the U.S. Air Force.
- Received its first contract for OmegA, to launch one or two Saturn Satellite Networks' NationSat satellites on the first certification flight of the rocket
- Was awarded a flight demonstration contract by Made in Space for the Archinaut mission, which aims at building large structures directly in space through additive manufacturing

Partnerships

- Teamed up with Blue Origin, Lockheed Martin and Draper for a lunar lander. Northrop Grumman will provide the transfer element.

Country

Germany

Core activity

Upstream - Manufacturer

Employees

1000 – 5000

Corporate developments

- Acquisition of Teleconsult Austria, a company specialised in the use of data from satellite-based systems

Major announcements and achievements

- Announced plans to develop small launchers (200 kg in LEO) from 2021, which would launch from European spaceports. Development of the rocket will be self-funded by OHB.
- Launch and entry in operation of EDRS-C, the second SmallGEO satellite of OHB, part of Airbus' "SpaceDataHighway". The spacecraft uses innovative laser technology to strongly reduce the time needed for Earth observation satellites to deliver information to the ground.
- Made progress on both the platform and the optical payload of the Meteosat Third Generation weather satellite

Major contracts

- Contract from ESA to design, develop and test the prototype of a 3D printer suitable for the ISS. OHB leads a consortium involving three other companies; the project is called IMPERIAL

Partnerships

- Letter of Intent with Airbus Defence & Space Netherlands
- Teaming agreement with Israel Aerospace Industries to offer to ESA the commercial delivery of payloads to the lunar surface

Together ahead. RUAG

Country

Switzerland

Core activity

Upstream - Manufacturer

Employees

1000 – 5000

Corporate developments

- Expansion of facilities for thermal insulation in Austria

Major announcements and achievements

- Unveiled a new product line: Thermal Insulation for launchers (while the company is already leader in thermal insulation for satellites). This technology will be implemented on Ariane 6
- Developed a unique satellite dispenser which was used on Canada's Radarsat launch
- Successful development and test of a separation and jettison system for payload fairings. The new system will avoid excessive shocks to the payload and is scalable, thus enabling its adoption by various categories of launchers.

Major contracts

- Contract from Firefly Aerospace to provide payload adapters (i.e. separation systems) for its small launch vehicles. This is a long-term purchase agreement which starts with an order for six launches.
- Contract from Mitsubishi Heavy Industries to develop the payload fairing and payload supporting structures for the H3 launcher

Partnerships

- Agreement between Kubos and RUAG to provide "ready-to-fly" computer systems to constellation developers; RUAG provides the satellite computing hardware

Country

Italy

Core activity

Upstream

Employees

1000 – 5000

Major announcements and achievements

- Success of a campaign of experimental flights with several remotely piloted aircraft systems (RPAS). Full Flight View (F2V), a project entirely funded by the companies of the industrial team led by Telespazio, has been conceived for public utility purposes, in particular to test new safety procedures for drone operation and to develop innovative applicative products and services aimed at territorial control for the city of Turin, with state-of-the-art utilisation and accuracy modes.
- Start of a new Launch and Early Orbit Phase control room at the Fucino Space Center. It manages, among others, these activities for COSMO-SkyMed Second Generation.

Major contracts

- Contract with ASI (as part of the Space Alliance) to develop Ital-GovSatCom, the Italian contribution to EU GOVSATCOM programme
- Contract from ESA to develop, maintain, and manage operations for the PRISM (Copernicus Contributing Missions access Support Functions and Platform) system.
- Contract with Petrobras to use COSMO-SkyMed satellite data
- E-GEOS, a company set up by Telespazio and the Italian Space Agency, signed two contracts with the Joint Research Center of the European Commission and with the European Union (EU) Satellite Center. The contracts are worth a total of €37 million.

Partnerships

- Partnership with Airbus to sell excess military satellite communications capacities on the future French Syracuse IV spacecraft. It will lead to the creation of France's leading private operator of military satellite telecommunications. The contracts provided to third parties will last 10 years.
- Memorandum of Understanding with Cloud Constellation Corporation for a joint go-to-market strategy in Europe and South America and to evaluate potential requirements and scenarios of cooperation in the domain of SpaceBelt constellation ground segment operations. For Telespazio, it enables to go beyond SATCOM and towards integrated services.

Country

France

Core activity

Upstream - Manufacturer

Employees

5000 – 10 000

Corporate developments

- Expected reduction of the headcount by about 500 people
- Inauguration of the LeoStella factory, a joint-venture between Thales Alenia Space and Spaceflight Industries which will produce the BlackSky constellation (Earth observation)
- Extension of a facility in Spain for the integration of large satellite payloads and instruments (e.g. SpainSAT NG will be integrated there)

Major announcements and achievements

- Unveiling of a new reprogrammable GEO satellite series (Inspire)
- End of the collaboration with Maxar in the bid to manufacture the Telesat constellation; both companies are now competing on their own
- Announced that it is in the concept development phase for a future in-orbit servicer, especially focused on active debris removal. To start the business, the condition is to get a government customer.
- Started to use 3D printing into serial production to make components for telecom satellites built on the company's new Spacebus Neo platform.

Major contracts

- Won the contract for Eutelsat-10B, which will be based on the Spacebus NEO platform (Ku-band HTS payloads, plus C- and Ku-band widebeam capacity)
- Part of the winning team for the contract of the two SpainSAT NG for Hisdesat. Thales Alenia Space will build the UHF and military Ka-band payloads.
- Contract from NileSat to build a new GEO satellite, NileSat-301
- Contract with ESA (€78 million), on behalf of the European Commission, to upgrade Europe's EGNOS satellite navigation system.
- Contract with ASI (as part of the Space Alliance) to develop Ital-GovSatCom, the Italian contribution to EU GOVSATCOM programme

Partnerships

- Statement of strategic intent and cooperation with the Australian Space Agency to mutually identify key areas of investment, as well as potential research, development, and commercial opportunities
- Memorandum of Understanding with the Hellenic Space Agency for space cooperation, especially on Earth observation

2.4.3 Satellite operators

AsiaSat

Country

Hong Kong

Core activity

Downstream - Satellite Operations

Employees

50 – 200

Corporate developments

- The two main shareholders (CITIC Group and The Carlyle Group) decided to delist AsiaSat from the Hong Kong Stock Exchange. AsiaSat thus became private.

Major contracts

- Selected by WarnerMedia as strategic partner for HD channels distribution in Asia Pacific

EchoStar

Country

United States

Core activity

Downstream - Satellite Operations

Employees

1000 – 5000

Corporate developments

- Sold (through a spin-off and its subsequent merger) its broadcast satellite services business (nine satellites and the employees) to Dish Networks for $800 million, reshaping EchoStar as a company whose primary focus is on internet connectivity.
- Acquisition of Helios Wire, a start-up that wanted to launch a constellation for Internet of Things purposes. EchoStar obtained the S-band spectrum rights that the company had requested to the International Telecommunications Union.

Major announcements and achievements

- EchoStar contributed to arrange a $199 million loan for the operator Globalstar
- Ordered two S-band smallsats from Tyvak to secure the spectrum rights it got by acquiring Helios Wire and start a constellation for Internet of Things purposes
- Hughes Network Systems (a subsidiary of EchoStar) partnered with Facebook to provide wifi hotspot service in Colombia
- Creation of a second joint venture between Hughes Network Systems and Yahsat, focused on broadband in Brazil
- Hughes Network Systems secured a license to provide in-flight connectivity in India

Major contracts

- Xplornet, a Canadian service provider, signed a contract worth more than $250 million spread out over 15 years to use capacity on Hughes Network Systems' upcoming Jupiter-3 satellite and for terminals and services
- Hughes Network Systems has been awarded an $11.8 million R&D contract by the U.S. Army, to enhance network management, automated control, and system interoperability among SATCOM systems for military communications

Partnerships

- Agreement with RigNet to promote and distribute EchoStar Mobile Internet Protocol-based Mobile Satellite Services (MSS) for voice and data to RigNet's European customer base

eutelsat

Country

France

Core activity

Downstream - Satellite Operations

Employees

500 – 1000

Corporate developments

- Announcement of the LEAP-2 plan: 100 employees will be laid off, the wages will be frozen, and hiring stopped. The objective is to save €20-25 million by 2025.

Major announcements and achievements

- Launch of a new connectivity service dedicated to IoT devices (Eutelsat IoT First service), which uses its GEO fleet and Ku-band. The hardware for the service would cost around $200 and data subscriptions a few euros per month. The company also announced that it was planning to launch a LEO constellation (called ELO) which is meant to be complementary to this service.
- Eutelsat 5 West B, a satellite launched in October 2019, suffered a solar array issue
- Eutelsat left the C-band Alliance, a consortium of companies (SES, Telesat, Intelsat and, previously, Eutelsat) defending their interests in the process to allocate C-band frequencies in the United States
- Postponed from end 2019 to the second half of 2020 the launch of Eutelsat Quantum, a software-defined, reprogrammable satellite which is able to change the size, shape and power of its beams

Major contracts

- Ordered Eutelsat-10B to Thales Alenia Space. More than one third of the satellite's capacity is already leased. For instance, Gogo, an in-flight wifi provider, and Panasonic Avionics, are already customers.
- Selected by NASA to participate in its Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) within NASA's Space Relay Partnership and Services Study, which aims at improving NASA's space-based communications architecture, especially for future exploration missions
- Obtained its first customer for Eutelsat Cirrus (Mondo Globo) as well as the first contract for this product with an African operator (Orao Telecom Congo)

Partnerships

- Sigfox signed a strategic partnership with Eutelsat to use the future ELO constellation in order to provide Internet of Things services

Globalstar

Country

United States

Core activity

Downstream - Satellite Operations

Employees

50 – 200

Corporate developments

- Borrowed $199 million through a loan arranged by Thermo (its controlling shareholder) and Echostar

Major announcements and achievements

- Developed with Echo Ridge a stand-alone Positioning, Navigation, and Timing (PNT) capability to backup and/or complement GPS in case of GPS unavailability or unreliability. The system is based on new Augmented Positioning System (APS) technology that uses ordinary signals from communications satellites to produce accurate position and timing information in compatible user devices. The companies have also signed an agreement to collaborate, share data, and jointly pursue market opportunities related to this technology. They will undertake an assessment of the commercial and government market requirements and use cases.
- Bought a license ($700 000) from one of its suppliers for a solar-powered asset tracking device. With this license, Globalstar gets intellectual property, production equipment and other assets.
- Received Mobile Satellite Services (MSS) and terrestrial authorisations for S-band spectrum in South Africa, Mozambique, Gabon, and Rwanda

Partnerships

- Partnership with Nokia to provide communications solutions in Africa hispasat

Country

Spain

Core activity

Downstream - Satellite Operations

Employees

50 – 200

Corporate developments

- Change of shareholding: the company Red Eléctrica Corporación purchased 89.68% of Hispasat for €949 million (by buying the shares of Abertis)

Major announcements and achievements

- Decided to stop funding LeoSat, a start-up aiming at establishing a constellation of several dozens of satellites in LEO for telecommunications purposes

Major contracts

- Satlink chose Hispasat to provide high-capacity connectivity to ships

Partnerships

- Strategic partnership with Ovzon to provide a high-capacity portable broadband solution. There will be technical collaboration as well as joint go-to-market initiatives in Europe and Latin America. The combined offer includes the terminal and connectivity in a single service with a monthly fee.
- Partnership with Facebook to offer satellite-based wifi hotspots in Brazil in order to reach underserved areas. In Colombia, Hispasat has already installed terminals with Bansat.
- Hispasat and Mexican telecommunications company Wibo will offer broadband satellite and Internet Protocol phone services for the next three years to extend connectivity in Mexico. The satellite used will be Amazonas 5
- Agreement with GetSat to offer Satellite on the Move services (useful, e.g., for emergency and security services) in Latin America, Europe and North Africa
- Agreement with the Hispatec Group to promote the use of new technologies in the agricultural sector in Europe, the Americas, and North Africa

inmarsat

Country

United Kingdom

Core activity

Downstream - Satellite Operations

Employees

1000 – 5000

Corporate developments

- Inmarsat delisted from the stock exchange and became private. It was sold for $3.3 billion to a consortium, Connect Bidco, made of UK-based Apax Partners, U.S.-based Warburg Pincus and two Canadian pension funds.

Major announcements and achievements

- Ordered three reconfigurable satellites to Airbus (Inmarsat.7), based on the OneSat platform, allowing it to adapt to the evolution of demand
- Launch of Inmarsat GX-5 satellite, which has more capacity than the first four Global Xpress satellites already in orbit combined
- Announced that it will put payloads on two satellites bought by Space Norway, in order to extend its Ka-band connectivity service in high latitude regions
- Got the authorization to provide Ka- and L-band services to aviation and maritime customers in India (through its local partner BSNL)
- Launch of a new service for crew, Crew Xpress, which includes a managed Wi-Fi solution 'Fleet Hotspot', a leased antenna, a business use data package, automated billing and a usage revenue recovery scheme to incentivise ship managers to invest in crew connectivity

Major contracts

- Inmarsat was awarded a competitive single-award blanket purchase agreement by the U.S. Department of Defence, for an amount of $246 million
- Contract with ESA to trigger the Phase 2 of the Iris air traffic modernisation programme. During the Phase 2, flight trials will be conducted to assess Iris in a real operational environment.

Partnerships

- Partnership with Microsoft on the Azure cloud network, especially for the transfer of data related to Industrial Internet of Things activity
- Long-term agreement with Orbit Communications System to offer end-users a new modular, multi-role aviation terminal, optimized for use over Inmarsat's Global Xpress (GX) network.

INTELSAT

Country

United States

Core activity

Downstream - Satellite Operations

Employees

1000 – 5000

Corporate developments

- Appointment of David Tolley as Executive Vice president and CFO
- Appointment of two new members to the Board of Directors: General (ret.) Ellen M. Pawlikowski and Jacqueline D. Reses
- Joined GSMA, the organisation representing mobile operators worldwide, to further strengthen the integration of satellite and terrestrial technologies and advance 5G deployment

Major announcements and achievements

- Presentation of a new product: Mobile Reach Manage, which enables Mobile Network Operators (MNOs) to quickly and cost effectively deploy their network infrastructure into areas once considered unreachable. With this product, MNOs do not need to invest in space or ground infrastructure.
- Presentation of a new service: FlexGround, which enables ground troops at tactical level to remain connected. The service's high data rates and open architecture allow ground forces to use a wide array of ultra-portable antennas.
- Unexpected loss of the Intelsat-29e satellite because of a fuel leak. The spacecraft was uninsured for problems happening in orbit.
- Sued OneWeb and SoftBank for breach of contract, fraud and conspiracy to steal information

Major contracts

- Selected by Lintasarta to support the deployment and expansion of Indonesia's broadband and wireless communications infrastructure. The agreement will last five years.

Partnerships

- Loaned $50 million to, and established a commercial partnership with, BlackSky to jointly develop data and imagery products
- Partnership with Microsoft to connect remote customers to the Azure cloud network
- Renewal and expansion of the partnership with Marlink to deliver additional throughput to ships
- Agreement with Stratosat Datacom (based in South Africa) to deliver high-speed broadband services to sites across Central Africa

iridium

Country

United States

Core activity

Downstream - Satellite Operations

Employees

500 – 1000

Corporate developments

- Closing of a $1.45 billion, seven-year term loan with BPI France which was used to finance Iridium-NEXT, the new constellation of the company
- Appointment of Suzi McBride as Chief Operations Officer

Major announcements and achievements

- Completion and start of the operations of the Iridium-NEXT constellation, a $3 billion investment for the company. The constellation is made up of 66 operational satellites, nine spares in orbit and six spares on the ground.
- Launch of a new product for commercial customers: the Iridium broadband service. Iridium Certus is a platform designed for the development of specialty global broadband service applications, offering on-the-move internet and voice access.
- Commercial service activation of a new southern hemisphere ground station, located in Punta Arenas, Chile. This is the first southern hemisphere site of Iridium, allowing network redundancy for the constellation.

Major contracts

- Seven-year agreement with the U.S. government for unlimited use of Iridium's constellation. The contract is worth $738.5 million and will ensure continuity for voice, data, broadcast and other services to the Department of Defense and associated users.

Partnerships

- Announcement of collaboration with OneWeb to provide a combined global satellite services offering. The L-band of Iridium will combine with the Ku-band of OneWeb. An early focus area will probably be the maritime market. This is the first cross-bandwidth service collaboration between two LEO constellation operators.

Country

Malaysia

Core activity

Downstream - Satellite Operations

Employees

50 – 200

Major announcements and achievements

- The company announced its wish to provide high-throughput services and to support a government programme in Malaysia focused on connecting the country's offline citizens; the operator wants to complement terrestrial components of the plan
- Broadcasts now Himalaya TV High Definition over Nepal and Asia-Pacific

Major contracts

- Measat selected Airbus Defence & Space to build MEASAT-3d, which will replace two satellites, MEASAT-3 and -3a. It will carry different types of payload (C-, Ku-, Ka- and L-band). One hosted payload, built by MDA, will support the Korea Augmentation Satellite System. The satellite will be launched by Arianespace. In addition, the company signed a customer to use the entire Ku-band payload on MEASAT-3d for the satellite's lifetime.
- Renewal of a contract with the BBC to use the Neasat-3 satellite

Country

United Kingdom

Core activity

Downstream - Satellite Operations

Employees

200 – 500

Corporate developments

- Opening of the OneWeb Satellites (joint venture between OneWeb and Airbus) production facility in Florida, which will manufacture the satellites of OneWeb's constellation
- OneWeb Satellites joined the Satellite Industry Association
- OneWeb announced that it will create 150 jobs by expanding its Global Operations Centre in London

Major announcements and achievements

- Launch and successful operation of its first six satellites, which allowed the company to confirm its spectrum rights in Ku-band
- OneWeb and OneWeb Satellites committed to implement an advanced-technology grappling fixture, developed by Altius Space Machines, on OneWeb's satellites in order to facilitate their safe and reliable capture to prevent the creation of space debris
- Sought the approval of the Federal Communications Commission for up to 1.5 million ground terminals that customers would use to receive and transmit satellite data
- Postponed the start of its satellites' monthly launches to 2020
- OneWeb was sued by Intelsat for breach of contract, fraud and conspiracy to steal sensitive information. It was also sued by Virgin Orbit for having cancelled all but four of 39 launches it had purchased without paying a termination fee.

Major contracts

- Announced its first customer contracts with Talia for regions in Africa and Middle East and with Intermatica for businesses in Europe
- Awarded a contract to Astroscale for an active debris removal mission under ESA-OneWeb Sunrise Project. In the frame of this Project, the UK Space Agency, through ESA, provided $23.3 million to OneWeb.

Partnerships

- Announcement of collaboration with Iridium to provide a combined global satellite services offering. The L-band of Iridium will combine with the Ku-band of OneWeb. This is the first cross-bandwidth service collaboration between two LEO constellation operators.

Country

United States

Core activity

Downstream - Satellite Operations/Product

Employees

200 – 500

Major announcements and achievements

- Announcement that Planet will provide a better resolution for its SkySat constellation (from 72 to 50 cm) and update its Dove constellation to gather imagery in eight spectral bands
- Launch of "Planet Analytics Feeds", an AI-based platform aiming at making possible the automatic analysis of satellite imagery
- ESA announced that Planet is a "Third Party Mission under evaluation"
- Creation of the California Forest Observatory with Salo Sciences and Vibrant Planet to provide an updated view of wildfire risk

Major contracts

- Planet Federal, a subsidiary, got a contract from the U.S. National Reconnaissance Office to obtain an unclassified, multiyear subscription for daily, large-area, three- to five-meter resolution commercial imagery
- Extension of the contract with the U.S. National Geospatial-Intelligence Agency
- Was awarded a $6.7 million contract by NASA for climate research, in order to assess the usefulness of Planet data to researchers

Country

Russia

Core activity

Downstream - Satellite Operations

Employees

500 – 1000

Major announcements and achievements

- Joined the pilot project of Maritime Unmanned Navigation (MUNIN). In this project, the company intends to provide communications services on mobile platforms using the maritime Very Small Aperture Terminal (VSAT) technology.
- Completed the installation and commissioning of five central stations

Partnerships

- Signature of an Agreement of Intention with Thaicom to collaborate on the joint development of a service offering for maritime satellite broadband connectivity
- Cooperation agreement with the Belarusian manufacturing enterprise "Precise Electromechanics Factory" ("Belintersat" satellite operator). The cooperation agreement provides for exchanges of requisite technical information and consultations of experts on the joint use of the existing RSCC satellite constellation capacity. Also discussed were new satellites, created as part of the program to expand the Russian orbital constellation of communications and broadcasting spacecraft.
- Cooperation agreement with Azercosmos to jointly create and provide satellite communications and broadcasting networks and services in the Caspian Region, but the partnership also aims at Europe, the Middle East and Africa

SES your satellite company

Country

Luxembourg

Core activity

Downstream - Satellite Operations

Employees

1000 – 5000

Corporate developments

- Appointment of Ruy Pinto as Chief Technology Officer and of John Baughn at the new position of Chief Services Officer

Major announcements and achievements

- Demonstrated interoperability between its MEO and GEO satellites by switching between them to provide connectivity to a flight between Florida and Nicaragua
- Completion of the first generation of the O3b constellation. These satellites are located in MEO, at approximately 8000 km of the Earth
- The critical design review of the O3b mPower satellites, the next generation of the O3b system, was successfully completed

Major contracts

- Received a managed connectivity services contract from the European Maritime Safety Agency, especially to provide connectivity to the RPAS services provided by EMSA to EU Member States and agencies.
- Agreement between SES and the Luxembourg Government to renew for 20 years the concession allowing SES to operate satellites flying under Luxembourg jurisdiction. The agreement starts in January 2022, and SES will give €1 million per year from 2025. Moreover, it will give up to €7 million per year from 2022 into a fund to support and strengthen the Luxembourg space sector.
- Agreement with Teleglobal to bring broadband access and mobile connectivity services to rural communities in Indonesia, in the frame of the universal service obligation project of the Indonesian government. Teleglobal will contract capacity on SES-12.

Partnerships

- Partnership with Microsoft on the Azure cloud network to offer more data more quickly to its customers. SES will provide global reach and fiber-like high-performance to Azure customers via its complete portfolio of satellites.

SKYPerfect JSAT Corporation

Country

Japan

Core activity

Downstream - Satellite Operations

Employees

500 – 1000

Corporate developments

- Appointment of a new CEO: Eiichi Yonekura

Major announcements and achievements

- Decided to stop funding LeoSat, a start-up aiming at establishing a constellation of several dozens of satellites in LEO for telecommunications purposes
- JAXA agreed to transfer SDS-4 to JSAT; this is a 50-kilogram demonstration satellite carrying an automatic identification system payload for ship tracking. It will be the first LEO satellite of the operator.
- Launch of its second high-throughput satellite, JCSAT-18, whose platform is shared (but not the payload) with the start-up Kacific

Major contracts

- Won a contract from LEO remote sensing company Axelspace to link the start-up's satellites with its ground stations. This is the first win with Norwegian partner KSAT following a strategic alliance between the companies in 2016.

Partnerships

- Cooperation agreement with Airbus for the design preparation of the European Data Relay Satellite (EDRS)-D node. It will be positioned over Asia-Pacific in 2025. JSAT will co-finance the design and development studies of the payload and system, and will commercialise the SpaceDataHighway service in Japan.
- Business partnership agreement with Pasco Corp. to add two Japanese ground stations to the Earth Observation business of JSAT and to offer services to LEO Earth observation and SATCOM companies. Two other domains are involved in the partnership: space data utilisation and market expansion.
- Partnership with Elefante Group to study how stratospheric airships can provide high-capacity links without the signal lag inherent with geostationary satellite broadband

spire

Country

United States

Core activity

Downstream - Satellite Operations/Product

Employees

50 – 200

Corporate developments

- Opening of an office in Washington D.C.
- Hiring of Paul Damphousse to lead the national security business development
- Launch of Spire Maritime as a separate business unit

Major announcements and achievements

- Launched its 100th Lemur satellite
- Unveiling of two new products: Spire Forecast and an AirSafe application programming interface
- Launch of two satellites with an innovative GPS reflection technology, enabling to use GPS signals to improve knowledge of Earth's surface conditions
- Launch, in partnership with ESA, of two tiny supercomputer nanosatellites, which will receive and process data directly in orbit and will then be able to choose high-quality data and to transfer them to Earth, therefore reducing the amount of time required to download them
- ESA announced that Spire is a "Third Party Mission under evaluation"
- Spire Global Luxembourg will launch its open source Data Lake. It will provide, free of charge, AIS, ADS-B, radio occultation and Total Electron Content data, to all start-ups, research institutes, and public agencies in Luxembourg. The data will be used for research and non-commercial product development activities.

Major contracts

- Signed a deal with KeyW Holding Corp., a defence contractor, to host intelligence, surveillance and reconnaissance payloads on Spire's constellation

Partnerships

- Collaboration agreement with Kleos Space, creating the Safety at Sea Collaboration. The companies will develop maritime safety tools focused on detecting "dark vessels". There will be a combination of Spire's automatic identification system (ship-tracking data) with radio-frequency reconnaissance data from Kleos Space. Another partnership was set with Iceye for the same objective of tracking dark vessels.
- Partnership with Concirrus, an insurance analytics company, to share data and develop new products, especially in the realm of maritime insurance

telenor

Country

Norway

Core activity

Downstream - Satellite Operations

Employees

> 10 000

Corporate developments

- Telenor bought 94.36% of the shares of DNA, a Finnish telecommunications company
- Appointment of Lars Erik Lunøe as CEO of Telenor Maritime

Major announcements and achievements

- Creation, with Nordic Entertainment Group, of a new company which combines satellite-pay TV and broadband-TV. This will create a Nordic TV distribution business in the Direct-to-Home (DTH) segment.
- Opening of Scandinavia's largest 5G pilot in the Norwegian municipality of Elverum and of the northernmost 5G pilot in Svalbard.

Country

Canada

Core activity

Downstream - Satellite Operations

Employees

200 – 500

Major announcements and achievements

- The Telesat LEO Phase 1 satellite carried out the world's first 5G connection over a LEO satellite. Tests included video chatting, web browsing, and video streaming in 4K and 8K ultra-HD. Other tests took place on the Phase 1 during the year.
- Telesat said Loon (a subsidiary of Alphabet) has agreed to deliver a network operating system design that Telesat can use to support its LEO constellation. Under the agreement, Loon will adapt its software-defined (SDN) platform design to enable Telesat's LEO constellation to help consistently deliver a fiber-like broadband experience on a global basis to both fixed and mobile terminals. Loon's SDN platform will be specifically customised for Telesat's use.
- Delayed the selection of the manufacturer of its LEO constellation to Q1 2020 (the constellation should be operational in 2022) but all contenders have made progress on the design of the system.

Major contracts

- Signature of a trial partner as first customer of its LEO constellation: OmniAccess, a maritime connectivity provider signed a "major, multiyear contract" for broadband service. OmniAccess got certain limited exclusivity to serve the superyacht market.
- Signed a contract with Blue Origin to launch several of its future LEO satellites on the New Glenn (undisclosed number of launches and satellites)
- Announcement that Telesat will be one of the first customers of Relativity Space (Terran 1 launcher)

Partnerships

- Memorandum of Understanding between the Canadian government and Telesat as part of an effort to provide better broadband internet access to rural and remote communities. The partnership is expected to generate CA$1.2 billion for Telesat over 10 years (it includes CA$600 million from the government). Additionally, the Government of Canada will contribute CA$85 million to Telesat through the Government's Strategic Innovation Fund (SIF). Telesat, as part of the agreement, will support approximately 500 jobs in Canada, and invest CA$215 million in R&D over the next five years.

Country

United States

Core activity

Downstream - Satellite Operations

Employees

5000 – 10 000

Corporate developments

- Opening of two sovereign Maintenance, Test, and Integration Facilities in Australia in order to support defence actors
- Opening of two offices in Brazil

Major announcements and achievements

- Postponement of the launch of the first ViaSat-3 to 2021 (instead of June 2019) because of issues with a component supplier.
- Started to work on the early development of ViaSat-4 series
- Upgraded the NATO's Ultra High Frequency (UHF) satellite communications (SATCOM) control stations to comply with the new Integrated Waveform (IW) baseline

Major contracts

- Was awarded a $10 million contract by the Air Force Research Laboratory Space Vehicles directorate to test whether a Link 16 terminal on a small satellite could serve as a communications network relay. Viasat selected Blue Canyon Technologies (BCT) to design and manufacture a Cubesat for this test in low Earth orbit. It will be equipped with ViaSat's Link 16 terminal.
- Contract with Telebras to commercialise broadband services on Telebras' SGDC (Geostationary Satellite for Defense and Strategic Communications) Ka-band satellite in order to provide internet service across all of Brazil

Partnerships

- Partnership with Microsoft to connect remote customers to the Azure cloud network
- Strategic partnership with China Satcom to provide in-flight connectivity services to aircraft in China
- Collaboration with Facebook to establish wifi hotspots in Mexico

3 Economy & Business

3.1 Global space economy

3.1.1 Overview and main indicators

The value of the global space economy is estimated every year by The Space Foundation, an American non-profit organisation advocating for the sector, and by the Satellite Industry Association (SIA), the trade association of the American satellite industry.

According to these two sources, the global space economy was worth between $360 billion (SIA/Bryce)[411] and $414.8 billion (Space Foundation)[412] in 2018.

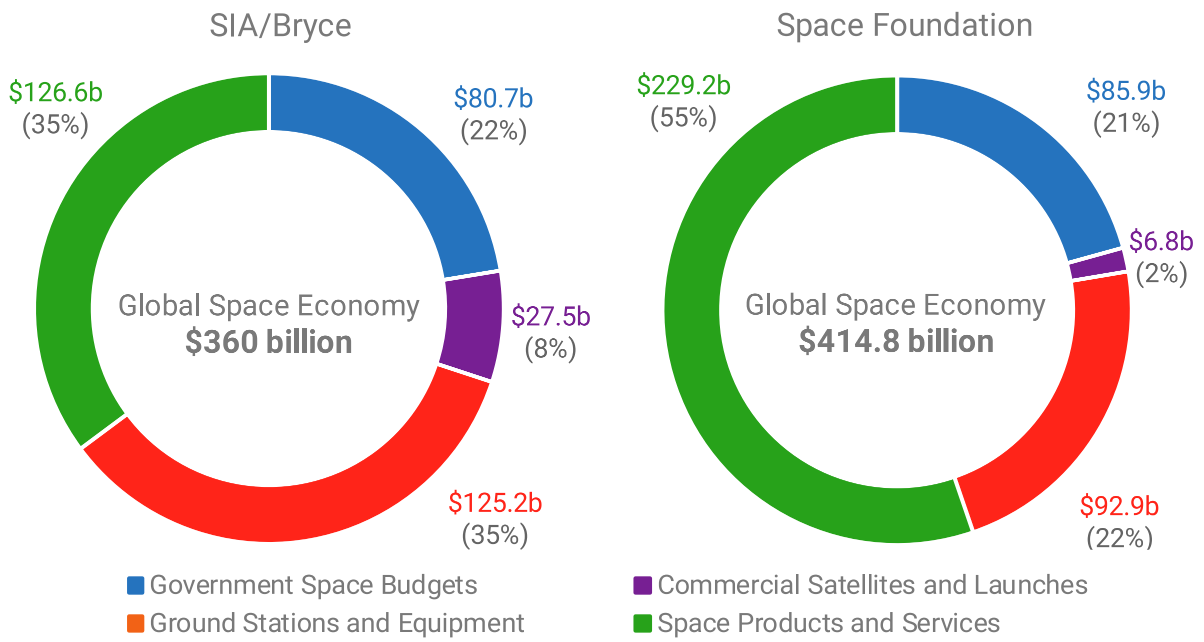


Figure 14: Global space economy estimations by SIA/Bryce (left) and Space Foundation (right)

These two estimations can be broken down into four major segments:

- Government space budgets, correspond to the economic activity directly related to government spending. It covers in particular public space programmes and other activities of governmental space organisations (i.e. space agencies, development agencies, military organisations and bodies, etc.).
- Commercial satellites and launches, correspond to the economic activity of satellite manufacturers and launch service providers outside public markets (i.e. commercial space). It covers in particular the provision of private satellites and commercial launch services to private operators.
- Ground stations and equipment, correspond to the economic activity related to the ground segment of space infrastructures including in particular stations, teleports, networks and user equipment.
- Space products and services, correspond to the economic activity of companies selling space-enabled products and services such as Direct-to-Home services or satellite imagery products. This part of the space economy is usually referred to as downstream and is the most complex to delineate.

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[411] Satellite Industry Association, *2019 State of the Satellite Industry Report* (prepared by Bryce Space and Technology). Summary available at: https://sia.org/news-resources/state-of-the-satellite-industry-report/

[412] Space Foundation, *The Space Report 2019* (Q2 and Q3).

The following table provides a more detailed overview of global space economy estimations by SIA/Bryce and the Space Foundation, for each segment:

Global Space Economy	SIA/Bryce		Space Foundation	
	$360 billion		$414.8 billion	
Government Space Budgets	$80.7b	U.S. budget: $50.1b Non-U.S. budget: $30.6b	$85.9B	U.S. budget: $48.3b Non-U.S. budget: $37.6b
Commercial Satellites and Launches	$27.5b	Satellites: $19.5b Launches: $6.2b Human Spaceflight: $1.8b	$6.8B	Satellites: $5.3b Launches: $1.5b Human Spaceflight: $0
Ground Stations and Equipment	$125.2b	GNSS:[1] $93.3b Others:[2] $31.9b	$92.5B	GNSS:[1] $62.4b Others:[2] $30.1b
Space Products and Services	$126.5b	Television: $94.2b Communications:[3] $24.4b Remote Sensing: $2.1b Satellite Radio: $5.8b PNT:[4] $0 (not included)	$229.2B	Television: $96.3b Communications:[3] $25b Remote Sensing: $5.8b Satellite Radio: $5.8b PNT:[4] $98.7b
Others	-	-	$0.5B	Insurance premiums

1 Includes GNSS chipsets and navigation devices
2 includes network stations and user equipment such as satellite TV dishes or satellite mobile phones
3 includes Fixed Satellite Services (FSS), Mobile Satellite Services (MSS) and Broadband services
4 Positioning, Navigation and Timing services, enabled by GNSS and augmentation systems

Table 13: Detailed comparison of space economy estimations by SIA/Bryce and The Space Foundation

Although both organisations attempt to provide an estimation of the global space economy based on government space budgets and space-related company revenues, there are significant discrepancies between the two assessments originating from different methodological approaches.

Estimations of government space budgets by SIA and the Space Foundation are relatively similar, with a variation of $5.2 billion, originating mainly from a different estimation of non-U.S. space budgets. While the Space Foundation estimates a slightly lower U.S. budget than SIA, the Space Foundation also provides a much higher estimation of non-U.S. budgets.

More substantial differences start occurring with the estimation of the value of commercial satellites and launches. Adopting different methodological approaches, the Space Foundation estimates the value of this segment about four times lower than SIA. While both estimations seem to rely on a valuation of commercial satellites launched during the year to provide a proxy for industry revenues, this valuation differs significantly. The same seems to occur for commercial launches. Furthermore, the Space Foundation inputs zero revenues for human spaceflights whereas SIA estimates this part of the space economy to be worth almost $2 billion.

As for the ground stations and equipment segment, SIA estimates the value of GNSS chipsets and navigation devices almost $30 billion higher than the Space Foundation. The estimations of other ground stations and equipment revenues converge between $30.1 to $31.9 billion.

Finally, the main difference takes root in the calculation of the value of space products and services. Here, the two assessments have a fundamental difference in scope. While SIA and the Space Foundation converge on their valuation of satellite television, communications and radio services, their assessment of remote sensing revenues diverge substantially. It is, however, the inclusion of value-added PNT services by the Space Foundation that leads to a lopsided estimation of the total value of this downstream segment. As a result, the Space Foundation considers $98.7 billion additional revenues part of the space economy perimeter. It is unclear whether a share of these revenues is actually accounted for by SIA in the ground stations and equipment segment, which could explain the additional $30.9 billion of SIA's estimation. Terminology used seems to indicate that it is not the case.

Both SIA and the Space Foundation reported a significant growth of the global space economy in 2018 with a 3.4% and 8.1% growth with comparison to 2017 respectively.

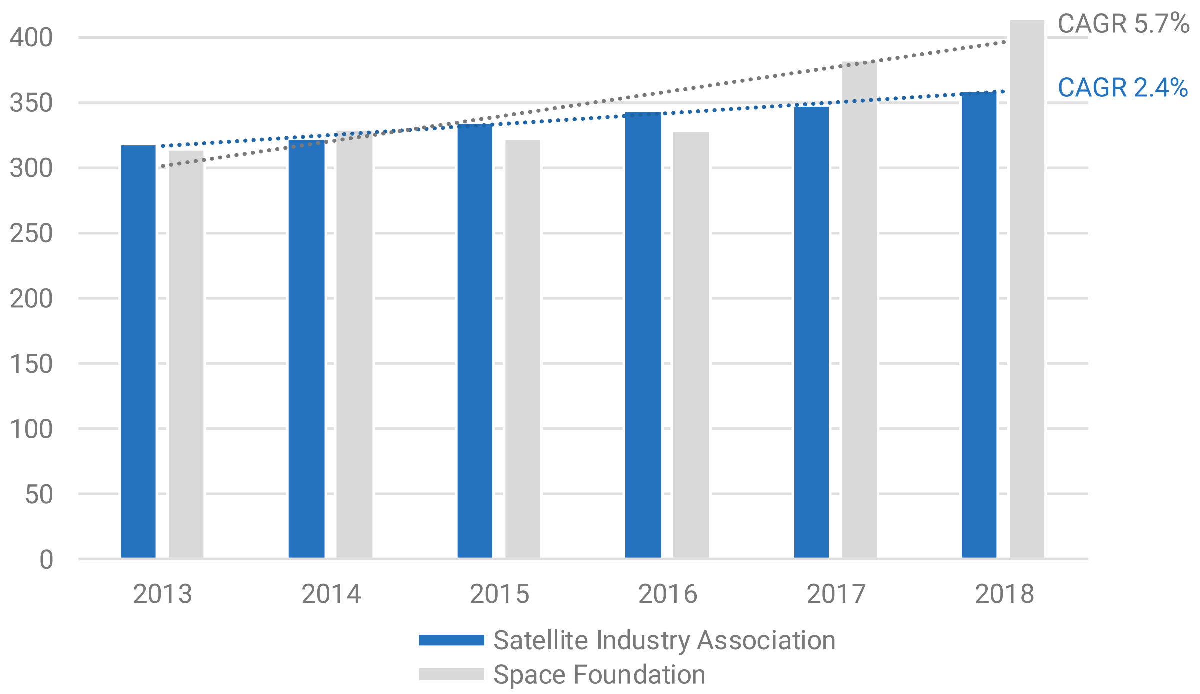

Figure 15: Global space economy evolution (Source: SIA, Space Foundation, ESPI)

While the Space Foundation and SIA estimated the global space economy between $314.7 and $319 billion in 2013, a very close figure (1.3% difference), their estimations deviated over time, in particular in 2017 and 2018. As a result, the global space economy Compound Annual Growth Rate (CAGR) of the Space Foundation over the period 2013-2018 is 5.7% while SIA considers a much less steep growth, with a CAGR around 2.4%. A number of factors may explain this situation, including changes in methodologies or in scope as well as different approaches to the way macro-economic variations are considered (e.g. inflation, currency exchange rates). The valuation of the space products and services segment by the Space Foundation however stands out as the principal factor explaining this discrepancy. The valuation of this segment by the Space Foundation increased from $126 billion in 2015 to $229 billion in 2018 as a result of the inclusion of value-adding PNT services to the perimeter of analysis. As a result, the value of this segment almost doubled in the span of three years.

Rising reservations about available space economy indicators

Efforts to estimate the size of the global space economy are rather limited. Today, only a few organizations provide regular economic assessments: SIA and the Space Foundation on an annual basis and the OECD every other year.

With the rising importance of sound economic indicators for decision-making, available estimates have recently become the target of criticism by various stakeholders and experts.

In a recent article*, SpaceNews reported the intention of the Bureau of Economic Analysis, an agency of the U.S. Department of Commerce, to develop its own estimate of the size of the space industry on the basis of the consolidation of various available economic accounts in a Space Economy Satellite Account to measure the size of the space industry in the United States.**

This decision seems to follow criticism by some experts of the conclusiveness of available space economy indicators. The article reports, for example, that an analyst from the Science and Technology Policy Institute (STPI) argued that studies done so far are likely to be overestimating the size of the industry. This overestimating may come from double-counting as well as including revenues not actually related to the space economy.

Current economic indicators have led some firms such as Morgan Stanley to forecast that the global space economy could be worth a trillion dollars by 2040. The growth rate that such economic development suggests, in the order of 11% per year, also seem very confident, in particular as they depend on the successful development of markets that have yet to materialize such as space tourism, suborbital point-to-point travel or even satellite internet providers.

It would be an understatement to say that providing a robust and comprehensive valuation of the economic activity related to space exploration and utilisation is a complex exercise. It requires extensive access to information and data (sometimes proprietary), a sound methodology to consolidate economic accounts and avoid double-counting, clear definitions to delineate industry and market perimeters (in particular in the downstream part of the value chain), among other things. This task becomes even more complex when performing it annually. Ensuring consistency along the years requires to consider macro-economic phenomenon such as inflation and exchange rate fluctuations to provide estimations in constant currency.

The provision of a more robust estimation of the size of the U.S. space industry will not solve the issue of the assessment of the global space economy but will certainly contribute to improving stakeholders' appreciation of economic dynamics in the space sector.

This raises the question of European efforts in this domain. Today European stakeholders and decision-makers rely extensively on U.S.-based economic assessments and no European institution has taken up the issue yet. With the rising need to rely on solid economic information for space policy developments in a number of domains such as stimulation of private investment, support to business development and competitiveness or maximisation of socio-economic benefits of public space programmes, supporting the elaboration of European-based indicators, both to estimate the size of the European space industry and global space economy, should become a priority.

*Jeff Foust, "Commerce Department to develop new estimate of the size of the space economy". SpaceNews (January 2020): https://spacenews.com/commerce-department-to-develop-new-estimate-of-the-size-of-the-space-economy/
**Tina Highfill, Patrick Georgi and Dominique Dubria, "Measuring the Value of the U.S. Space Economy". *Survey of Current Business*, vol. 99, n°12 (December 2019): https://apps.bea.gov/scb/2019/12-december/1219-commercial-space.htm

3.1.2 Commercial satellites and launches

According to SIA, the global commercial satellite and launch industry recorded its best year in 2018 with a total economic activity worth $27.5 billion while the Space Foundation estimated the same activity in the order of $6.7 billion. Although the two organisations seem to follow a comparable methodological approach, major discrepancies in the perimeter of analysis and in determining what is commercial, and what is not, are leading to very different estimations.

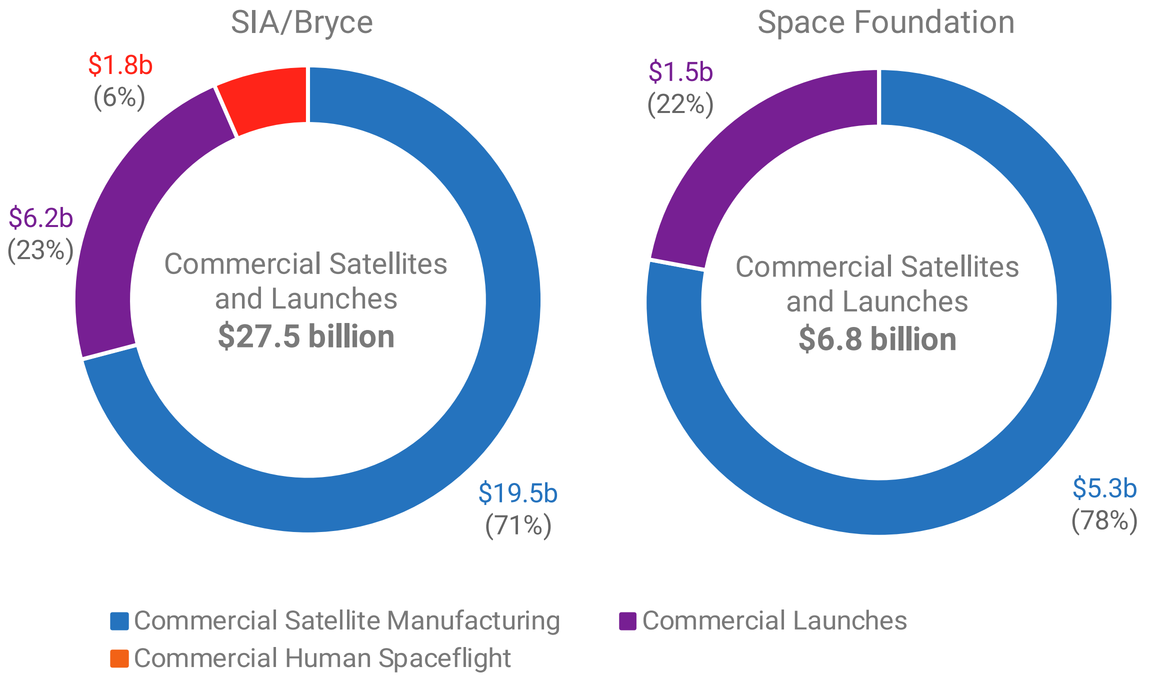

Figure 16: Commercial satellite and launch industry revenues (Source: SIA, Space Foundation)

In 2018, the Space Foundation estimated that the commercial satellite manufacturing economy was worth $5.3 billion and the commercial launch sector $1.5 billion. With a drastically different perspective, SIA estimated that the commercial manufacturing was worth $19.5 billion and the commercial launch sector $6.2 billion in 2018. Furthermore, SIA integrated revenues related to commercial human spaceflight which corresponds to an additional value of $1.6 billion in 2018.

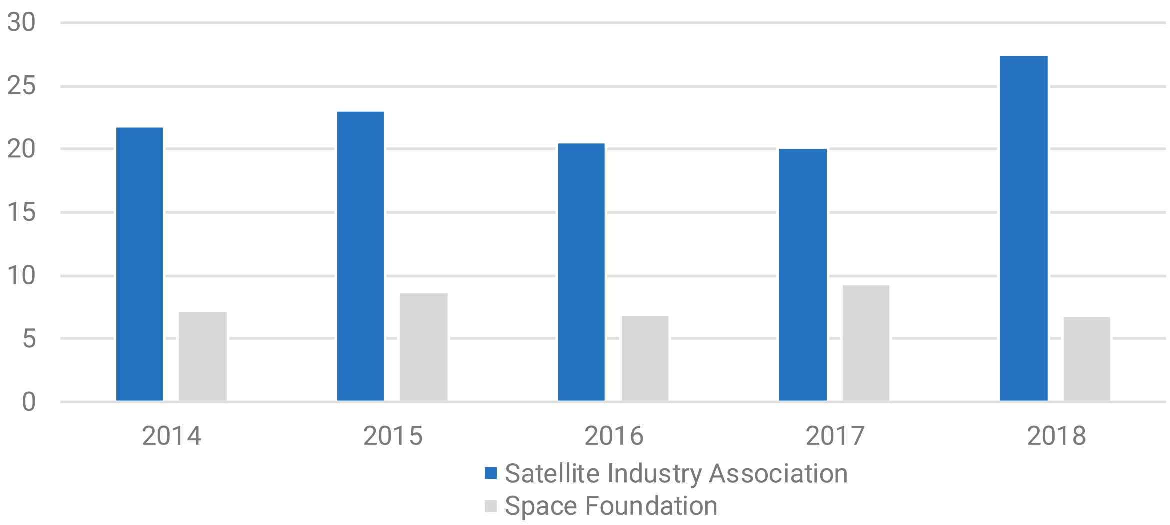

Figure 17: Commercial satellite and launch industry revenue evolution (Source: SIA, Space Foundation)

Commercial launches

To estimate the global economic activity related to commercial launches, both SIA and the Space Foundation rely on a valuation of the share of all launches operated during the year that they qualify as "commercial launches".

In 2018, ESPI recorded a total of 114 attempted launches, including 112 successful launches and two failures. The Space Foundation and SIA recorded the same number of launches but with different definitions of "commercial launches", leading to very different estimations:

- The Space Foundation considers that 24 out of 114 launches were "commercial" with an estimation of the total value of these launches at $1.5 billion.
- SIA, on the other hand, considers that 93 out of 114 launches were "commercial" with an estimation of total value of these launches at $6.2 billion.

The difference comes from the definition of "commercial launch". SIA seems to define "commercial launches" as those involving a financial transaction, including for governmental payloads, while the Space Foundation seems to focus on launches of commercial payloads, excluding the launch of governmental payloads, even if they gave way to a transaction between a public agency and launch service provider for example.

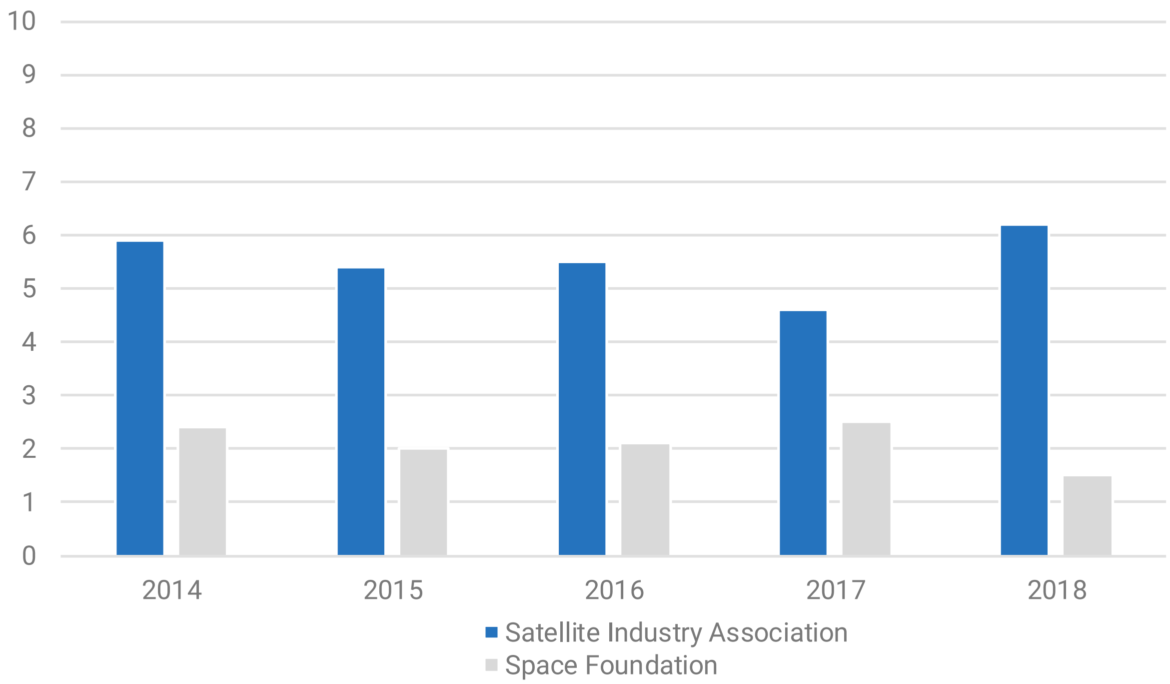

Figure 18: Commercial launch revenues evolution (Source: SIA, Space Foundation)

Commercial satellite manufacturing

According to SIA, the commercial spacecraft manufacturing industry was worth $19.5 billion in 2018. This represents a growth of 26% compared to 2017 when the sector was estimated to be worth $15.5 billion. On the other hand, the Space Foundation estimated the commercial spacecraft manufacturing industry to be worth $5.3 billion in 2018 which represents almost a 25% decrease compared to the $6.8 billion revenues recorded in 2017.

Here again, SIA and the Space Foundation's estimations of the global economic activity related to commercial satellite manufacturing seem to rely on a valuation of "commercial satellites" launched during the year, with different definitions of what is considered a "commercial satellite".

In 2018, ESPI recorded a total of 477 spacecraft put in orbit, including 208 commercial spacecraft (i.e. spacecraft which is primarily intended to serve a commercial market and to make profit). SIA estimated that 314 of satellites launched were commercial. Of these 314, almost 40% were used for remote sensing and 22% for telecommunication. The Space Foundation considered that only 167 of the spacecraft put in orbit in 2018 were commercial satellites, corresponding to 36% of the 465 spacecraft recorded by the Space Foundation. The Space Foundation estimates that commercial spacecraft manufacturing accounts for only 11.7% of the overall spacecraft manufacturing economic activity.

These major discrepancies eventually lead to a $14.4 billion gap between the two estimations.

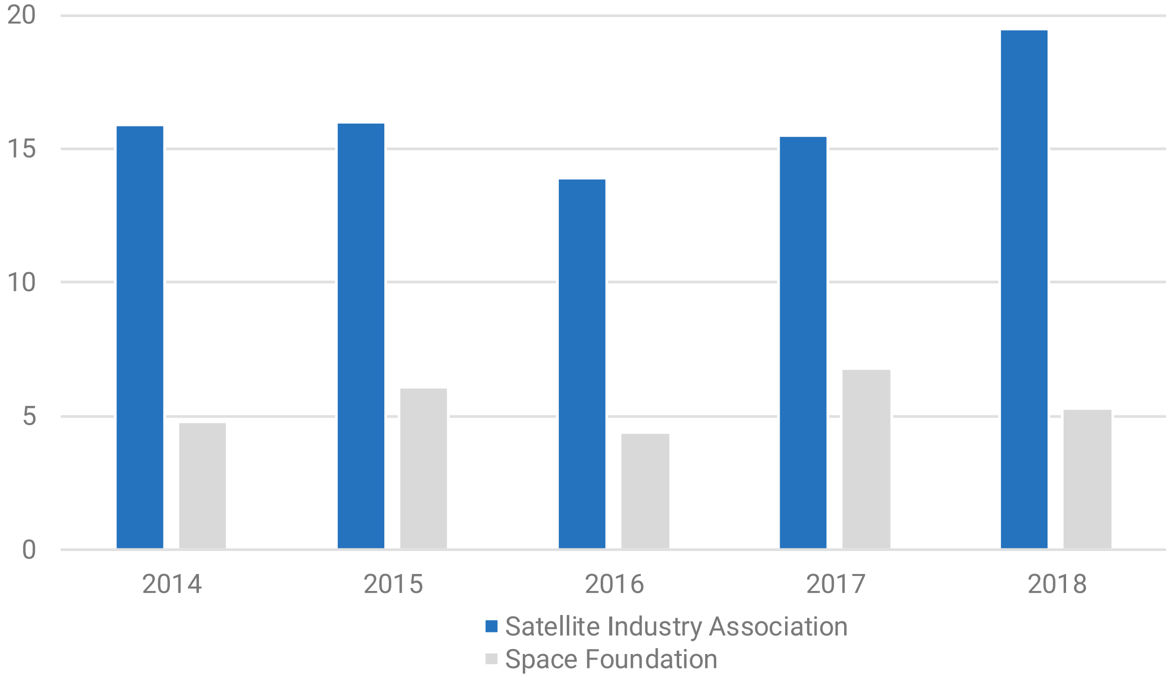

Figure 19: Commercial satellite manufacturing revenues evolution (Source: SIA, Space Foundation)

3.1.3 Ground stations and equipment

The economic activity related to ground stations and equipment stood between $92.5 and $125.2 billion in 2018 according to the Space Foundation and SIA (respectively).

Limited details are available about this segment of the space economy but the difference between the two estimations seems to be mainly explained by the respective assessments of the GNSS chipsets market. In 2018, SIA estimated the sector of GNSS chipsets to be worth $93.3billion, almost $30 billion more than the $62.4 billion estimated by the Space Foundation on the basis of the GNSS market report published by the European GNSS agency.

Both SIA and the Space Foundation showed that the sector of ground stations and equipment grew in 2018 compared to 2017. According to SIA, the global ground stations and equipment sector accounted for a total of $125.2 billion in 2018 which is a $5.4 billion or 5% increase compared to 2017. The Space Foundation on the other hand estimated the ground stations and equipment sector to be worth $92.5 billion which represents a $6.7 billion or a 6% increase compared to 2017.

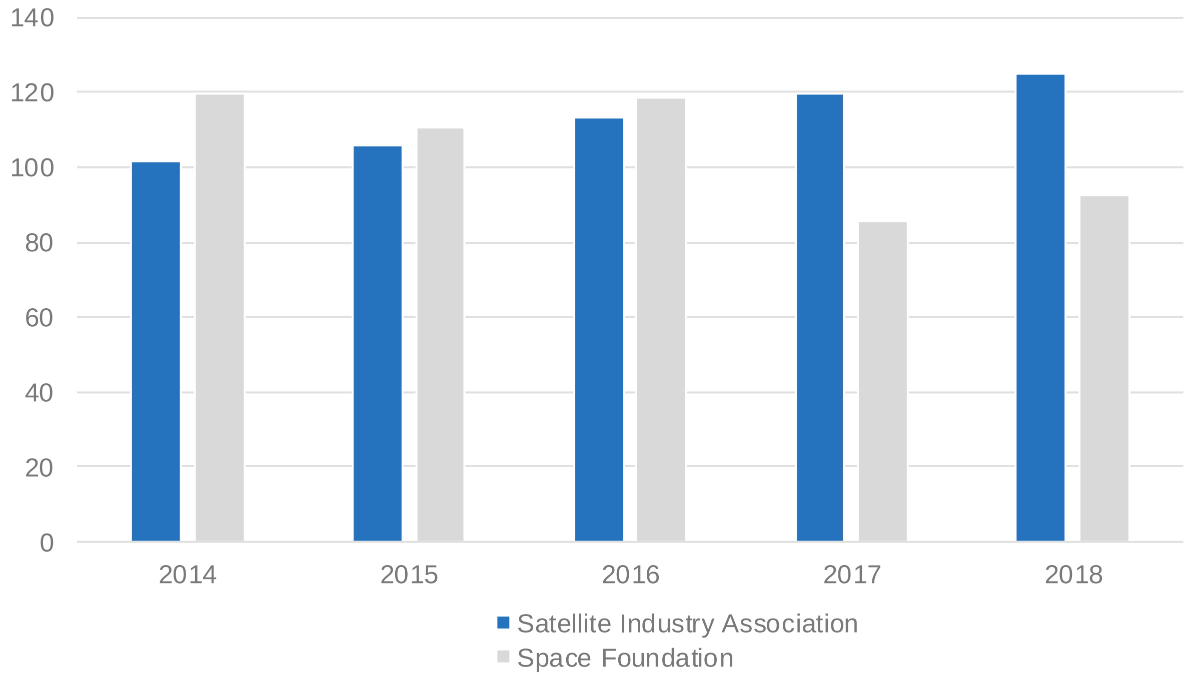

Figure 20: Ground stations and equipment evolution (Source: SIA, Space Foundation)

Beyond GNSS chipsets, the sector also includes sales of user equipment such as satphones, terminals, and dishes as well as stations and networks comprising the ground segment of the space infrastructures. Limited details are available for these revenues estimated to stand between $30.1 and $31.9 billion according to the Space Foundation and SIA respectively. SIA estimates that these revenues can be split between broadband equipment with a total of $18.1 billion (14%) and Network equipment with $13.1 billion (11%).

3.1.4 Space products and services

The segment of space products and services, commonly referred to as the downstream sector, comprises the sales of a variety of space-based products and services to end-users including governments, businesses and individuals. Categories of space products and services include:

- Television: TV broadcast and Direct-to-Home services
- Communications: Services ranging from texting and telephony to broadband internet.
- Remote Sensing: Wide variety of solutions enabled by optical and radar satellite imagery, from sales of raw data to turnkey analytics services.
- Satellite Radio: Radio services via satellites, usually for personal vehicles (mainly XM Sirius revenues).
- PNT value-added services: Wide variety of solutions enabled by GNSS signals (not included by the SIA in their assessment).

The Space Foundation estimated that the revenues for the sector of commercial space products and services to be $229.2 billion in 2018 while SIA estimated the same segment to be worth $126.5 billion. The main difference is related to the inclusion of PNT value-added services by the Space Foundation. This economic activity describes the large downstream market exploiting GNSS signals to create products and services ranging from personal navigation to shipping management. Corresponding to a $98.7 billion revenue, this category accounts, alone, for 43% of the total estimation by the Space Foundation. While this is a domain where the satellite constellations are dominated by governments (GNSS), there is no direct revenues linked to the operation.

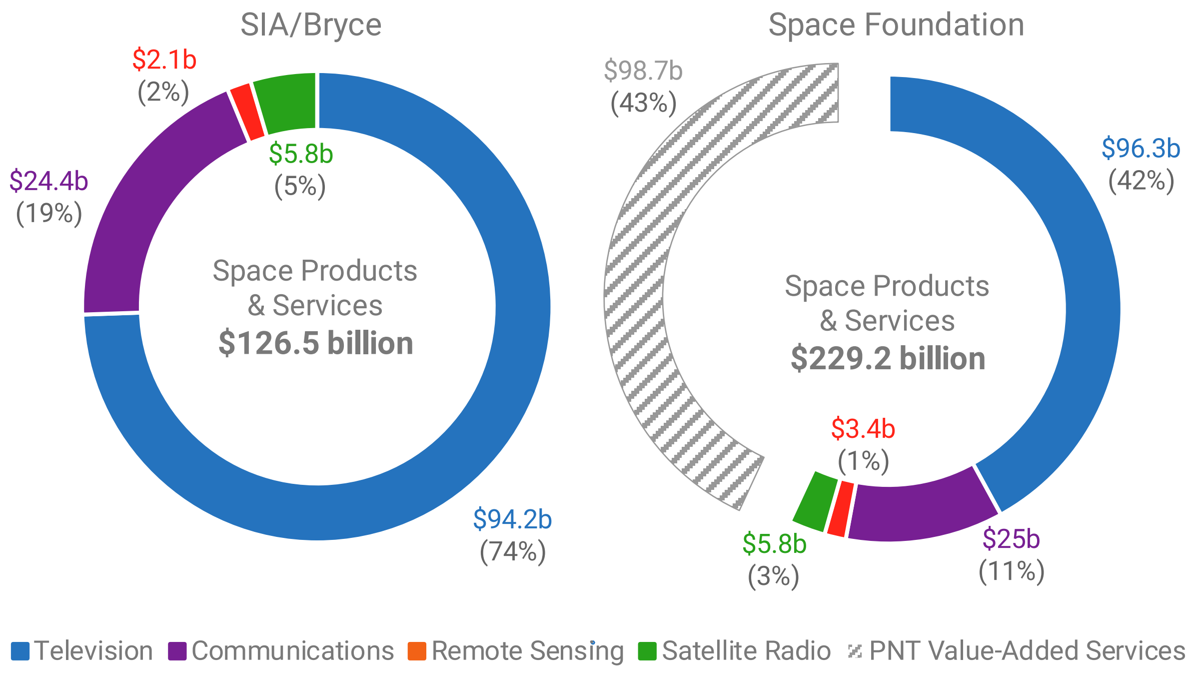

Figure 21: Commercial space products and services revenues (Source: SIA, Space Foundation)

The Space Foundation and SIA converge on the assessment of the value of other segments. Direct-to-home television accounts for between $94.2 and $96.3 billion. These revenues have been steady with a slight augmentation in 2018 due to the large audience that tuned in for the 2018 Football World Cup. Satellite communications, radio and remote sensing services accounted together for a total ranging between $32.3 and $34.2 billion in 2018.

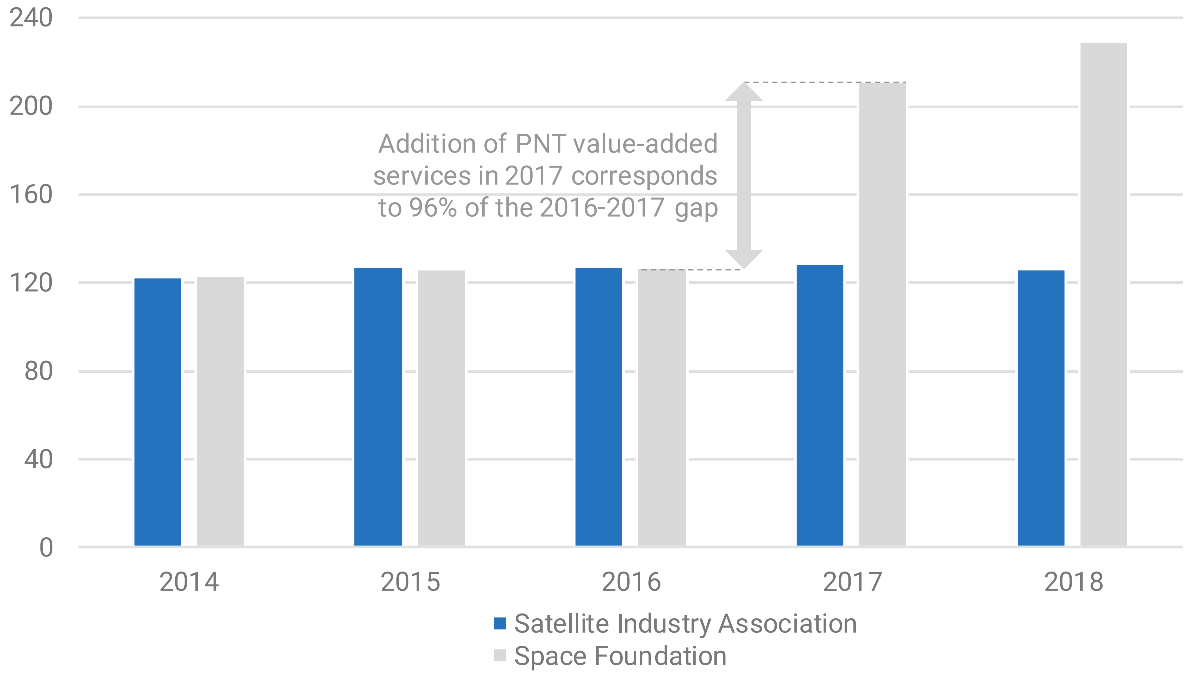

Figure 22: Commercial space products and services evolution (Source: SIA, Space Foundation, ESPI)

The Space Foundation saw an 8.4% increase compared to 2017 while SIA estimated that revenues decreased by 1.7%.

When looking atFigure 22, we can see that the estimates for the market size comparison between 2014 and 2017 were practically the same for both SIA and the Space Foundation. However, in 2017 the Space Foundation began evaluating the revenues for commercial space activities much higher than SIA. This valuation originated in the addition of PNT. The total revenue estimate by the Space Foundation for this sector jumped by almost $85 billion in a single year.

3.1.5 Insurance sector

Space activities entail risky operations and the insurance sector provides space actors with solutions to help mitigate financial setbacks that can arise as a result of technical failures or delays. Insurers usually compete on coverage terms, capacity and most often on premium prices. Typically packaged together in most insurance products, there is a distinction between property insurance (first party) and liability insurance (third party). Property insurance insures against the failure of a satellite during launch or operation and will typically cover the cost of the satellite, excluding any future revenue losses. The liability insurance of a satellite insures against damage caused to a third-party by the launch or satellite operator. In-orbit liability insurance is generally required only by a small number of countries; the vast majority of commercial satellite ventures carry property insurance, and it is typically their third-largest expenditure after launch and manufacturing.[413]

In 2018, approximately 50 insurers insured assets in the space market. The space insurance market is characterized by a strong European presence: In 2018, European players represented over 68% of the global insurance capacity for the launch sector and over 67% for in-orbit activities.[414] France and the UK were standouts, as they combined to make up 50% of the world space market. In this competitive ecosystem, just two players exceeded $100 million in insurance capacity for launches in 2018. These were Munich RE and the Dubai-based Elseco. Elesco was also the only insurer exposed over the $100 million threshold for in-orbit activities.[415]

In line with previous years, over 60% of orbital launches were insured in 2018,[416] half of which were in-orbit commercial GEO satellites. GEO satcom are very often the most expensive private satellites to produce, assemble and launch, so customers are more risk-adverse than with other types of satellites. In comparison, only 5% of LEO satellites are covered by a type of insurance product.

The data science company Seradata estimated that the total insurance premiums paid in 2018 for the space sector reached $458 million.[417] According to the Space Foundation, the premiums paid in 2018 were the lowest seen in almost two decades.[418] This marked a 34.8% decrease compared to the premiums paid in 2017 ($704m).[419] However, insurance claims increased from $452 million in 2017 to a reported maximum of $605 million[420] in 2018, which represents an increase of over 30% depending on the source. The table below illustrates the major insurance claims in 2018 and begins to look at 2019 satellite failure.

As reported in the table hereafter, the main insurance claims in 2018 were issued for the failures of WorldView-4 worth $183 million, Angolsat-1 worth $121 million, Al Yah 3 worth $115 million, Soyuz MS-10 worth $71million and finally Turksat-4b with a claim of approximately $40m.

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[413] Stimson Centre and the Secure World Foundation (SWF) "Insurance and Responsible Behaviour in Space Event Report" (April 2018): https://www.stimson.org/wp-content/files/file-attachments/2018_stimson_swf_insurance_event_report.pdf

[414] Aon International Space Brokers, "Aon ISB Space Insurance Fundamentals, Part 1 – Introduction to Space Risk Management". Presentation at the Institut aéronautique et spatial (2019), p. 89 : https://www.inst-aero-spatial.org/wp-content/uploads/2018-Space-Insurance-Training-IAS-PART-1.pdf

[415] *Ibid.*, p. 90

[416] Space Foundation, *The Space Report 2019* (Q3, p. 4). Available at: https://www.thespacereport.org/register/the-space-report-2019-4-quarterly-reports-pdf-download/

[417] Caleb Henry, "Big claims, record-low rates: Reshaping the space insurance game". SpaceNews (September 2019): https://spacenews.com/big-claims-record-low-rates-reshaping-the-space-insurance-game/

[418] *Ibid*.

[419] *Ibid*.

[420] Space Foundation, *The Space Report 2019* (Q3, p. 4).

2018	Reported claims	Cause
WorldView-4	$183 million	In-orbit failure
Angosat-1	$121 million	In-orbit failure
Al Yah 3	$115 million	Partial launch failure
Soyuz MS-10	$71 million	Launch failure
Turksat-4b	$25 to $60 million	Partial launch failure
2019	Reported claims	Cause
Falcon Eye-1	$415 million	Launch failure
ChinaSat-18	$250 million	Post-launch anomaly

Table 14: Major insurance claims in the space sector 2018-2019[421]

Over the last 20 years, insurance claims have exceeded premiums only 5 times. This happened in 2000, 2001, 2007, 2013, and 2018.[422] However, and perhaps most importantly, the gap between insurance claims and premiums in 2018 was the highest recorded since 2000. The year 2000 should not be used as a benchmark however, as it saw the historical failure of 5 satellites: Mitsubishi M-5, Zenit-3SL, ICO F1, QuickBird1 and Geonets 07.

In the first half of 2019, a decrease in overall premium insurance prices was recorded. This is primarily due to the high competition between insurers in this sector.[423] The price of premiums was however exacerbated by two unfortunate events: the Maxar Technologies' Worldview-4 claim ($183 million loss incurred in 2018 and paid in January 2019) and the failure of Vega launch on 10 July 2019 leading to the loss of both launcher and payload.[424]

In such a competitive environment, and with such low margin and high risks, the space insurance market is reportedly at a critical juncture. On July 31st 2019, the Swiss insurance company Swiss Re announced that it would be leaving the market due to poor financial result and unsustainable premium rates. This announcement sent shockwaves throughout the industry as Swiss Re represented 5% of the space insurance market and is one of the largest insurance companies in the world.

While remaining marginal regarding to the overall size of the sector, this exit of Swiss Re should not be overlooked as it might represent a potential longer-term risk for the industry. The question should be asked whether a lack of competition in the space insurance sector may make way for prohibitively high prices for space insurance. As such, reflexion should be made into the possibilities and limits of the insurance market in the space sector.

Finally, this negative trend reported above may represent another risk for the development of commercial of space tourism. In the case of tourism, insurance will play a fundamental role to ensure the sector's development and may be the only way to assure commercial activity.

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[421] Caleb Henry, "Big claims, record-low rates: Reshaping the space insurance game". SpaceNews (September 2019)
[422] Space Foundation, *The Space Report 2019* (Q3, p. 4).
[423] Jeff Foust, "Space insurance rates increasing as insurers review their place in the market". SpaceNews (September 2019)
[424] Mike Wall, "Vega Rocket Launch Failure in July Caused by Faulty Motor, Investigators Find". Space.com (September 2019)

3.2 Institutional space budgets

3.2.1 Global overview and evolution

As of 2018, a total of 88 countries have invested in space programmes. Amongst these 88 countries, 14 have launch capacities and 8 of those have a space agency with a budget of over $1 billion per year: USA, Russia, China, India, France, Japan and Italy. 2018 saw the emergence of 5 new space agencies with the development of national programmes in Luxembourg, Portugal, Greece, Australia and Zimbabwe. The increasing number of spacefaring nations demonstrates the willingness of governments to invest in space capabilities and leverage related strategic and socio-economic benefits.

The total institutional spending in space programmes in 2018, including that of intergovernmental organisations, is reported to stand between $70.8 billion (Euroconsult) and $85.9 billion (Space Foundation). While global institutional budgets have been relatively steady over the past few years, a recent forecast by Euroconsult suggests that global institutional spending could increase by almost 20% in the next five years as a result of renewed ambitions in space exploration and human spaceflight programmes (Artemis, Lunar Gateway) and other trends.[425]

It is important to note that institutional budgets provide an incomplete perspective on governments' investment in the space sector and cannot be directly compared. The influence of currency exchange rates and purchase power differences should not be overlooked.

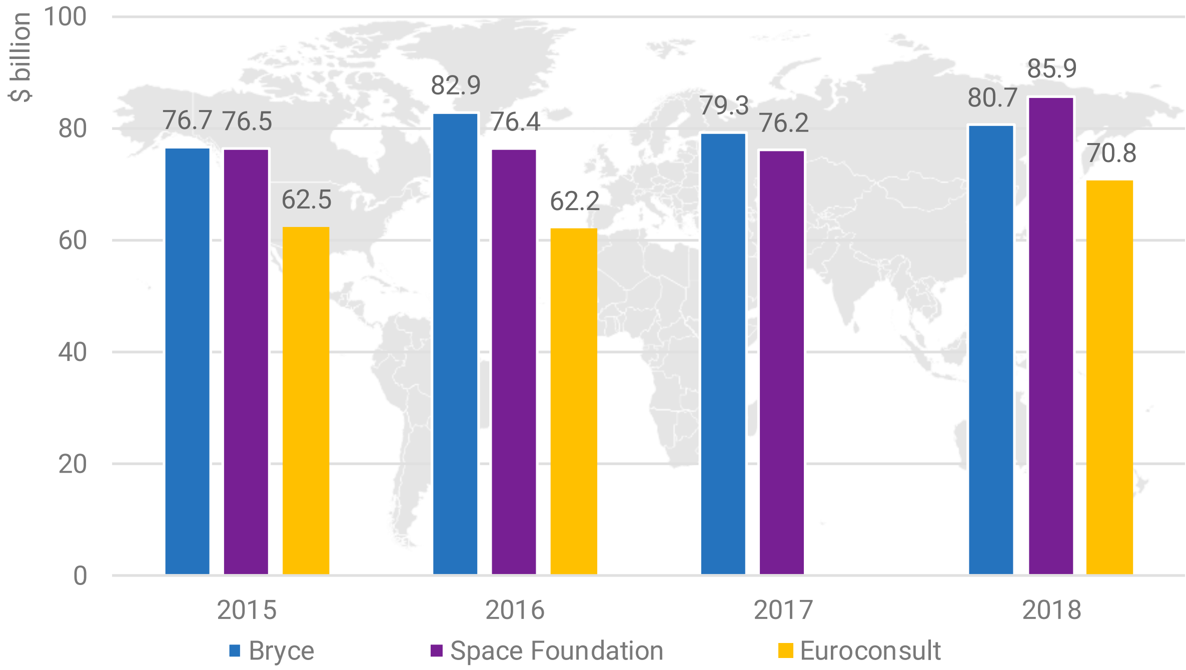

Figure 23: Global institutional space budget evolution (Source: SIA, Space Foundation, Euroconsult)

Available assessments show an irregular increase in government spending over the past 4 years with a CAGR between 1.3% and 3.2%.

There are also large variations in the national estimates of governmental budgets. We can notice that the Space Foundation estimates the U.S. budget for 2018 to be worth a total of $48 billion while Euroconsult estimates it to be worth $41 billion. Bryce Space and Technology even goes as far as to estimate the U.S.

[425] "Euroconsult predicts 10-year growth cycle for government space programs". Euroconsult (July 2019): http://www.euroconsult-ec.com/25_July_2019

governmental budget to be worth $50.1 billion. This difference between Euroconsult, Bryce and Space Foundation can partially be explained by the exclusion of US agencies such as the NRO and the US Air Force, which are included within Bryce and the Space Foundation numbers. Furthermore, the combination of the rest of the world's institutional budgets varies as well. The Space Foundation estimates it to be a total of approximately $12.2 billion while Euroconsult works with a lower estimate of $3.8 billion. The main difference of estimate originates from the fact that the Space Foundation includes within their assessment non-US military spending as well as civil spending such as EUMETSAT and ESA. Euroconsult includes those expenditures with national budgets and as such final estimations can be caused by methodological differences in sourcing numbers.

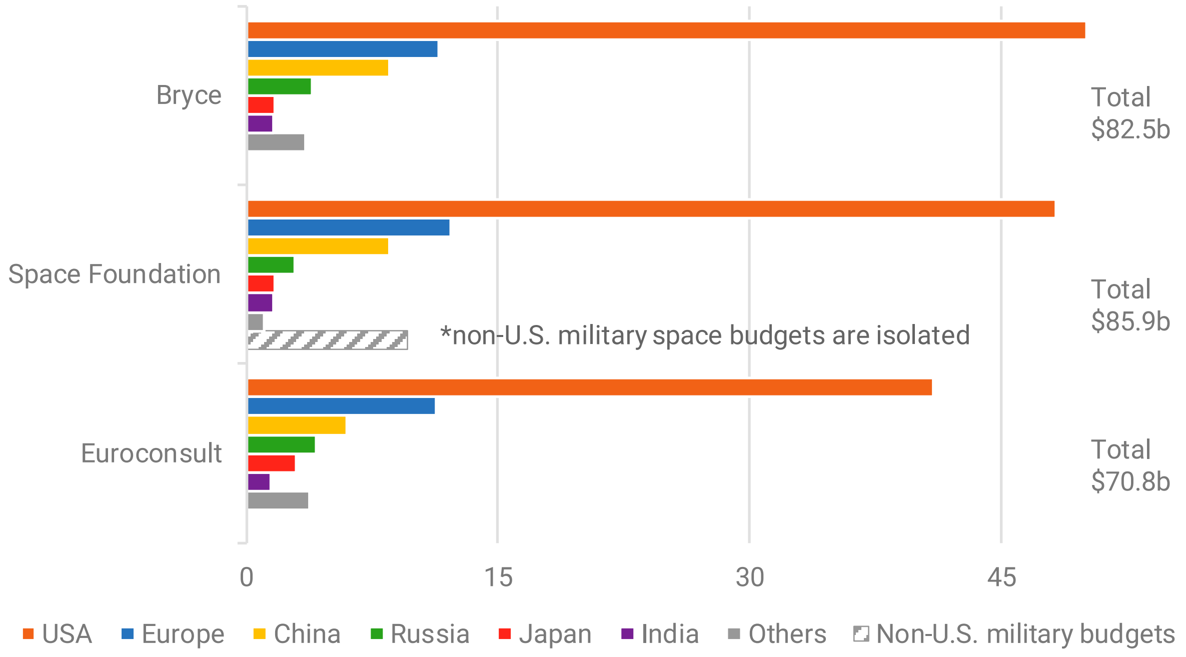

Figure 24: Institutional space budgets in 2018 (Source: SIA, Space Foundation, Euroconsult)

It is also interesting to look at the difference between military and civil budgets. In 2018, the United States allocated $24.5b (52% of their total space budget) to military activities managed by the Department of Defense (DoD) and other American military bodies. This is an increase compared to 2017 where the military budget spending was $20.7b and the civil spending was $22.7b. In other words, the U.S. military budget increased less than the U.S. civil budget (8% increase vs. 15%).

The rest of the world does not operate on such a precise delineation of civil and military budgets. In 2018, the Space Foundation estimates that the military budget of all other spacefaring nations was around $9.6b, corresponding to 25% of the overall space budget outside of the United States. This is in large contrast to U.S. space military investments where more than half of the total US space budget went towards the DoD.

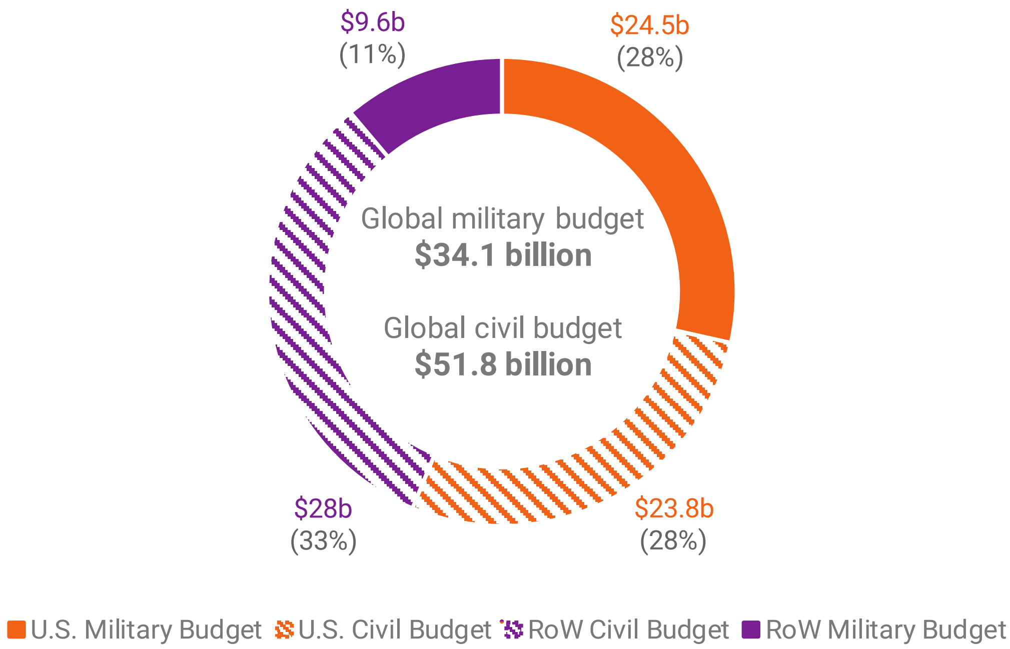

Figure 25: Civil vs Military spending in the U.S. and Rest of the World (Source: Space Foundation)

The hierarchy of major space powers has not changed significantly over the years, at least in terms of budget. In 2018, the United States continued to represent the largest contributor to space programmes worldwide. Euroconsult estimates that the U.S. government budget went from $36 billion in 2016 to $41 billion in 2018. This is a 14% increase in two years. The Space Foundation on the other hand points out that the US 2018 budget grew by 9% compared to 2016. It went from $44.5 billion in 2017 to $48.5 billion in 2018. This represents 58% of global institutional spending. While it may appear to be a lot, it is a decrease from the 75% of global institutional spending that the United States represented in the early 2000s. While the decrease of its share in global institutional spending is caused by other nations beginning to invest in space, the U.S. budget has still been steadily growing. This is caused by the expansion of its science, technology, human spaceflight and defence programs. With the development of the U.S. Space Force and the Artemis programme, this U.S. budget is likely to keep on increasing over the next decade.

The second largest budget is Europe. The consolidated European budget was estimated by Euroconsult to be worth 16% of the total global government expenditure in 2018. The European budget is addressed in more details later in this report.

3.2.2 Space budget per country

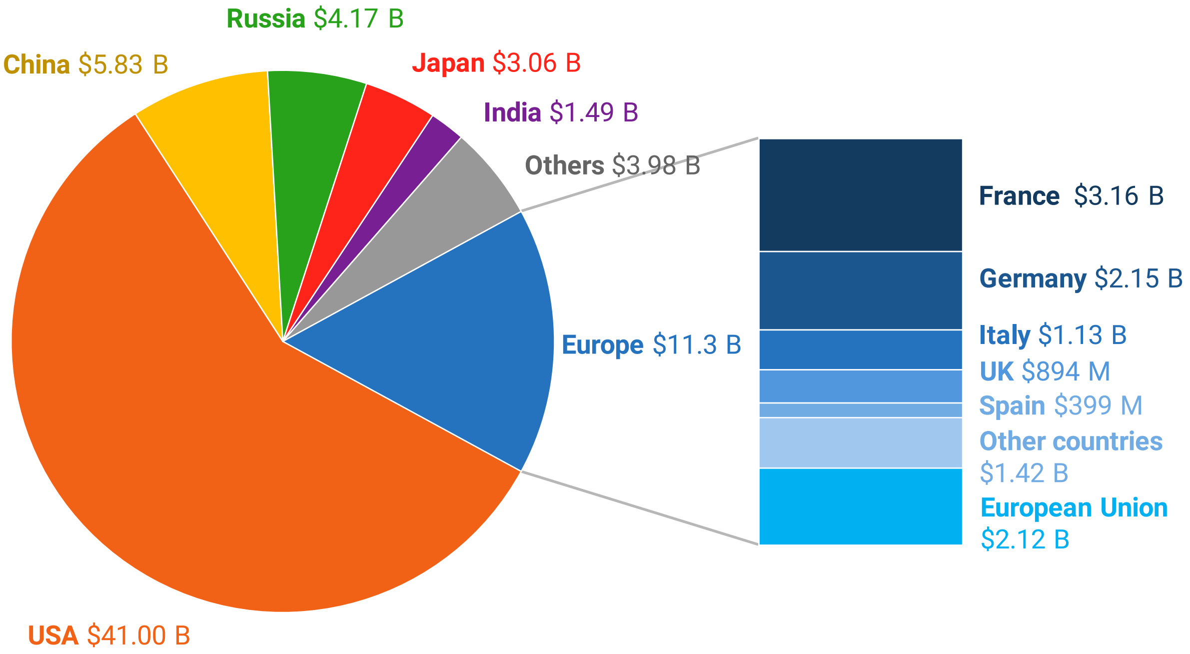

Figure 26: Institutional space budget per country in 2018 (Source: Euroconsult)

Similar to 2016, China's budget is the third largest, growing from $4.9 billion in 2016 to 6 billion in 2018, showing a significant growth rate of 18%. China sustained one of the world's highest launch rates in 2018. The deployment of multiple simultaneous constellations with the Yaogen and Gaofen Earth observation systems as well as Beidou satellites allowed the country to keep up with the increase of expenditure coming from the US. This pace is expected to continue for the next decade. It is however important to mention that information regarding Chinese space budgets are not based on official figures and purely speculative due to China's policy of opacity regarding information on its space program. The SF estimates the government expenditure on the basis of Chinese GDP. As such, true numbers can vary from the ones produced by Euroconsult or the Space Foundation. In this case, the Space Foundation estimated the Chinese government space expenditure to have been worth $4.3 billion in 2016 compared to the $8.5 billion in 2018. This represents a 50% increase in two years. Therefore, with a variability of 32% between Euroconsult and the SF, all estimates should be taken with caution.

Russia is one of the nations where Euroconsult estimates a higher government expenditure than the Space Foundation. With $4.2 billion in expenditure, Euroconsult's estimate is $1.3 billion higher than the Space Foundation's ($2.9b) which shows an astounding 30% difference in estimates. Furthermore, with an increase of expenditure of $1 billion since 2016, Euroconsult assesses that the Russian federation has increased it's spending by almost 25% in two years. The Space Foundation on the other hand, while still presenting a lower estimate compared to Euroconsult, shows a 45% increase in two years, going from $1.6 billion in 2016 to $2.9 billion in 2018. Forecasts show that while a short decline may be seen in 2019 and 2020, according to the Russian space strategy, the country is planning to increase its telecommunication capacity and spending by replenishing its Earth observation systems and optimizing it's launch fleet. Finally, GLONASS infrastructure maintenance is expected to happen as well.

Japan follows as the fifth country with the highest expense in government space expenditure. It is approximately the same budget JAXA allocated for 2016. However, while estimating the Japanese budget to be worth approximatively $3 billion in 2016, the Space Foundation estimated it to be only worth $1.7 billion in 2018. This marks a 43% decrease in two years, diverging drastically from Euroconsult. In the short to medium term, Japan has announced the expansion of its existing programmes on Navigation (QZSS) and the development of the next generation of HTS ETS-3 satellite, which helps anticipate a future modest budget growth (2% per year).

Finally, India is the last nation that spent over a billion dollars on its annual government space budget. Furthermore, India is one of the rare countries where all consulting firms appear to agree of the government space budget expenditure. In 2016, both Euroconsult and the Space Foundation estimated the government spending to be worth $1.1 billion. In 2018, Euroconsult estimates the institutional budget to be worth $1.5 billion while the SF is at $1.6 billion. This shows an average increase of 25% over the past two years.

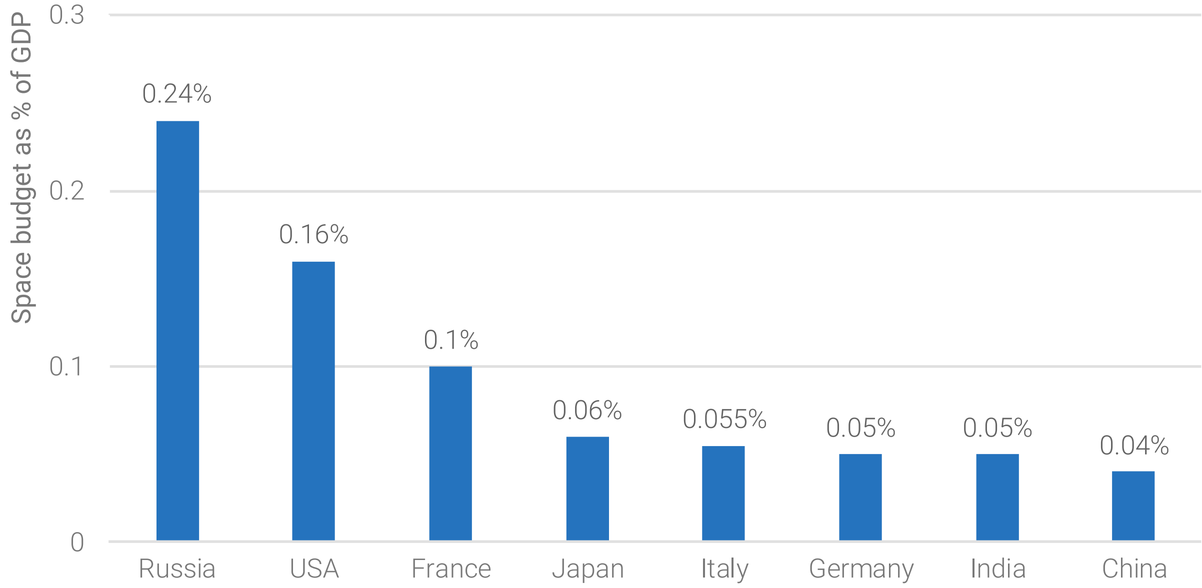

Figure 27: Space budget as % of GDP in 2018 (Source: Euroconsult, World Bank, ESPI)

An interesting way to measure a country's effort in developing its space sector is to put the space budget data into perspective compared to Gross Domestic Product (GDP). A few numbers here stand out specifically. Russia is now first in terms of space budget as percentage of GDP. This is surprising, as historically the United States was consistently first in space budget as percentage of GDP. It should be mentioned however, that using SIA or Space Foundation numbers rather than Euroconsult results in the US being first rather than second. Interestingly France is third behind Russia and the US. This shows France's commitment to position themselves as a leading nation in spatial development. Furthermore, 2018 was the second year in a row in which France was the first biggest donor to ESA over Germany. Finally, while China would be expected to rank higher, the size of its GDP compared to its commitment to space investment makes it rank last in terms of space budget as percentage of GDP.

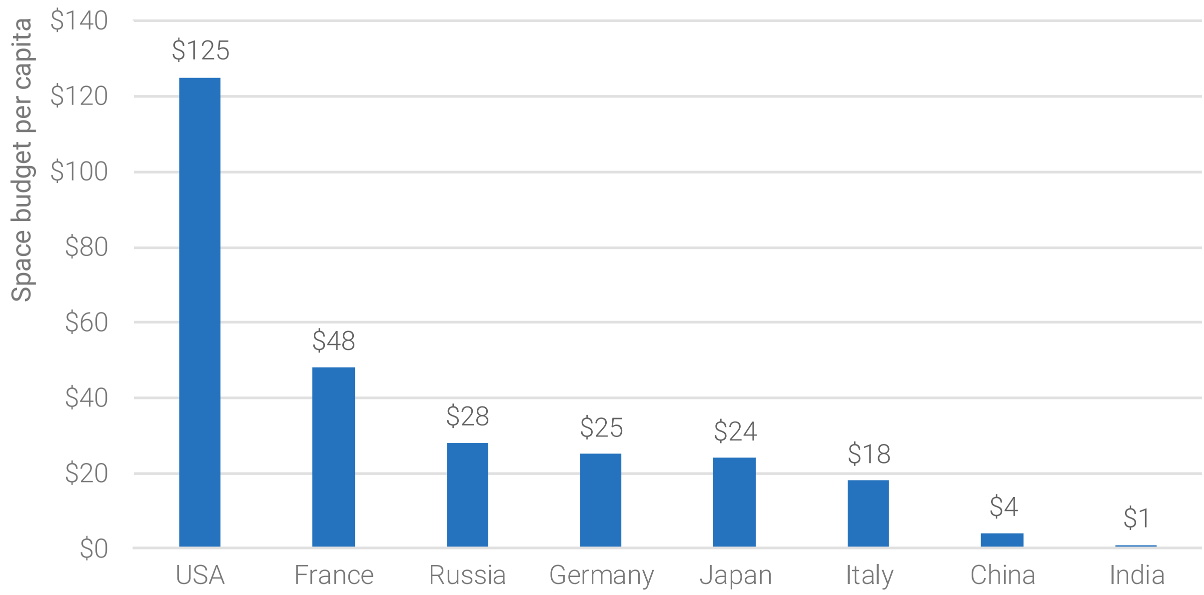

Figure 28: Space budget per capita in 2018 (Source: Euroconsult, World Bank, ESPI)

An additional perspective to visualize space investments is to calculate the government space budget per capita. Here, the United States holds the undisputed first position with an expenditure of $125 per U.S. inhabitant. France once again holds a position of choice totaling investments of $48 per inhabitant in 2018. France is followed by Russia, Germany, Japan and Italy, which have similar expenditures per capita. China and India are evidently last due to their extremely large populations. Some small countries, even though not counted among the world space powers, are worth mentioning for their space spending in proportion of population. The standout country is Luxembourg. With 600 000 inhabitants in 2018 and a total space government budget of $78m, the expenditure per capita reaches 130$ making it the country that spends the most per inhabitant, higher than the US. Furthermore, the UAE invested $39.5 per inhabitant in 2018, theoretically placing itself before Russia in Figure 15. Switzerland with $22 per capita in 2018 would surpass Italy, China and India. Countries like Belgium ($21), Israel ($17) and Sweden ($12.5) also have an expenditure per capita worth mentioning.

3.2.3 European space budgets

Consolidated European space budget

Space budgets in Europe are intertwined with a variety of budget transfers (delegations, contributions) between different national, intergovernmental and supranational actors. Overall, and after consolidation, the European space budget was around €10.2 billion in 2018.

This includes two main sources of public funding:

- National space budgets are the primary source of public funding in Europe. In 2018, the total space budget of European countries (ESA and EU Member States) was around €8.4 billion.
  This budget includes:
  - Contributions to ESA budget for €3.98 billion
  - Contributions to EUMETSAT budget for €594 million
  - Budget remaining with national bodies for the management of national space programmes and other space projects outside ESA and EUMETSAT
- The European Union space budget is the second source of public funding in Europe. This budget is financed through Member States contributions to the budget of the Union but managed as a supranational budget complementing national budgets. In 2018, the EU space budget represented an additional public investment of €1.8 billion.

In 2018, the budget of the European Space Agency was €5.6 billion, including national contributions (€3.98 billion) and the implementation of institutional programmes for the EU (€1.3 billion) and EUMETSAT (€221 million).

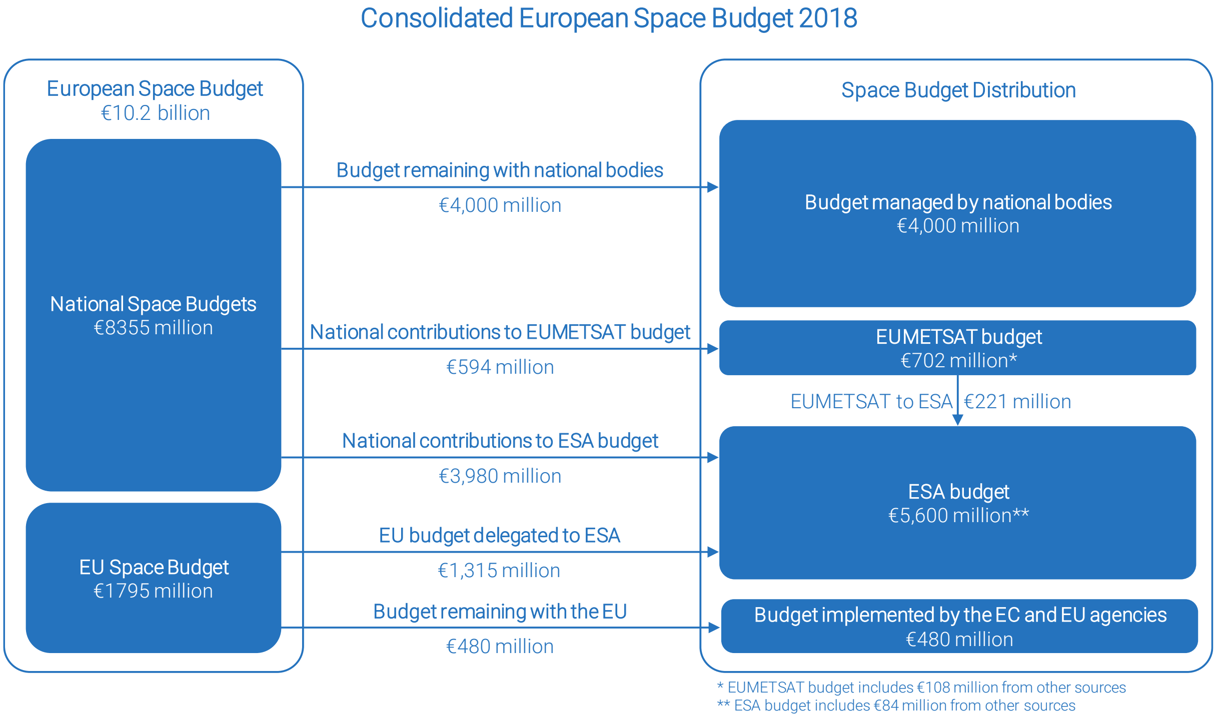

Figure 29: Consolidated European space budget 2018 (multiple sources, ESPI consolidation)

National space budgets

European countries delegate more than half of their national space budget to ESA (and EUMETSAT to a lesser extent) and therefore contribute primarily to European space programmes. For some countries, a vast majority of the national space budget is implemented through ESA and EUMETSAT. The table below shows the estimated national space budget (civil and military) for ESA Member States in 2018.

European countries	National space budget 2018	ESA contribution	National activities
Austria	€64.4 M	€47.4 M	€17.0 M
Belgium	€209.5 M	€203.4 M	€6.1 M
Czech Republic	€50.0 M	€32.5 M	€17.5 M
Denmark	€39.9 M	€31.6 M	€8.3 M
Estonia	>€2.6M	€2.6 M	*unknown*
Finland	€49.2 M	€19.4 M	€29.8 M
France	€2,678.0 M	€961.2 M	€1,716.8 M
Germany	€1,824.0 M	€920.7 M	€903.3 M
Greece	€18.7 M	€10.5 M	€8.2 M
Hungary	€10.2 M	€6.2 M	€4.0 M
Ireland	€21.2 M	€17.4 M	€3.8 M
Italy	€955.7 M	€470.0 M	€485.7 M
Luxembourg	€74.6 M	€26.6 M	€48.0 M
Netherlands	€121.3 M	€91.1 M	€30.2 M
Norway	€106.0 M	€64.4 M	€41.6 M
Poland	€76.3 M	€34.6 M	€41.7 M
Portugal	€23.7 M	€18.2 M	€5.5 M
Romania	€52.6 M	€42.6 M	€10.0 M
Slovenia	€11.0 M	€2.7 M	€8.3 M
Spain	€338.4 M	€204.9 M	€133.5 M
Sweden	€107.7 M	€72.4 M	€35.3 M
Switzerland	€171.3 M	€149.4 M	€21.9 M
United Kingdom	€758.1 M	€334.8 M	€423.3 M

Table 15: National space budgets of European countries (Source: Euroconsult, ESA, ESPI)

European Space Agency

The ESA budget experienced a considerable increase from €5.60 billion in 2018 to €5.72 billion in 2019. The biggest ESA budget allocation was for Earth Observation programmes (24.3% of total the ESA budget 2019), although it decreased from €1,456 million in 2018 to €1,390 million in 2019 from €1,456 million in 2018. The highest increase in budget allocation occurred in Space Transportation, which increased from €1,111 million (19.8% of the 2018 total budget) to €1,287 million in 2019 (22,5% of the budget), it also represents the second largest budget allocation. Expenditure on Telecom & Integrated Application has also faced a significant boost, from €275 million in 2018 to €389 million of 2019.

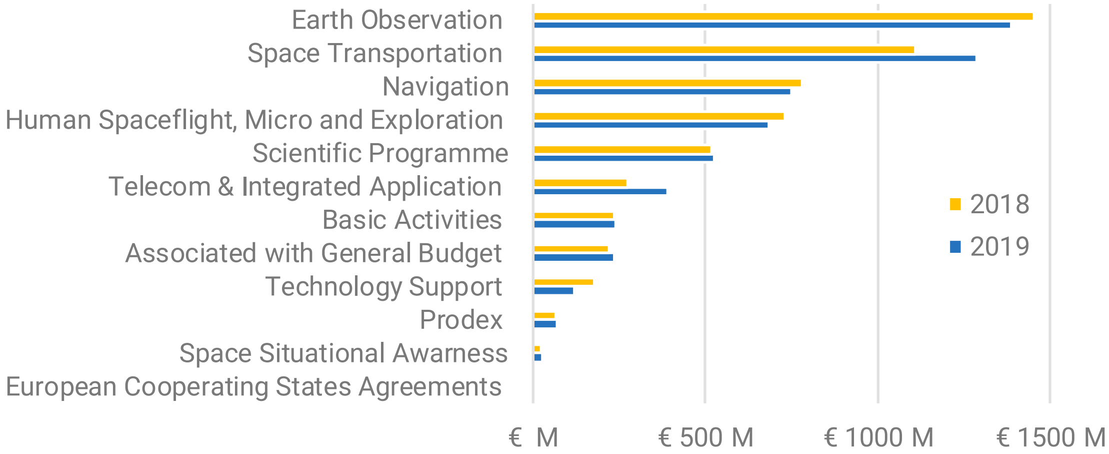

Figure 30: ESA programmatic budget allocation in 2018 and 2019 (Source: ESA)

National contributions to the ESA budget saw some meaningful changes in 2018. The total ESA budget saw a slight increase due to Member States contributions increasing from €3.98 to €4.18 billion in 2019.

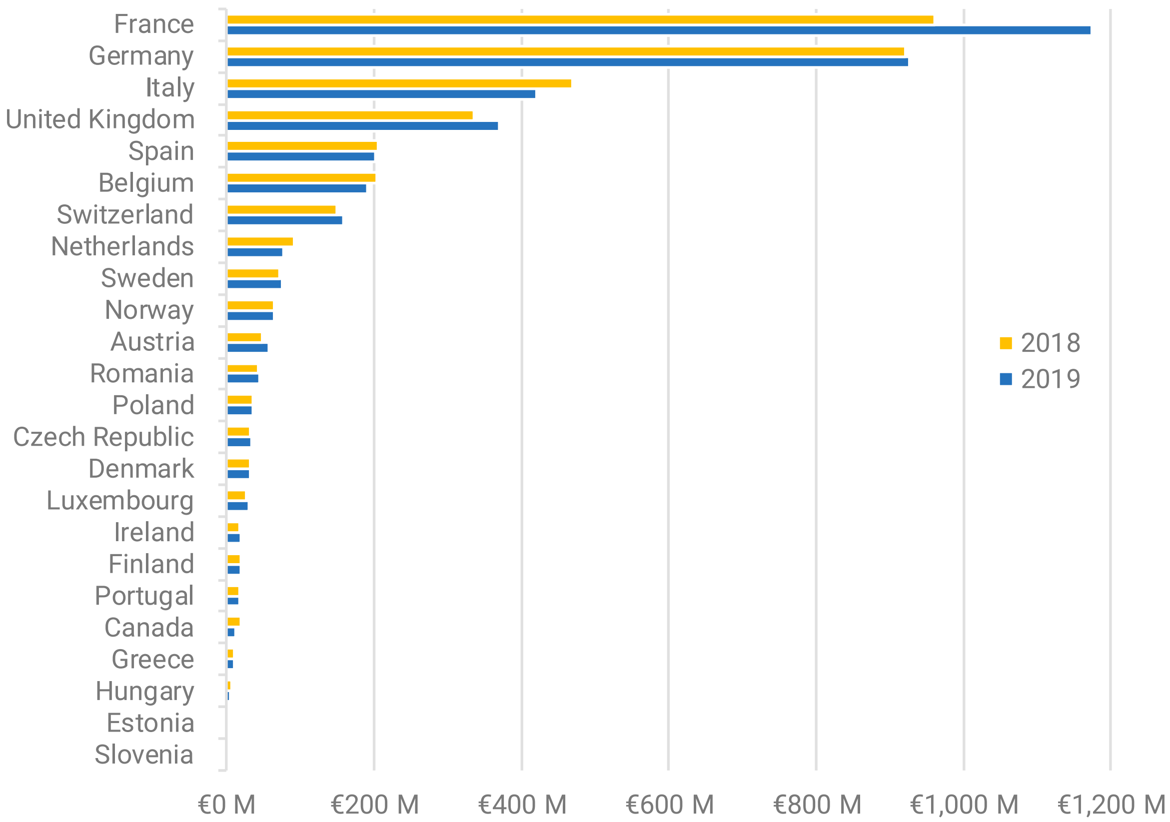

Figure 31: Member States contributions to ESA's budget in 2018 to 2019 (Source: ESA)

The leading contributor is France, contributing €1174 million in 2019 (+22% YoY). The second contributor is Germany with a slight increase totalling €927 million in 2019. Italy holds the third place as highest ESA contributor even though it decreased its contribution by 11% from 2018 to 2019. In a context largely marked by the Brexit, the UK increased its funding to ESA reaching €370 million in 2019 compared to €335 million in 2018. The figure above highlights these variations as it compares the Member States budget allocation to ESA from 2018 to 2019.

Other significant contributors with a budget of over €100 million for the current year to ESA are Spain, Belgium and Switzerland. All countries providing similar budgets to 2018.

The figure below provides an overview of the total allocation for the development of space programmes by ESA Member state highlighting the amount devoted to national initiative and the contribution to ESA. It is possible to note that only a few countries keep more than 50% of their total national space budget under national management. Overall ESA implements half of European national space budgets.

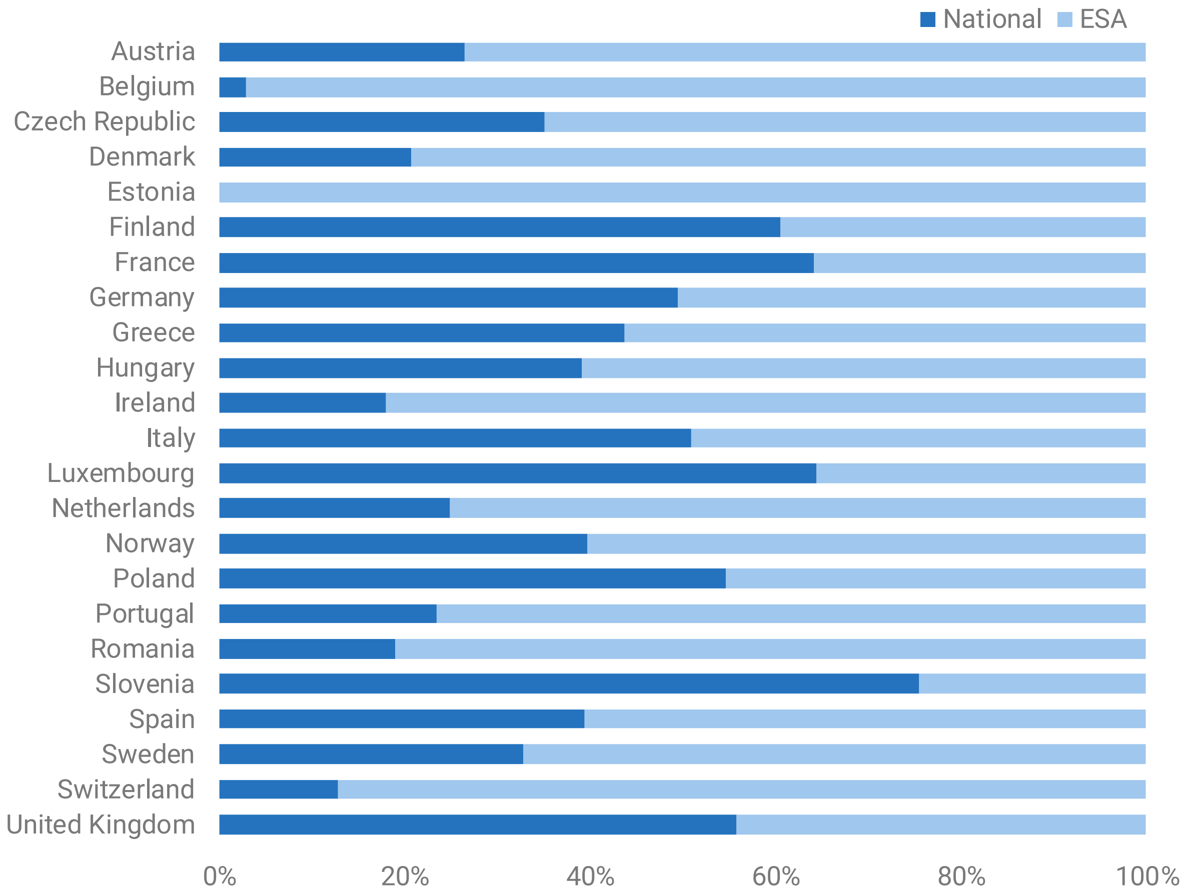

Figure 32: Member States Budget Allocation Comparison (Source: ESA, ESPI)

EUMETSAT

EUMETSAT is an intergovernmental organisation supplying climate and weather satellite data to European Member States national meteorological services since 1986.

EUMETSAT activities are primarily funded through Member States contributions, which represented 85% of its total revenue in 2018 compared to 83% in 2017. More specifically, Member States contributions were raised by 2.6%. They went from €579.4 million in 2017 to €594.7 million in 2018.

Member States contributions are calculated on the basis of their Gross National Income (GNI).

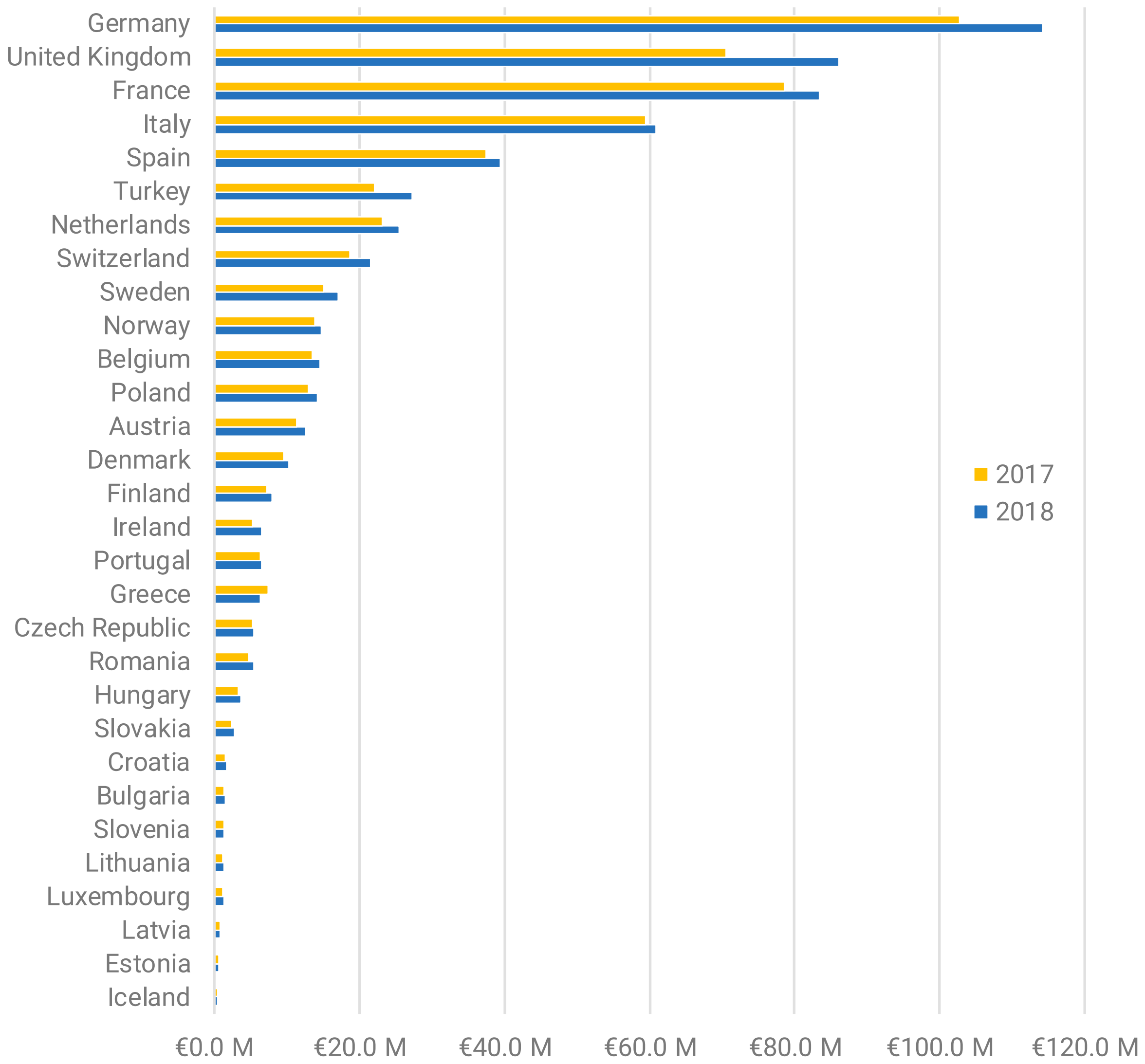

Figure 33: Member states EUMETSAT contributions comparison for 2018/2019 (Source: ESA, ESPI)

Germany remained by far the largest contributor with €114.2 million which is an 11.1% increase from the €102.8 million it funded in 2017. Even though its contribution increased by 6.1% reaching €83.5 million in 2018, France lost the second place to the United Kingdom which heavily expanded its contribution (+22.1%) to reach €86 million in 2018. The fourth contributor to EUMETSAT budget is Italy with a stable endowment of about €60.9 million.

Beyond Member States contributions, other sources of revenues for EUMETSAT originated from products sales and partnerships totalling €62.9 million of its income or 9% of its total revenue.

Following the increase in Member States participation and sales, the 2018 EUMETSAT revenue increased by 12.9% from 2018 to 2019.

In terms of programmatic allocation, as Figure 34 shows, in 2018, the largest part of the budget was allocated to the EPS-SG. EPS-SG is Europe's system contributing to the joint polar system developed in cooperation with U.S. NOAA and comprised of 2 satellites, Metop-SGA and B.[426] This programme received €304.3 million in 2018, representing 42.1% of total EUMETSAT expenditure, marking a 21.2% increase compared to 2017 distributions.

In 2018, around €164 million were earmarked for Meteosat Third Generation, 8.6% less than in 2017. EUMETSAT Polar System, the organisation's third largest expenditure in 2018 with €100.7 million, received 40.3% more than in 2017 (€71.8 million). Other significant budget allocations for the year went to Copernicus (€45.4 million), Meteosat-Second Generation (€32.5 million) and Jason-CS (€30.8 million).[427]

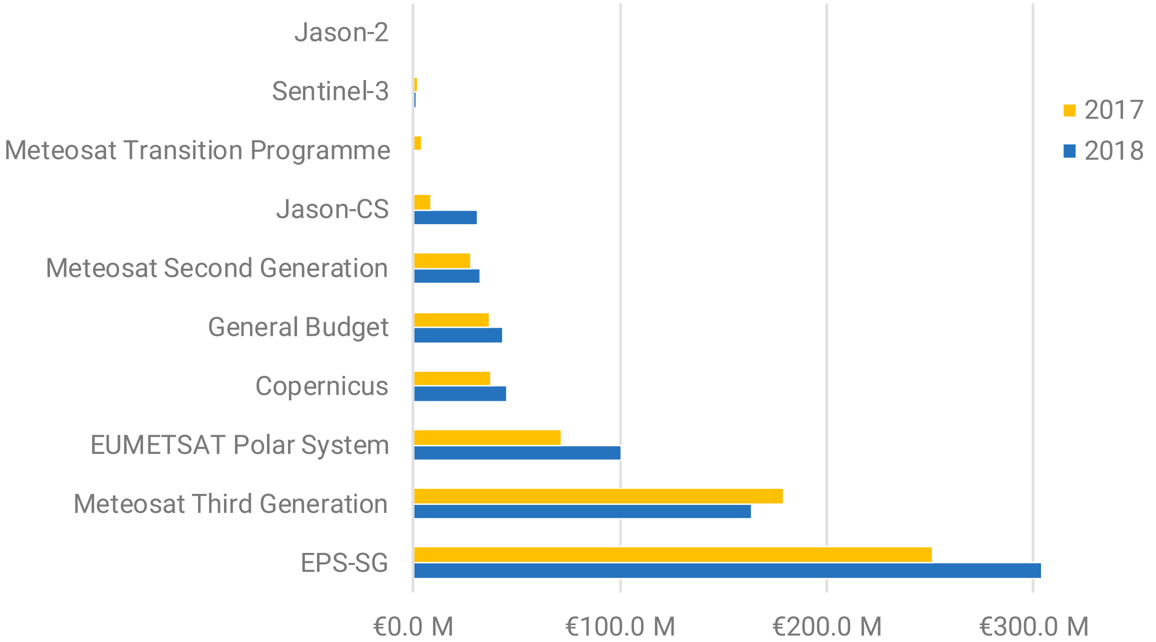

Figure 34: EUMETSAT programmatic allocations for 2017/2018/2019 (Source: ESA, ESPI)

[426] EUMETSAT, *Annual Report 2018*, p. 48. Available at: https://www.eumetsat.int/website/home/AboutUs/Publications/AnnualReport/index.html
[427] *Ibid.*

European Union

The European Union conducts various space activities that are implemented and managed by different executive bodies and agencies including in particular the European Commission, the GSA (proposed to become the European Union Agency for the Space Programme - EUSPA) and the European Space Agency.

In 2018, the European Union space budget stood between €1,657 and €1,795 million. Major EU space activities and cost items include:

- Galileo and EGNOS are Europe's GNSS and SBAS programmes providing improved positioning and timing information.
- Copernicus is the European Union Earth Observation flagship programme.
- Horizon 2020 is the EU Research and Innovation programme for the period 2014-2020 and includes a component for "Leadership in Enabling and Industrial Technologies - Space".
- GSA budget to manage various space programmes and activities of the European Union.
- Other space activities implemented by the European Commission, the European External Action Service, the EU Satellite Center, the EU Joint Research Centre and other European bodies.

Galileo and EGNOS

The European GNSS constellation Galileo currently has all planned 24 satellites in orbit. The European Commission Navigation and Positioning flagship programme entered its operational phase on the 15th of December 2016, following the European Commission's Declaration of Initial Service[428] and is reportedly on track to enter its full operational capacity by 2020. In 2018, the European Commission dedicated about €630 million to Galileo. The testing for the Galileo infrastructure is ongoing. On July the 11th 2019, Galileo signal suffered from downturn due to technical issues.[429] The service was restored after a 6-day blackout on July 17th.[430] Following this technical error, an important milestone was achieved on 10 September 2019: Galileo officially reached 1 billion smartphone users.[431] Moreover, Galileo is now supported by all European produced car models and is expected to be used by 95% of all European smartphone users.

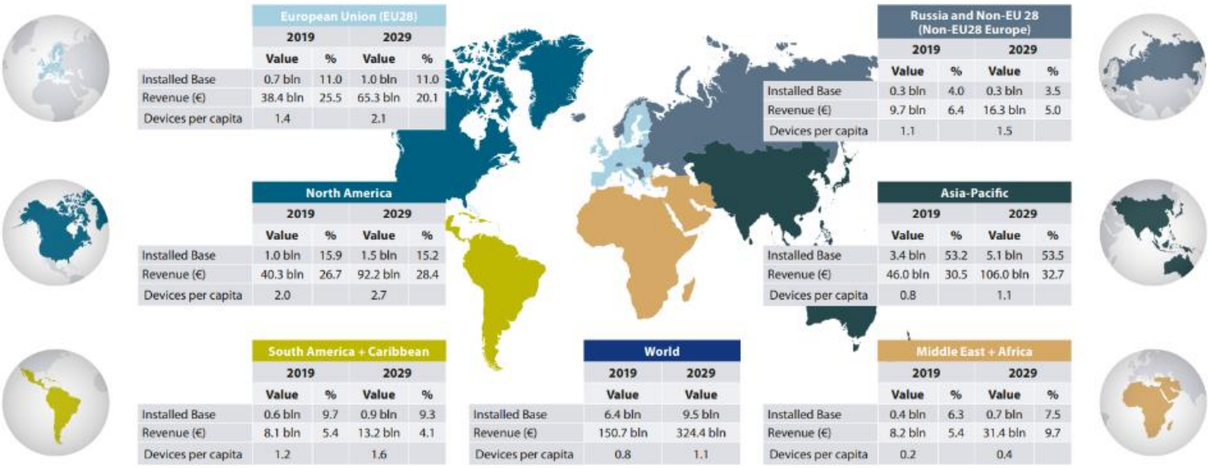

Figure 35: Global GNSS market (Source: GSA)

[428] "Galileo goes live!". European Commission (December 2016): https://ec.europa.eu/commission/presscorner/detail/en/IP_16_4366
[429] Zak Doffman, "Europe's GPS System Totally Down After Major Technical Issue Hits Its Satellites". Forbes (July 2019)
[430] AFP, "Europe's Galileo GPS system back after six-day outage". France24 (July 2019): https://www.france24.com/en/20190718-europes-galileo-gps-system-back-after-six-day-outage
[431] "Space: EU's satellite navigation system Galileo reaches 1 billion smartphone users". European Commission (September 2019): https://ec.europa.eu/commission/presscorner/detail/en/IP_19_5529

EGNOS is used to improve the performance of GNSS, such as GPS and Galileo in the future. EGNOS relies on 3 payloads hosted on GEO satellites and provides safety of life navigation services to aviation, maritime and land-based users. The EGNOS programme made several major steps towards Version 3 and the objective to cover whole European Civil Aviation Conference (ECAC) region by 2020. The year 2019 was marked by the launch of Eutelsat 5 West B carrying an EGNOS payload in October 2019. ESSP, the organisation in charge of EGNOS operations, reported 646 EGNOS based operational approaches in 338 airports in 2019. In 2018, the European Union dedicated about €180 million to EGNOS.

Copernicus

The Copernicus programme relies on a fleet of EO satellites named Sentinels. Currently Sentinel 1A-1B, 2A-2B, 3A-3B and Sentinel 5P have been deployed in orbit. The fleet of Copernicus satellites display a variety of capabilities and address various applications, from land monitoring to sea level rise study. As such, the Copernicus programme develops a global, continuous and autonomous high accuracy observation of Earth systems offering European countries scientific precision and independence in questions related to the global environment. In 2018, the European Union dedicated about €640 million to Copernicus.

On 20 March 2019, the Sentinel 3 mission has reached full operational capacity with its second Ocean monitoring satellite, Sentinel 3B. To complete the spectrum of the remote sensing constellation, Sentinel 4, 5, 6 are planned to be launched early 2020.

The Copernicus Market Report[432] issued by the European Commission provides an estimation of cost and benefits of the Copernicus programme on the European economy. The overall cost of the programme over the period 2008-2020 could be finalized at about €8.2 billion. Over the same time span the turnover of both manufacturers and service providers together would account for €11.5 billion. Over a much shorter time period, from 2018 to 2020, the benefits generated by the Copernicus programme for intermediate and end user would range from €4.7 to €9.8 billion.[433] Only for the year 2018, the benefits of the Programme have been estimated to range between €125 million to €150 million, with an expected CAGR of 15% by 2020.

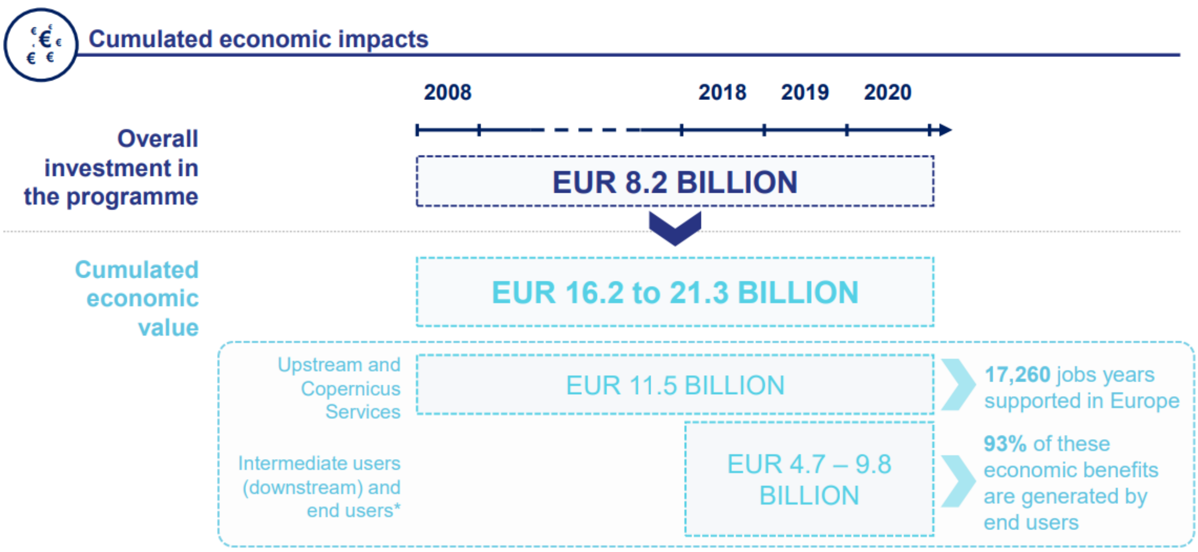

Figure 36: Overview of Copernicus programme costs and benefits (Source: PwC/European Commission)

[432] PwC (for the European Commission). *Copernicus Market Report – February 2019.* Available at: https://www.copernicus.eu/sites/default/files/2019-02/PwC_Copernicus_Market_Report_2019_PDF_version.pdf
[433] *Ibid.*

3.3 Private investment and entrepreneurship

3.3.1 Global overview of private investment in the space sector

Three main sources provide public information on global space investment: Space Angels' quarterly report,[434] Seraphim Capital's Space Index[435] and Bryce's annual Start-Up Space report.[436] These assessments are based on different methodologies and perimeters but provide comparable estimations.

Volume of investment

2018 proved to be a record year in terms of private space investment with between $3 billion and $3.2 billion invested into space companies, but 2019 broke this record again with estimations standing between $4.1 billion (Seraphim Capital) and as high as $5.8 billion (Space Angels). This is an enormous increase, as the total private space investment almost doubled between 2018 and 2019. Seraphim Capital and Bryce report more conservative growth rates of 20% and 62% respectively. While this shows a large variability in estimates, there is an overarching trend throughout the world of an increase of investments made towards the private space sector. With the massive increase recorded in 2019, the compound annual growth rate of space investment between 2015 and 2019 reached around 20%.

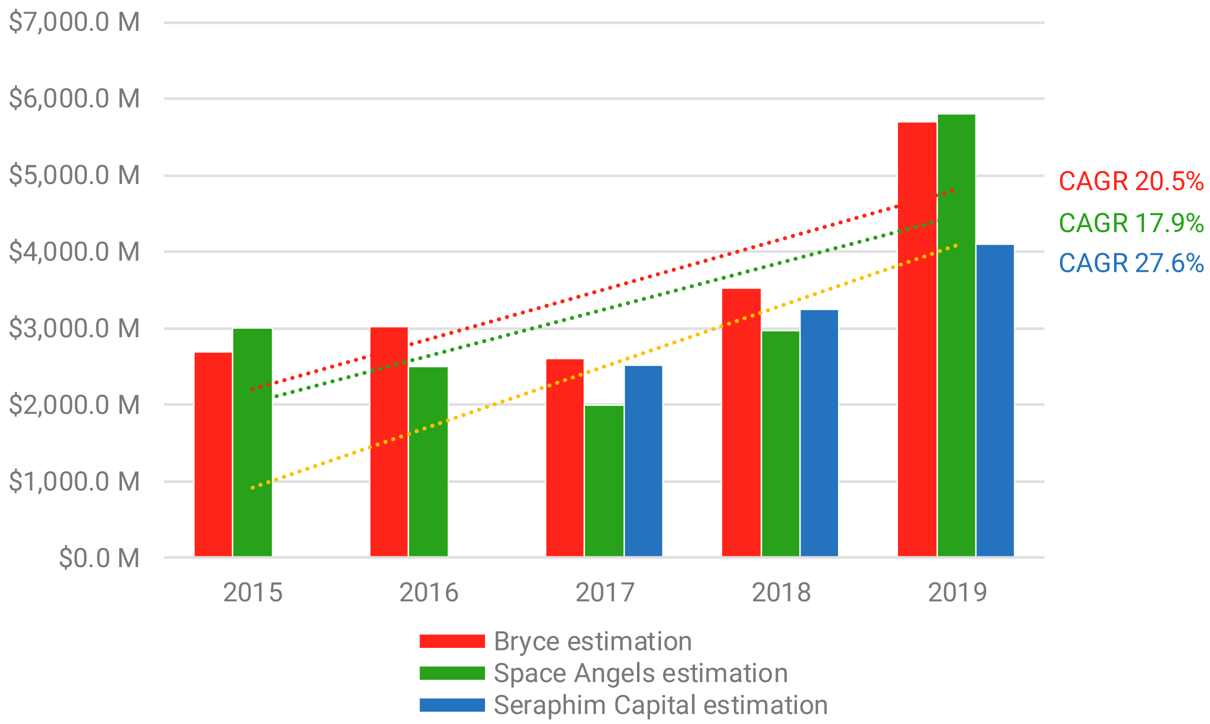

Figure 37: Private investment in the space sector 2015-2019 (Source: Bryce, Seraphim, Space Angels)

There is, however, a great concentration of the volume of investment in only a few very large deals involving high-profile companies. The circumstance was even more obvious in 2019 with close to 70% of the total investment going towards just four companies: SpaceX, Blue Origin, OneWeb and Virgin Galactic. Together, these companies saw a total investment of $3.9b out of the global total investment of $5.7b. While other small newcomers have been able to attract significant amounts of investment such as Relativity Space (US rocket maker) and Qianxun Spatial Intelligence (Chinese GNSS) with almost $140m

[434] Available on Space Angels' website: https://www.spaceangels.com/
[435] Available on Seraphim Capital's website: https://seraphimcapital.co.uk/
[436] Available on Bryce Space and Technology's website: https://brycetech.com/reports

each, the figure hereafter shows the disproportion between these "big four" and the rest of the private space ecosystem when it comes to investment.

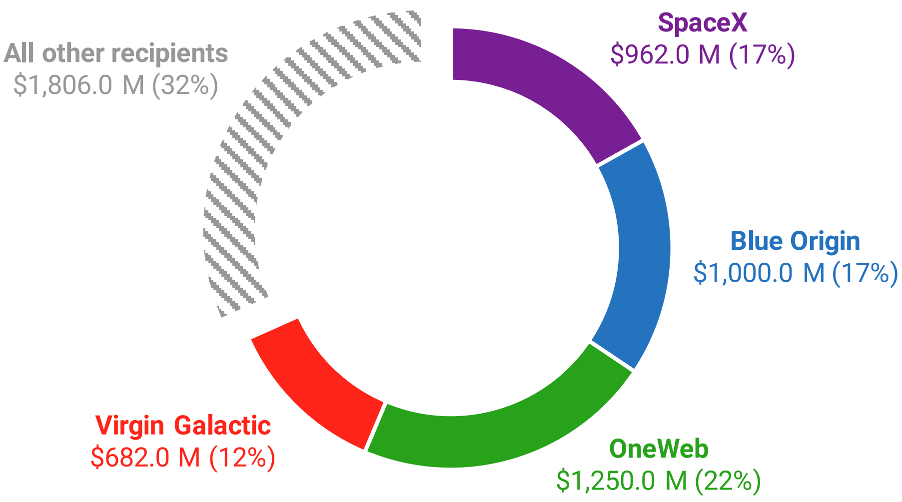

Figure 38: Investment per company in 2019 (Source Bryce, ESPI)

Nonetheless, with over 135 firms invested in and with the attraction of $5.7b of financing over the year, 2019 still proved to be fruitful in the private space sector. In total, over 200 private space companies have reported significant private investment deals since 2000 and out of these 200+ companies, 24 have been acquired for a total value estimated to be close to $4 billion. However, with the private space landscape shifting rapidly, most of these investments have occurred since 2015 with yearly investments surpassing $2 billion ever since.

Types of investment

In 2018, a total of 187 investors financed 82 space start-up companies with almost 90 deals recorded. In 2019, this total was even higher with a total of 135 investments made and the total investment increasing in average by 37% compared to the previous year. The main types of investors include (Bryce categories):

- Venture Capital Firms, investor groups that focus on early stage/seed investment which have a higher risk/reward component.
- Angel Investors, whom represent an individual or a network of high net-worth individuals that tend to invest primarily in equity of varying size.
- Banks, private or government-backed banks primarily investing in company debt.
- Private Equity Companies, investment firms that focus on equity in the private market and established companies.

To date, over 300 VC firms have invested in the private space sector with new investors recorded every year. In 2018, VC firms still represented the largest share of investment in space companies with approximately 46% of the total amount. These firms combined with angel investors comprised two thirds of all investments. 2019 followed the same pattern with VC firms representing $4b of the $5.7b invested. The second source of funding, seed investment, involves primarily the large investments made by industry tycoons such as Jeff Bezos, Richard Branson or Robert Bigelow.

An interesting change is the (limited) development of more risk averse sources such as debt financing and private equity, even though these forms of investment remain secondary with comparison to VC. Debt financing (banks) were almost negligible ($5 million) in 2017 but grew to $254 million in 2018 and then decreased slightly in 2019 by 9%. Private equity firms invested $85m in the space sector in 2018.

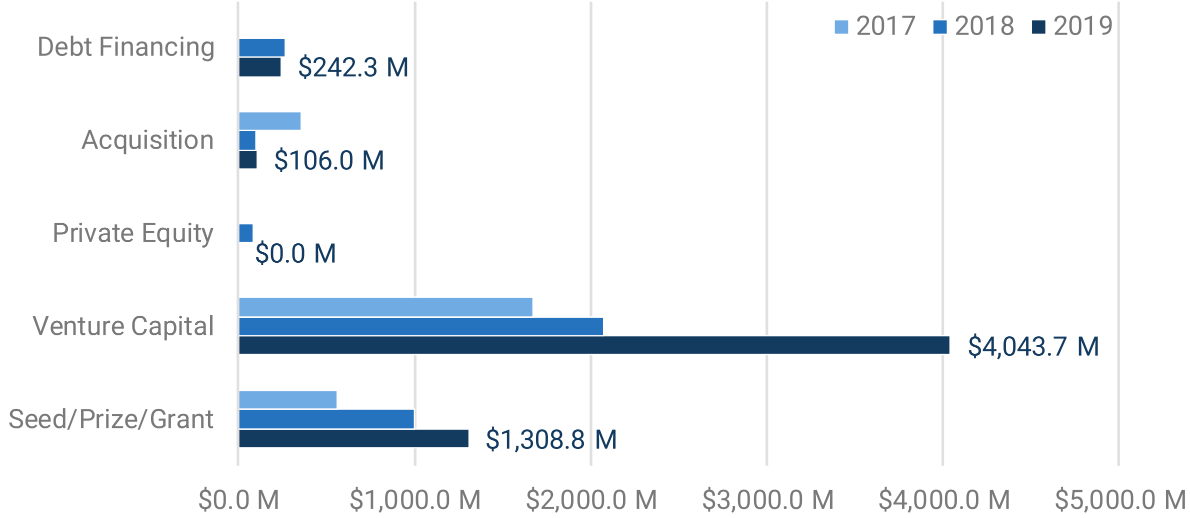

Figure 39: Global space investment by type of investment in 2017/2018/2019 (Source: Bryce)

Geographical distribution of investments and recipients

With the investment in space seeing a sustained compound annual growth rate, and with 2018 and 2019 shattering all past records, perhaps the most noteworthy changes are the increase of investment and investors from outside the United States. However, the USA still represents an overwhelming force in the investment landscape. With a total of $2.6 billion of investment received in 2018 and almost $5 billion in 2019, the USA tallied over total investments made for the rest of the World which were only at $610 million in 2018 and $900 million in 2019.The figure below compares the investment made in the USA to the rest of the world between 2016 and 2019.

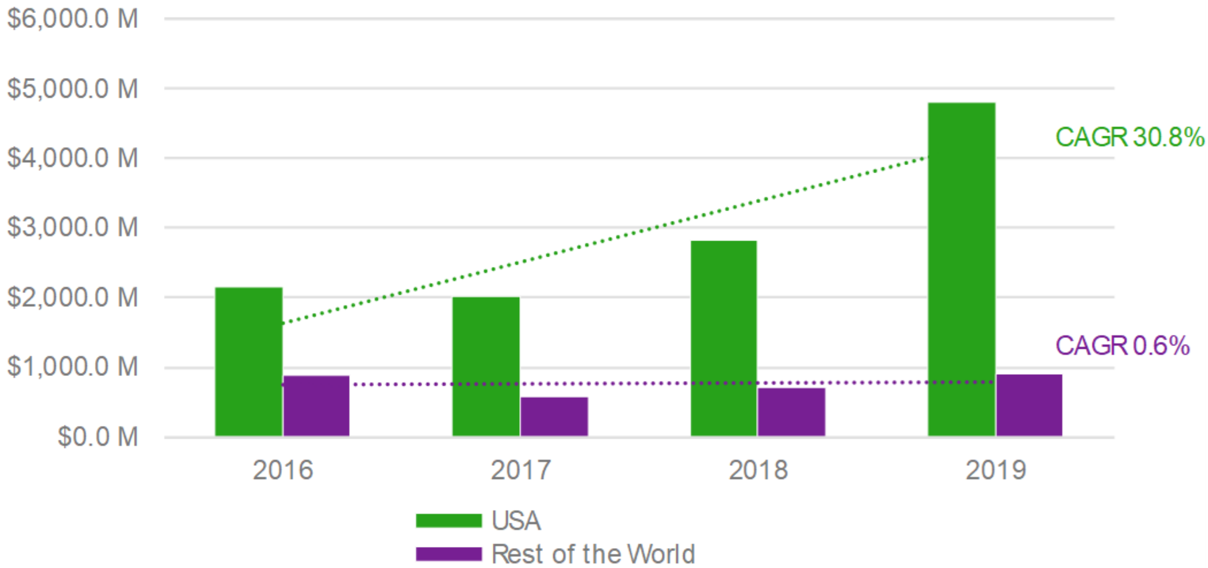

Figure 40: Comparison of investment in the USA and rest of the World 2016-2018 (Source: Bryce)

The outcome is an overwhelming dominance of the American market with a compared CAGR between 2016 and 2019 of 30.8% for the USA and only 0.6% for the rest of the World. However, the numbers from the figure above bring an incomplete perspective, as SpaceX, Blue Origin, Virgin Galactic and OneWeb account for a vast majority of U.S. investment. Leaving aside these companies, investment in U.S. companies actually compares to investment in the rest of the World, at around $900 million.

Another way to look at investments geographically is to consider the number of investors and the localization of investments made. The figure below shows the variation of the private space investment landscape since 2017.

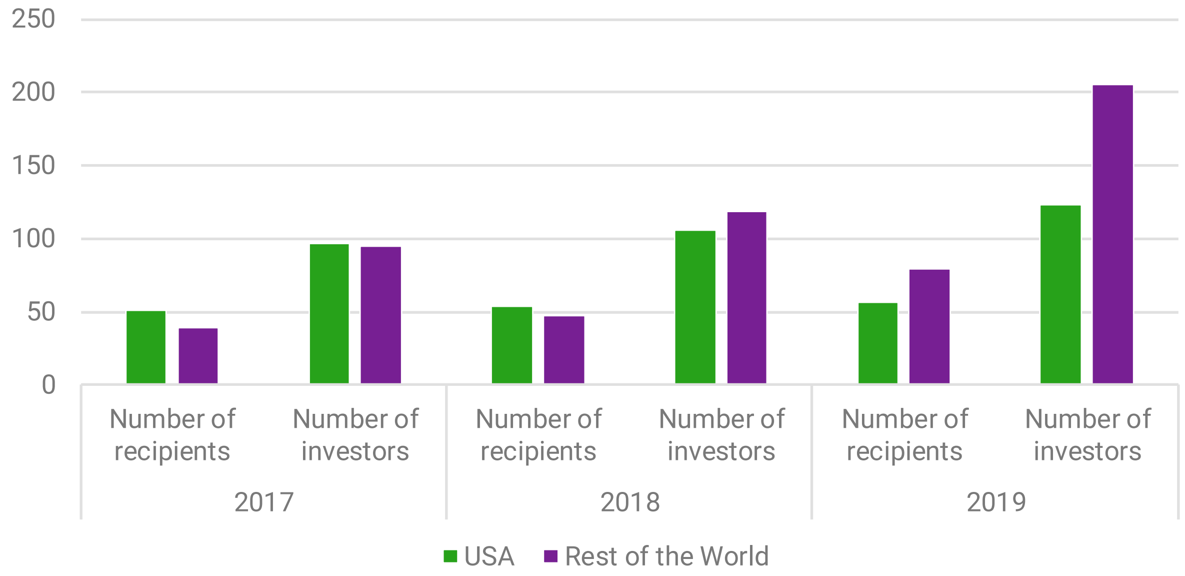

Figure 41: Comparison of investment statistics between USA and Rest of the World (Source: Bryce)

In 2017, we saw 97 American investors versus 95 for the rest of the world. In 2018, we saw 106 American investors and 119 coming from either Europe or China. 2019 saw 123 American investors versus 2015 investors from the rest of the World. As such, the total number of investors increased by 17% between 2017 and 2019. The number of European investors increased by 36% over the same time period and American investors increased by 9%. In terms of investments received, there is also a slight increase. In 2017, Europe and China were the recipients of 39 investments and in 2018 of 47 investments, all while the US saw its number of recipients increase by only 3, from 51 to 54. 2019 accelerated this remarkable trend and saw the amount of non-US start-ups receiving financing grow by almost 70%:79 in 2019 compared to 47 in 2018.This also represents the first time we see more non-US companies receiving investments than US firms (79 vs 56).

As such, the most noticeable trend is that both the number of recipients and investors for the rest of the World have been steadily approaching those of the US until 2018 and in 2019 there were both more investors and investments made for the rest of the World than for the US. This is important not only because it points out a strong shift in investor’s willingness to look at European and Chinese markets but also because it paints a different picture from the one we see when looking at the quantity of investments made geographically.

3.3.2 Private investment and entrepreneurship in the European space sector

In 2019, ESPI initiated a new report series "Space Venture Europe"[437] providing information about private investment and entrepreneurship trends in the European space sector on the basis of two complementary tools:

- The ESPI investment database recording available data on private investment in European space start-ups for the period 2014-2019
- The ESPI space entrepreneurship survey collecting the views of European space start-ups on their business and situation, on the European ecosystem and on their expectations for the future

This section provides an extract of Space Venture Europe 2018 and 2019. More detailed information is available in the reports, on ESPI website.

Overview and evolution

Private investment in European space start-ups has dramatically developed over the past few years. Over the period 2014-2019, ESPI recorded 175 private investment deals concerning European space start-ups for a total amount of €766.4 million. This value does not include investment in mature space ventures such as the acquisition of Hispasat by Red Eléctrica de España, of M7 Group SA by Canal+ or of Newtec by ST Engineering in 2019. Involving megadeals in the tens or hundreds of millions of euros, the total value of private investment in European space ventures, including mature ones, would reach €4,206.3 million during the period.

The period 2014-2019 has been marked by a steady growth of private investments in European space start-ups. Although the overall value of deals decreased in 2019 (€187.8 million, -14,4%), the number of deals actually went from 43 in 2018 to 56 in 2019. This is a conservative estimation as the value of some transactions was not disclosed.

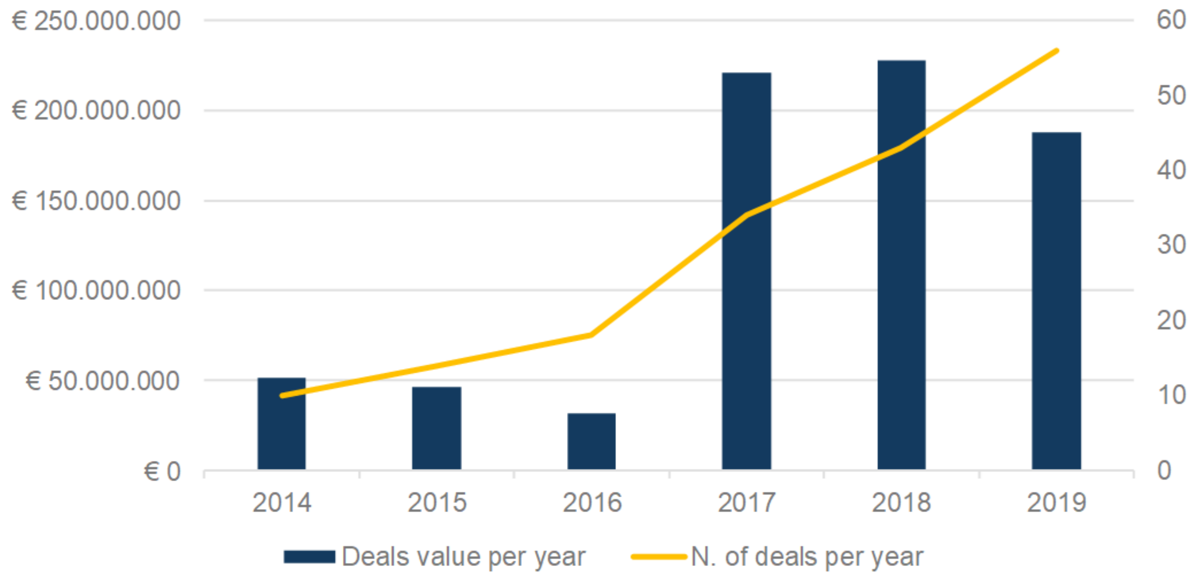

Figure 42: Private investment in the European space sector (Source: ESPI)

[437] European Space Policy Institute. *Space Venture Europe 2018* (February 2019) and upcoming *Space Venture Europe 2019*. Available at: https://espi.or.at/publications/espi-public-reports

Types of Investment

During the period 2014-2019, 66% of the investment came from VC firms. This accounted for a total of 75 deals and a volume of investment worth €480 million. Seed/Prize/Grants and Acquisition correspond, each to 9% of the value. This was followed by private equity, public offering and debt financing making up for the final 16%. While this may mark the sector's dependence on VC firms, it also points out that other sources are not uncommon in the private space landscape.

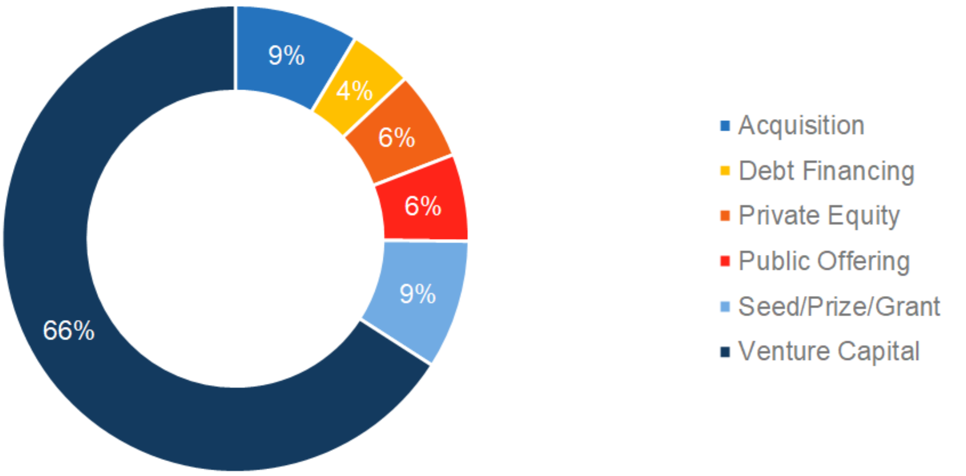

Figure 43: Share of total investment by category 2014-2019 (Source: ESPI)

When comparing on a yearly basis, the types of investment are highly variable. While VC firms consistently (apart from 2014) prove to be the main source of financing, the respective shares of seed, debt financing, acquisition and public offering vary significantly on a year to year basis. In 2017 for example, acquisition was the second highest source of financing before practically disappearing for the years 2018 and 2019. Public offering is another example, while being significant in 2017, it decreased in 2018 before disappearing altogether in 2019. However, the VC trend was confirmed in 2019 where the share of VC firms for the total private European space landscape was 70%.

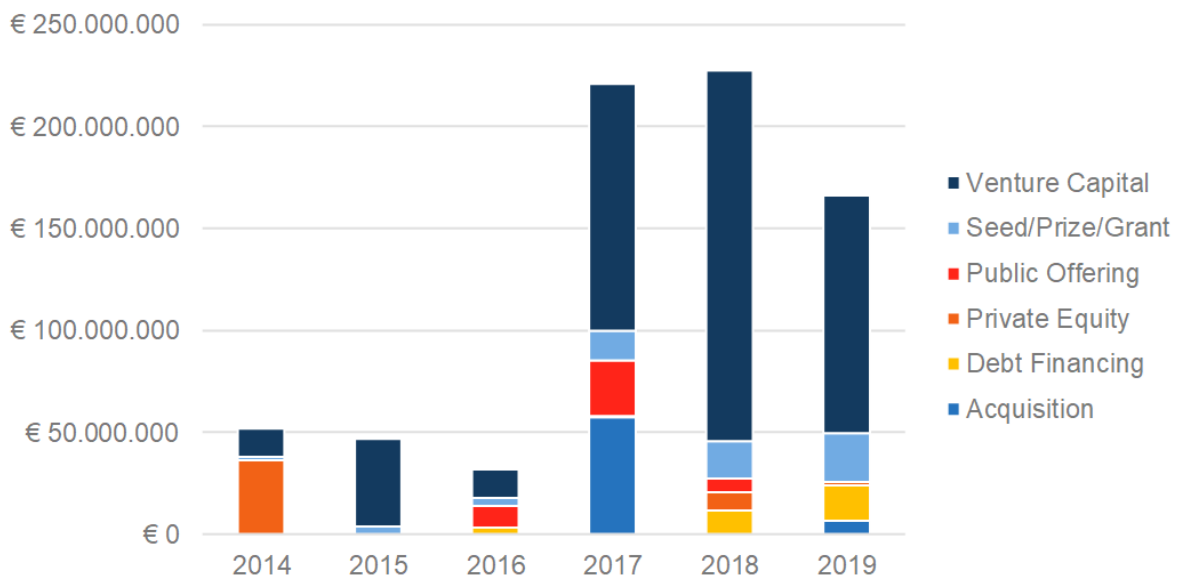

Figure 44: Value of investment by category and year (Source: ESPI)

Distribution of investment across of Europe

In 2019, 37% of the total investment value was concentrated in the 5 top deals, corresponding to €71 million. These deals concerned different company profiles located in the UK, Germany and Switzerland.

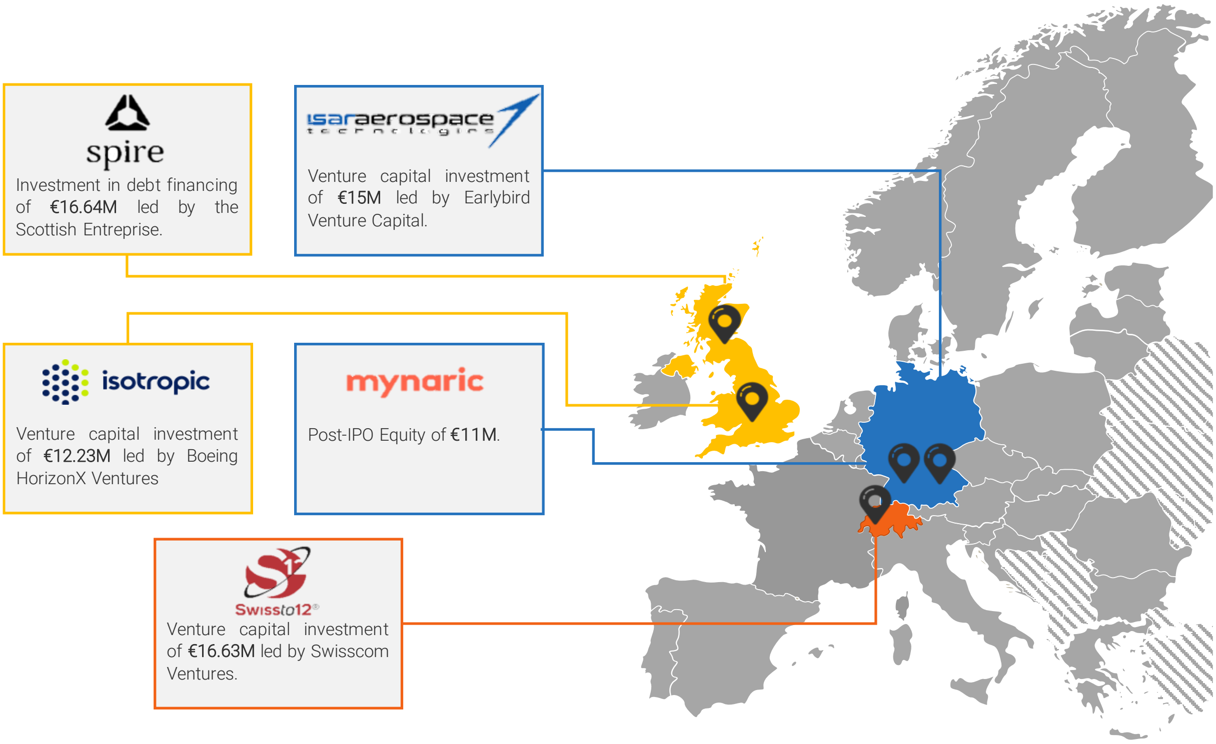

Figure 45: Five major European private space deals in 2019 (Source: ESPI).

Interestingly, the distribution of investment by country is not always proportional to national space budgets. Countries like France and Germany which are the highest contributors in Europe are not necessarily the ones that receive the most private investments. Over 2018 and 2019, countries like the United-Kingdom, Ireland and Finland, with a much smaller budget, received much higher volumes of private investment than the bigger EU donors.

Many factors are at play here and each country presents a different profile. The United Kingdom specifically stands out as a leader for space entrepreneurship in Europe. The country counts a large number of start-ups addressing different space markets and with many investors active in the space sector. Over the period 2014-2019, a total of 60 deals accounting for €320 million were recorded in the United Kingdom. In 2019, out of the five major deals, two were UK based.

Overall, major investment deals were recorded in most European countries. Most of the investment value comes from European investors, although European space start-ups also attracted private funds from Asia, the United States and other countries.

Entrepreneurship ecosystem in Europe

The results of the ESPI space entrepreneurship survey 2018 showed that:

Space start-ups are radically more innovation- and global-oriented than other European start-ups	• Space start-ups pursue innovation at a global level for each business component: Product (71%), Technology (60%), Processes (41%), Business model (47%). In comparison, only 52% of "non-space" start-ups offer a product that is a global innovation. • 63% of space start-ups address global markets. In comparison, only 24% of "non-space" start-ups address global markets.
The space sector offers a fertile ground for entrepreneurship	• Start-ups consider the space sector rich in opportunities both for innovation (62%) and commercialization (60%). • Most ventures structure their value proposition around New Space trends (e.g. CubeSats and system miniaturization, new launcher concepts, big data and digitization, analytics, etc.).
As compared to other sectors, space start-ups perceive their business environment as rather hostile but are confident in their growth perspectives	• Space start-ups are more concerned by their business environment than other start-ups (e.g. threats of new entrants or substitute products, bargaining power of customers and suppliers, intensity of competition). • This contrasts very much with the positive evaluation of their business situation (83% consider to be in a satisfactory or good situation) and with their optimistic outlook on the future (73% foresee an even better situation in the future). • This suggests that European space start-ups consider to be well equipped (or backed) to succeed, even in a difficult business environment. • Should European investors share the opinion that the space sector is a difficult business environment, this could represent a major barrier to access to finance.
Space start-ups expect financial and non-financial support, in particular from public sources	• 89% of start-ups benefited at least from one type of external backing and 38% benefited from both financial and non-financial instruments. • 78% of space start-ups are actively seeking financial support, including governmental support for 45% of them, confirming the prominent role of public funding in the sector.
Space start-ups highly value networking and mentoring	• Among non-financial support instruments, space start-ups are most interested in networking events (39%), independent expertise (36%) and competitions (25%) due to a very positive opinion of the benefits of these instruments. • This highlights the great importance granted by European space start-ups to networking to meet and exchange with potential mentors, partners, investors or customers. • This finding supports the recommendation by the European Investment Bank to organise a dedicated annual event for space start-ups.

For space start-ups gaining customers and securing sales is a greater challenge than raising capital	• Key challenges for European space start-ups: • Gain customers and secure sales (27%) • Raise capital (15%) • Manage liquidity and/or cash flow (14%) • Customer acquisition, also the top challenge for other start-ups (20%), is a more significant concern for space ventures. • This challenge mirrors the start-ups perception of a very strong bargaining power of customers in the space sector.

Space start-ups have higher expectations from politics than other start-ups	• Space ventures expect (or need) more support from governments than other start-ups for the conduct of their business and for access to finance:
	• For example, 53% of space ventures count on public support to raise capital, while only 33% of non-space start-ups do.
	• Space start-ups desire a much more entrepreneurship-friendly environment featuring:
	  ○ Improved exchanges between politics, start-ups and established companies;
	  ○ Better cultural acceptance for entrepreneurship and understanding of the need of start-ups.
	• Space ventures also call for a reduction of administrative burden (60%) and tax (57%) but not more than other start-ups.

3.4 European space economy statistics

3.4.1 European space manufacturing industry

Main indicators

ASD-Eurospace, the trade association of the European space industry, provides robust and detailed insights on the state of the industry in its authoritative *Facts & Figures* annual report.[438]

In 2018, the final sales of the European space manufacturing industry decreased by 3.1% to stand around €8,490 million. It is in fact the first time since 2005 that Eurospace records such slowdown of European activity, raising some concerns over the health of the sector. This decrease is a consequence of a strong decline of commercial and export sales of 18.1%, which the 7.3% growth of institutional sales on the same period did not offset. Space industry employment, on the other hand, continued to increase to reach 43,454 permanent staff (in Full-Time Equivalent - FTE) and 46,369 total staff when including other personnel, not directly employed by the companies.

Key figures employment (FTE) and sales (M€)	2016	2017	2018	Variation
Direct industry employment (FTE)	41,302	42,831	43,454	+1.5%
Other personnel working on site (FTE)	3,025	2,633	2,915	+ 10,7%
Total space industry employment (FTE)	44,327	45,465	46,369	+ 2,0%
Final sales (M€ current e.c.)	8,169	8,761	8,490	-3,1%

Table 16: Main industry facts
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European space industry results in 2018 raise concerns

In a changing global space context, the figures issued by Eurospace seem to convey an alarming signal regarding the leading role played by the European industry on global commercial space markets.

2018 has been remarkable with space budgets peaking at €10.2b but public funding only partially bridged the gap generated by the contraction of commercial orders in particular on the GEO satcom market. Historically, the European space strategy has been very successful at supporting the competitiveness of the space industry and allowing it to gain market shares for the benefits of the space sector at large. As a result, commercial markets played a major role in the development of a capable and cost-effective space industry while European institutions were offered access to space at the best conditions. This strategy supposes the existence of sizable, open and accessible commercial markets and such shrinking of the commercial demand was certainly not envisioned.

A key question to be addressed by policy makers now is to decide how the European space policy should be adapted to the new reality of global markets, with profound implications for the European approach to procurement and for public mechanisms supporting industry competitiveness.

[438] ASD-Eurospace. *Facts and figures – The European Space industry in 2018* (June 2019)

Industry sales by customer segments

The distribution of industry sales by customer segment shows that the European space industry addresses primarily domestic markets: in 2018, public and private European customers accounted for 83% of industry sales. The European public sector (ESA, EUMETSAT, European Commission, national space agencies and other civil and military institutions) remains the principal source of revenues for the European space manufacturing industry, corresponding to 64% of final sales in 2018.

The importance of European public programmes for the industry increased over the last decade as public sales grew faster than commercial sales and export. From this standpoint, 2018 deepened this gap with an increase of 7.3% of sales to European public customers and a decrease of 17.1% and 19.2% of commercial and export sales respectively. Actually, 2018 marks the 4th consecutive year of decline for export revenues (-28% since 2015), a blow for an industry relying more than its competitors on export markets. Despite a massive decrease between 2017 and 2018, sales to European private customers on the other hand, are still higher than in 2014, 2015 and 2016. 2017 was actually an exceptionally good year for the European industry on the commercial market.

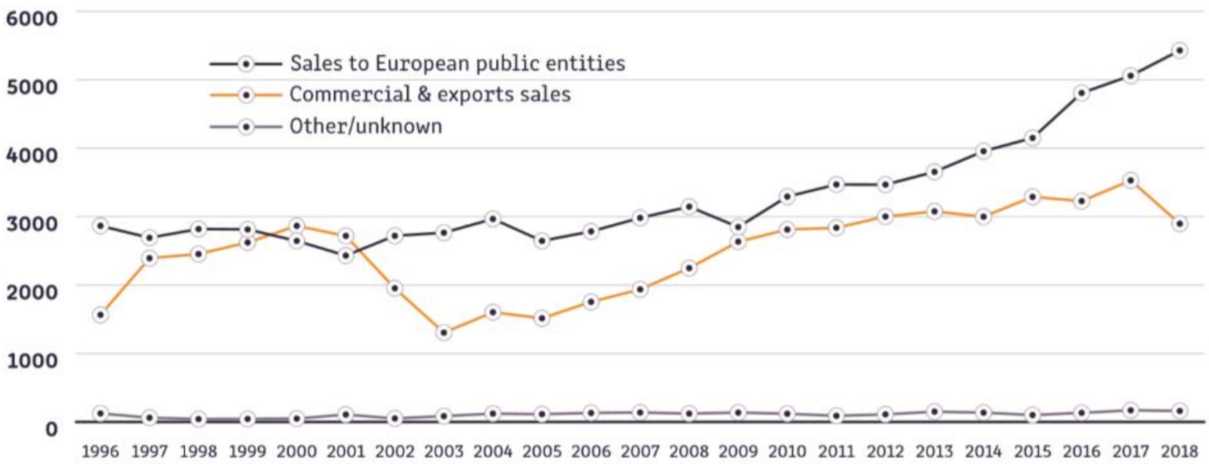

Figure 46: Sales by main market segment - European public entities vs Commercial and exports (M€)[439]

(Copyright by Eurospace - all right reserved, used with permission, reproduction forbidden)

Final sales by main customer segment (M€)	2016	2017	2018	Variation
European public customers	4808	5060	5430	+7.3%
European private customers	1325	1821	1510	-17.1%
Other European customers	77	90	104	+ 14.8%
Public customers RoW	736	808	593	-26,6%
Private customers RoW	1166	901	795	-11.8%
Other customers RoW	56	80	57	-28.2%

Table 17: Final sales by main customer segment (M€)

(Copyright by Eurospace - all right reserved, used with permission, reproduction forbidden)

[439] Commercial and export sales include the sales to: Privately owned satellite operators worldwide (e.g. Eutelsat, Intelsat), public satellite operators outside Europe (e.g. Arabsat, RSCC, Chinasat), privately owned launch services operators worldwide (e.g. Arianespace), public space agencies outside Europe (e.g. NASA, KARI), military institutions outside Europe, space manufacturing companies outside Europe.

Industry sales by product segments

The distribution of industry sales by product segment shows that satellite application systems, including the development and production of telecommunication, Earth observation and navigation systems, is the main market of the European space industry. This segment has been steadily growing since 2005, until 2018. Indeed, the reported decrease on commercial and export markets mainly concerns operational systems (mostly satcom).

Launcher systems are the second source of revenue. This market concerns mostly the design, development and production of European launchers of the Ariane and Vega families. Eurospace reports that a small share of revenues is associated to the export of launcher sub-systems and equipment for foreign launchers.

Scientific systems, including human spaceflight, exploration, Earth and space science programmes is the third industry market; and ground systems and services, including electric and mechanical ground segment equipment (EGSE & MGSE) as well as engineering and other specialised services is the fourth market.

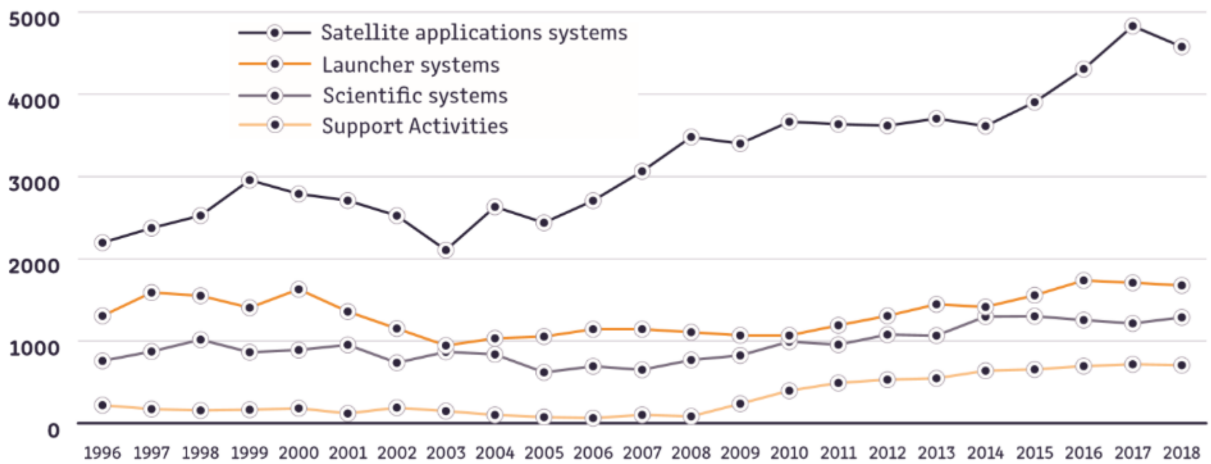

Figure 47: Sales by main market segment - type of system (M€)

Final sales by main product segment (M€)	2016	2017	2018	Variation
Launcher systems	1,737	1,709	1,677	-1.9%
Satellite applications systems	3,664	4,158	3,792	-8.8%
Scientific systems	1,255	1,215	1,288	+6.1%
Ground systems and services	1,339	1,390	1,493	+7.4%
Other & Unknown	174	290	239	-17.3%

Table 18: Final sales by main product segment (M€)

Industry employment

Employment in the European space industry has been steadily growing since 2005. A total of 904 jobs (FTE) were created in 2018 (+2%), including 623 direct jobs (+1.5%). The sector now employs a total of 46,369 workers (FTE). The space sector is a male-dominated industry where women count for only 22% of employment. The average age is 44 with a majority of employees in the 49-58 age range. The industrial space workforce is also highly qualified with 74% of employees having attained a tertiary level of education. The geographic distribution of industry employment within the European space sector is highly concentrated and grossly proportional to national space budgets, with some exceptions in countries with smaller budgets and workforce. Comparably to public budgets, almost 90% of the direct space industry employment is located in 6 countries: France, Germany, Italy, the United Kingdom, Spain and Belgium.

Industry employment (FTE)	2016	2017	2018
Austria	387	422	420
Belgium	1,767	1,752	1,554
Czech Republic	176	187	187
Denmark	228	238	257
Estonia	39	39	39
Finland	173	186	168
France	14,555	14,949	15,593
Germany	7,288	7,825	8,426
Hungary	97	97	97
Ireland	61	61	61
Italy	5,019	4,963	5,307
Luxembourg	26	30	36
Netherlands	968	965	1,166
Norway	334	364	419
Poland	60	213	213
Portugal	173	175	165
Spain	3,143	3,329	3,783
Sweden	914	954	976
Switzerland	878	831	836
United Kingdom	3,535	3,722	3,750

Figure 48: European space industry employment by country, 2018

3.4.2 European remote sensing industry insights

Every 2 years, EARSC, the European Association of Remote Sensing Companies, conducts an assessment study on companies whose core business is linked to remote sensing. The ventures participating in the survey were 515 throughout Europe and 96% of them either small or medium enterprises. According to the report, the number of companies active in the field of Earth Observation-based services grew at a rate of 5.8% per annum from 2016 to 2018. The total annual turnover in 2018 was approximately €1.25 billion, marking a growth of 10.6% over 2017.[440] The overall EO sector has been growing at a stable CAGR of about 10% over the last 5 years.

The respondents employ about 8400 staff and 77% of the companies are planning to have a slight or significant increase in the personnel in the next year. Considering the European EO workforce by gender, only 30% of employees are female. The sector workforce is characterized by a high level of education: 90% of employees hold University degree with 60% having also post graduate degree. Considering the business model of the respondent companies, the highest share of revenue comes from Value adding services (26%), followed by Data reception and distribution, which has increased by 9% from 12 to 21% in 2018.

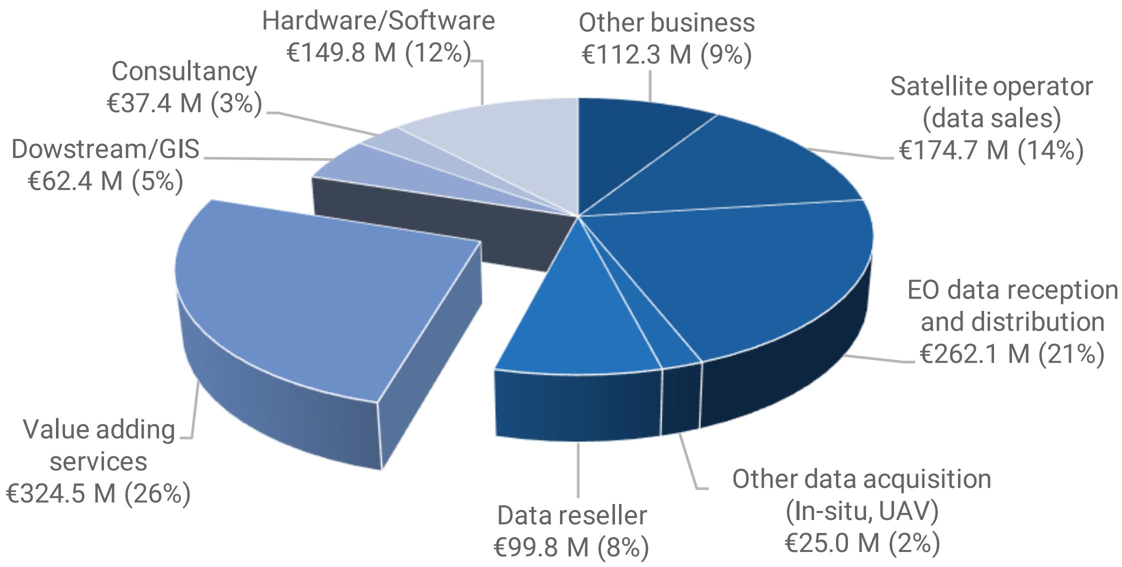

Figure 49: Split of activities based on 2018 revenues (Source: EARSC)

With regard to the geographic distribution of the companies within the European borders, a handful of countries namely UK, France, Germany, Italy and Netherlands host the vast majority of the companies. Europe remains the biggest market for European providers, however the share of revenues from sales in North America have grown from 10% in 2016 to 15% in 2018. On the other hand, the Asian market declined as share of total sales from 12% to 7% in 2018.

Public authorities still are the main customers with 66% of share (+4% from 2016), while local authorities declined from 9% to 7%, outperformed by Research and development sponsors (from 9% in 2016 to 15% in 2018). The sector that has gathered the most customers in 2018 is defence and security, marking an increase of 10% over the last two years. Notwithstanding a decrease of 6% of sales compared to 2016, the agriculture segment is the second in terms of sales, generating 12% of turnover in 2018.

[440] EARSC. *A Survey into the State & Health of the European EO Services Industry* (2019). Available at: http://earsc.org/library/survey-into-the-state-health-of-the-european-eo-services-industry-2019

3.4.3 European GNSS sector

The European Global Navigation Satellite Systems Agency GSA released the 6th edition of its GNSS Market Report in October 2019.[441] According to the report, the global installed base of GNSS devices included over 6.4 billion units worldwide and the global GNSS market was worth €150.7 billion in 2019. The GSA expects this value to double over the next decade with annual revenues reaching €325 billion by 2029 for an installed base of 9.5 billion units. Furthermore, added value services will increase to reach 51% of the GNSS sales, totalling €166 billion by 2029. While mid receivers are set to lead the GNSS growth, high end receivers are expected to contribute to 10% of all revenue while only representing less than 1% of shipments. From a physical standpoint, the majority of GNSS devices are receivers that cost less than 5 euros and smartphones are the category that incorporates the most chipsets worldwide followed by smart wearables and drones. From a geographical standpoint, the Asia-Pacific region represents 30.5% of the GNSS market while the United States and Europe represent 26.7% and 25,5% respectively.

The European market has consolidated its position as one of the World leaders in terms of GNSS market share. In 2019, the European industry accounted for 26.7% of the global GNSS market with revenues in the order of €38.4 billion (+2 points since 2015). The main market segments are Critical Infrastructures, Road, Maritime Technologies, Drones, Surveying and Emergency rescue. In all of these segments the EU owns an above average share of the market. Beyond the overall market segments, Europe holds a significant market share in Rail (51%), Agriculture (43%), Road (33%) and Aviation (34%) where it remains a market leader.

While the United States continues to lead the global GNSS market (at 28% of total industry revenues), thanks to key components & receiver manufacturers, system integrators and service providers, Europe is closing the gap. Currently accounting for 26.7% of total industry revenues, the total revenues estimated are expected to jump by almost 100% to reach €65.3 billion in 2029. The figure below shows the development excepted for the European Union market between 2019 and 2029. With an expected device per capita of 2.1 in 2029 and with the development and implementation of Galileo across most European sectors, the EU's influence is expected to last.

	2019		2029	
	EU28	Share of World	EU28	Share of World
Installed Base	700 million	15.9%	1 billion	11%
Revenue (€)	€38.4 billion	26.7%	€65.3 billion	20.1%
Device per capita	1.4	n/a	2.1	n/a

Table 19: EU28 GNSS market in 2019 and forecast in 2029 (Source: GSA)

Many other key statistics are publicly available in the GNSS Market Report.

[441] GSA. GNSS Market Report 2019. Available at: https://www.gsa.europa.eu/market/market-report

4 Launches & Satellites

4.1 Global space activity evolution 2000-2019

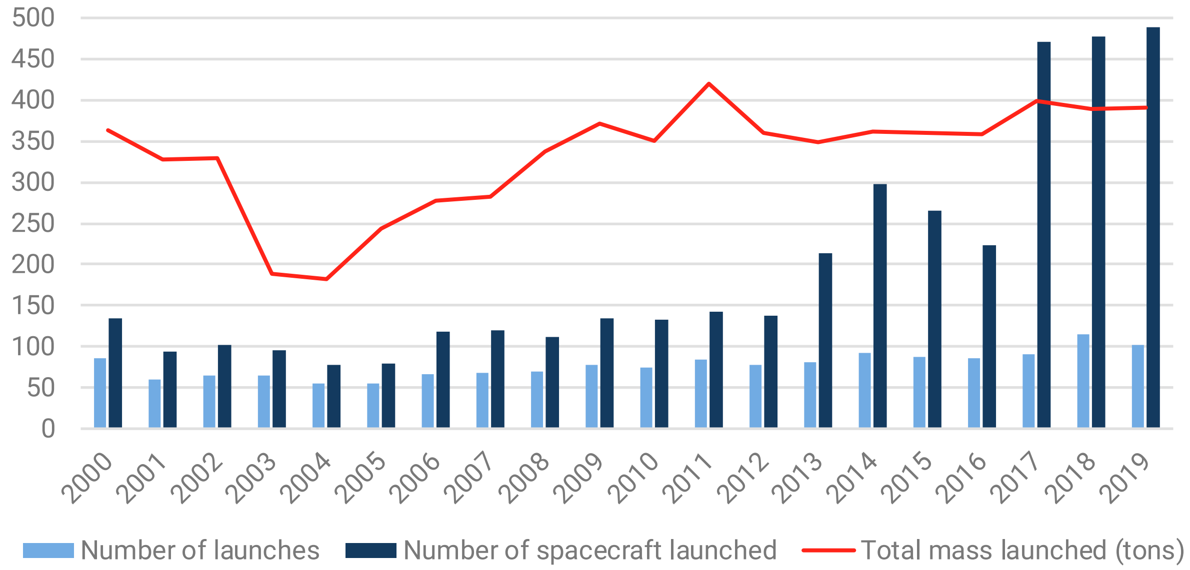

Figure 50: Evolution of launch activity over time (2000-2019)

With 103 launches worldwide, the number of launches decreased by 10.5% in 2019 as compared to the 114 launches in 2018, a record year. The number of spacecraft launched increased to reach 489 in 2019, 2.5% more than the previous record set in 2018 with 477 payloads put in orbit. The total mass launched remained stable with 385.2 tons put in orbit, just 0.6% more than last year.

Overall, the space activity in 2019 shows a comparable profile to the ones observed since 2017.

The total number of spacecraft launched per year has been multiplied by more than 3 in less than a decade. This massive growth did not translate into a comparable increase of the total mass launched which has been rather stable over the decade, ranging between 360 and 400 tons put in orbit every year since 2012. This highlights the explosive growth of small spacecraft (below 500kg) since 2013 and in particular over the last 3 years. While small satellites accounted for only 30% of satellites launched in 2010 (42 satellites), the category corresponded to more than 80% of all spacecraft launched in 2019 (392 satellites).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number of launches	74	84	77	81	92	87	86	91	114	103
Spacecraft launched	133	142	138	213	298	266	223	471	477	490
Mass launched (tons)	349.8	420.4	359.8	348.3	362.6	360.1	359.2	400.8	389.4	385.2

Table 20: Key space activity statistics (2010-2019)

Analysts foresee a steady growth of the number of satellites to be launched over the next years, driven, among other factors, by broadband mega-constellation projects. Involving heavier satellites than CubeSat constellations, these projects would also lead to an increase of the mass launched every year and consequently of the number of launches.

4.1.1 Launch activity evolution by country and orbit

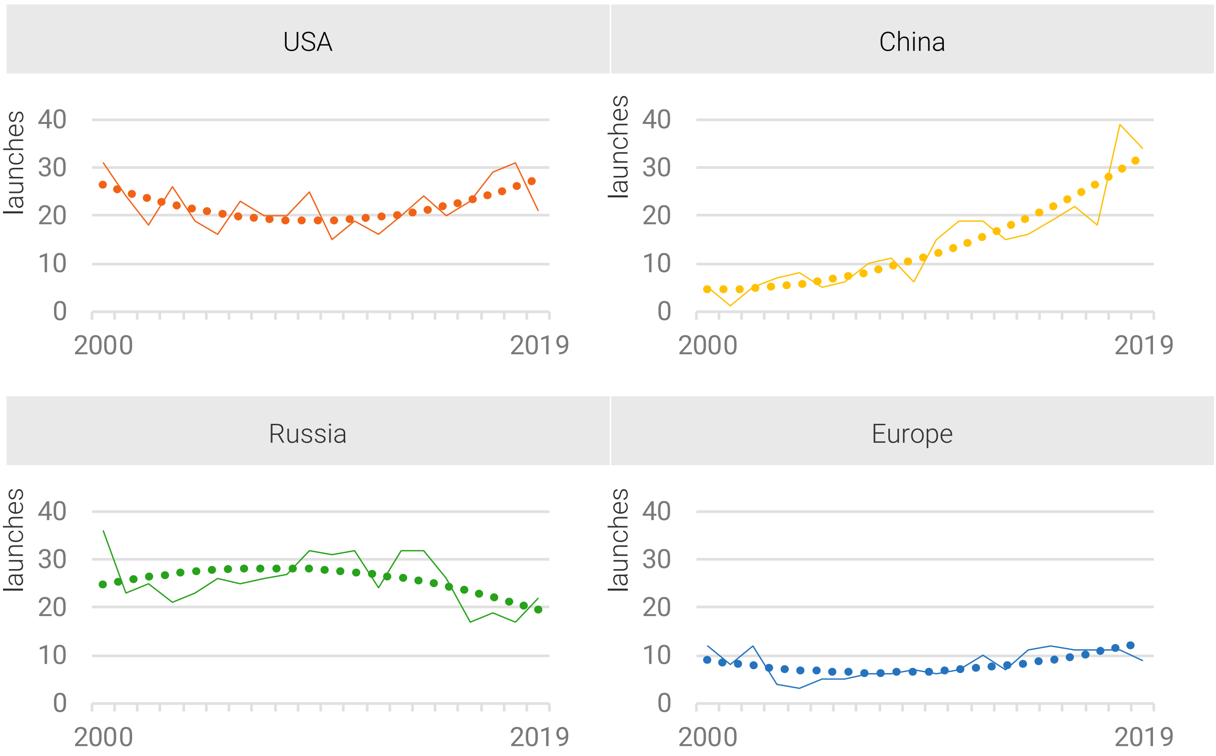

Figure 51: Evolution of the number of launches per country (2000-2019) with trendline

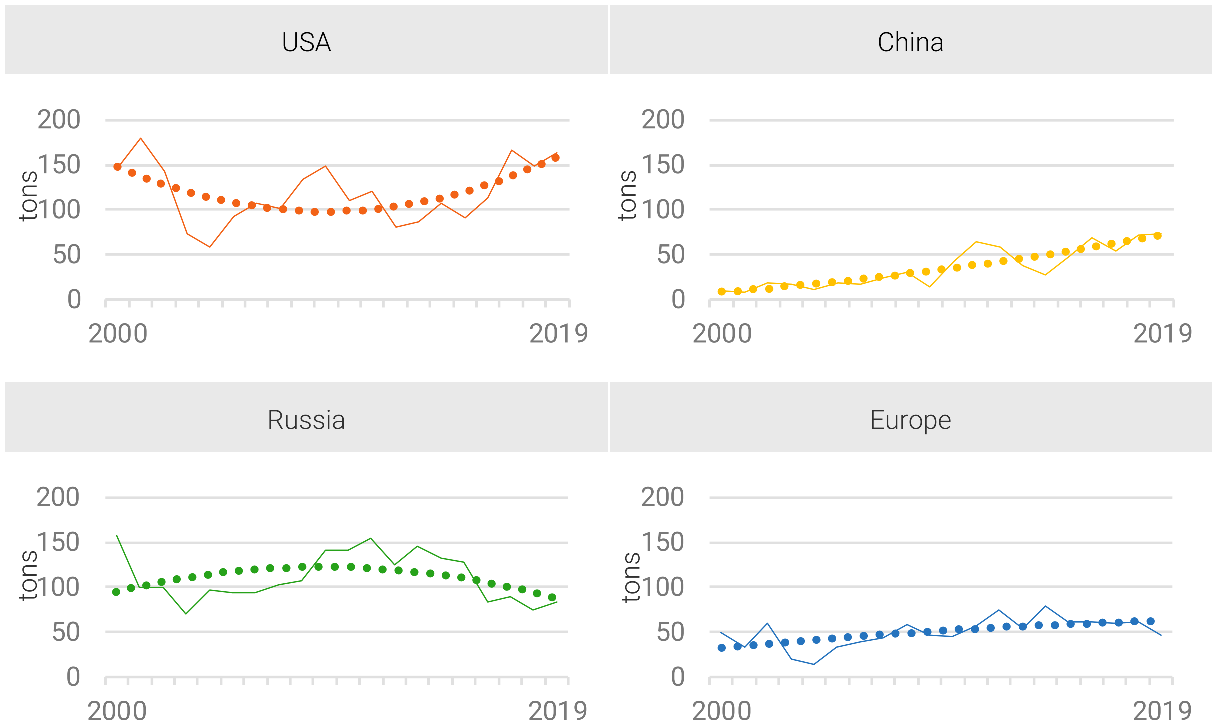

Figure 52: Evolution of the total mass launched (in tons) per country (2000-2019) with trendline

The evolution of the activity of World leading launch countries (United States, Russia, Europe, China) shows very different profiles:

- United States: after a decrease related to the retirement of the space shuttle and other factors, the U.S. activity is now experiencing a new growth, largely driven by new launch service providers such as SpaceX and the recovering of the capacity to service the ISS, at least for cargo delivery at the moment.
- Russia: along the rest of its space sector, the launch activity of the historical leader experienced a sharp decrease both in number of launches and mass launched. Reliability issues of the Proton rocket also contributed to this decrease. Today, the servicing of the ISS corresponds to a significant share of the Russian launch activity in terms of number of launches (30% of Russian launches in 2019) and of mass launched (60% of the total mass put in orbit in 2019).
- Europe: the launch activity remained rather stable around 10 launches and 50 tons put in orbit per year. The introduction of new launchers Vega and Soyuz contributed to expanding European launch capabilities.
- China: the Chinese launch activity skyrocketed since 2000 and China has now become the most active launch country in terms of number of launches (39 launches in 2018, a record). This is not yet the case in terms of mass launched. The strong growth in institutional demand from Chinese authorities remains the main driver, as almost all payloads launched by China are domestic and more than 80% are governmental (civil and military).

Despite a strong domestic space sector, other countries such as India and Japan still have a comparatively limited launch activity.

4.1.2 Spacecraft orbit and mass

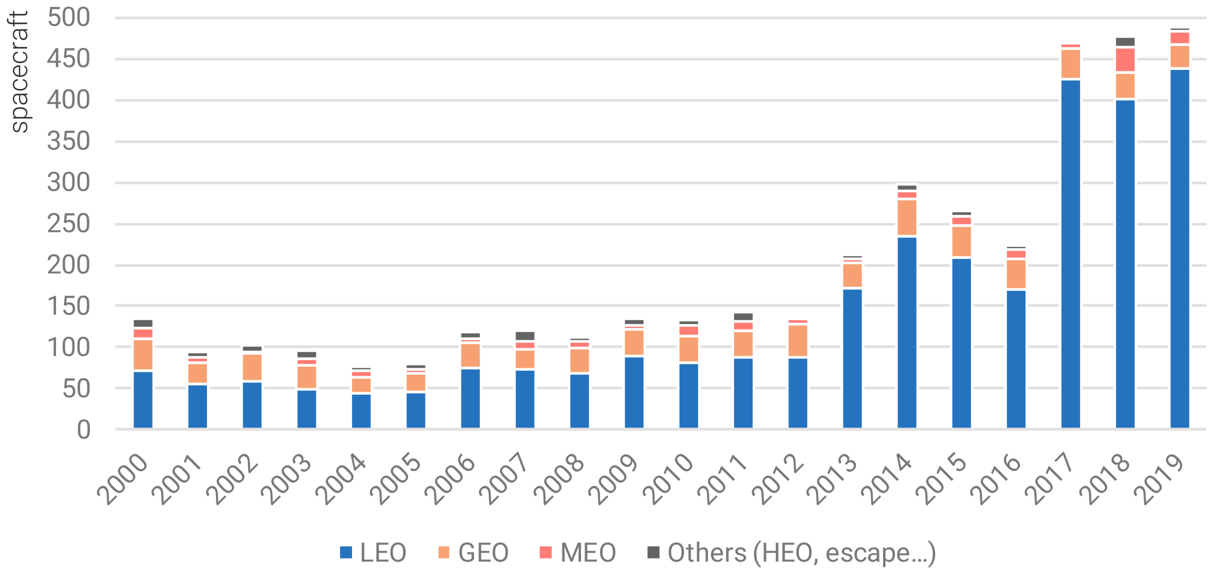

Figure 53: Evolution of the number of spacecraft launched per orbit (2000-2019)

Over the past ten years, the number of satellites launched to GEO remained rather stable, between 30 and 40, with a maximum of 45 in 2014 and a minimum of 29 in 2019. The vast majority of satellites is now launched to LEO (88% of all satellites launched in the period 2017-2019), mainly due to the launch of small spacecraft and CubeSats. The number of launches to MEO also increased but to a much lesser extent (5 in 2009, 16 in 2019, with a peak at 31 in 2018), due to the growing number of countries deploying their GNSS systems (China's Beidou, Europe's Galileo), as well as the development of satcom systems in MEO (e.g. the O3b constellation and its 20 satellites that were launched between 2013 and 2019).

While LEO is the dominating orbit in terms of the number of spacecraft launched (in particular since 2013), it is not the case in terms of mass launched. Between 2017 and 2019, spacecraft launched to LEO accounted for 88% of all spacecraft but only 39% of the total mass (half of which concerned human spaceflight, mostly ISS servicing). On the same period, spacecraft launched to GEO accounted for only 7% of all spacecraft launched but also 50% of the total mass (mostly telecommunication satellites).

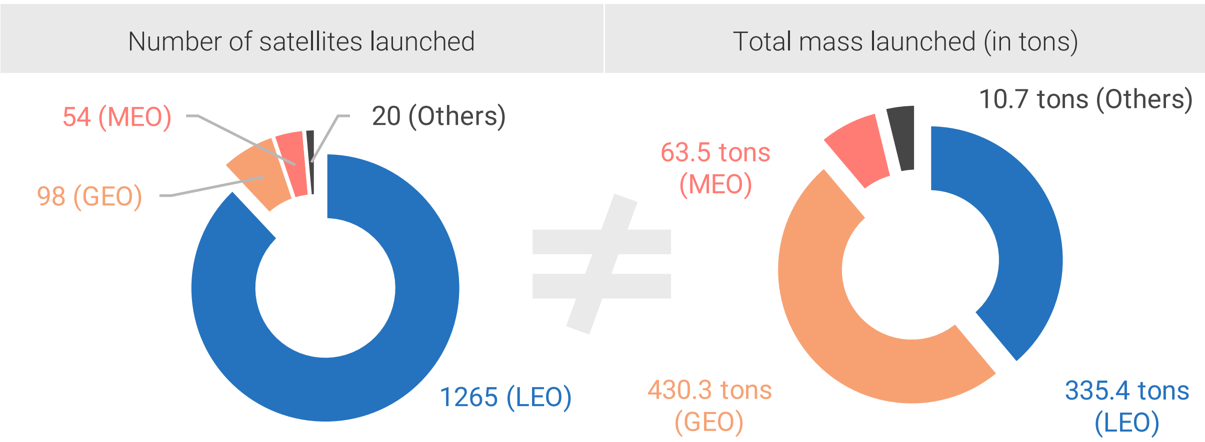

Figure 54: Number of satellites and total mass launched by orbit (2017-2019)

The total mass launched to GEO has increased over time (+34% between 2009 and 2017), with the exception of the last two years, where the mass drastically decreased due to difficulties in the satcom market (only 21 and 23 GEO satcoms launched in 2018 and 2019, as compared to 30 in 2017). The average mass of GEO satcoms also increased to reach 5 tons in 2019 (it was around 3 tons in the 2000s). The total mass launched to LEO is now around 200 tons per year, comparable to the 2000s when the ISS was under construction. Telecommunication and Earth Observation satellites are the two main drivers of this growth.

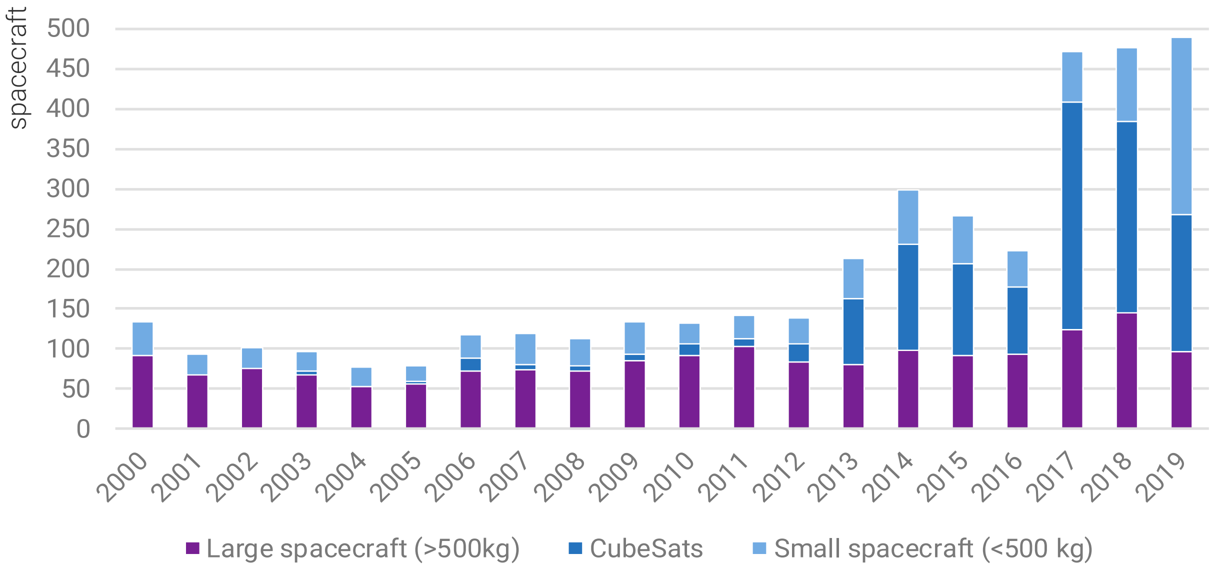

Figure 55: Evolution of the number of spacecraft launched per mass category (2000-2019)

Small spacecraft, including CubeSats, became the dominant category of payloads launched to orbit since 2013. In 2019, the number of small spacecraft launched reached an all-time high: they were four times more numerous than large spacecraft (80% of all spacecraft launched). Beyond the launch of 171 CubeSats (a lower number than in 2017 and 2018), this record is due to the 120 Starlink satellites launched by SpaceX (almost one third of all small spacecraft launched in 2019).

Despite the very high share of small spacecraft launched, larger spacecraft still account for the vast majority of the mass put in orbit every year. In 2019, almost 90% of the mass launched concerned larger spacecraft, despite the launch of multiple Starlink satellites. Even excluding human spaceflight, which involves very heavy spacecraft, large satellites still account for 85% of the total mass launched in 2019. Since 2000, the number and mass of large spacecraft have been highly variable ranging between 53 and 145 spacecraft for 180 to 420 tons. Since 2012 the total mass of large spacecraft stabilized around 360 tons per year.

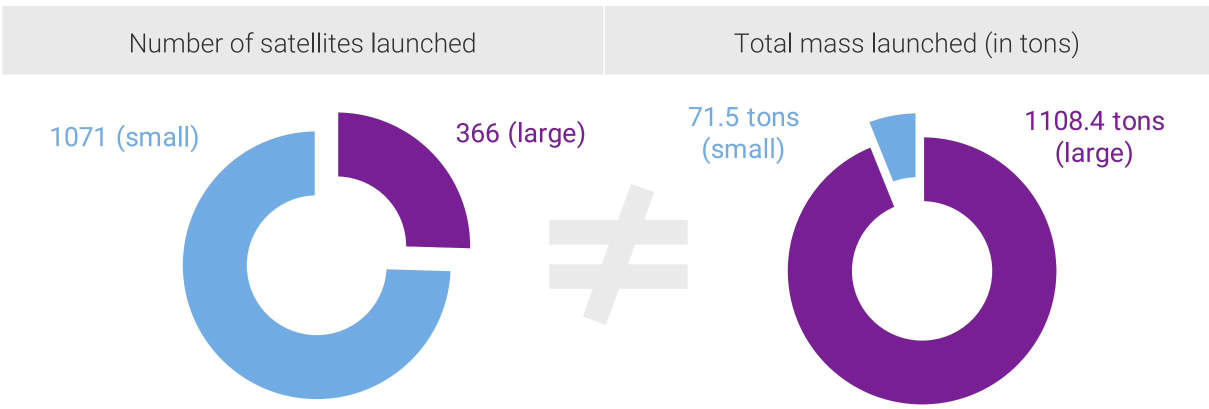

Figure 56: Number of satellites and total mass launched per mass category (2017-2019)

4.1.3 Space missions and markets

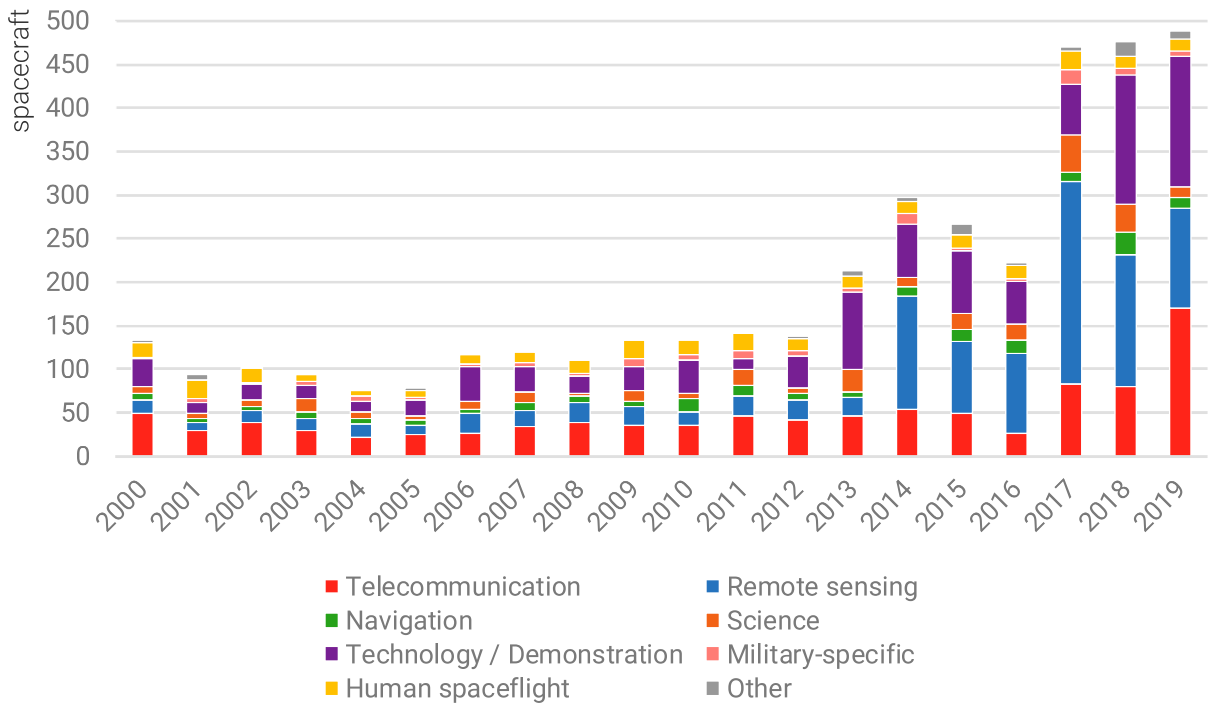

Figure 57: Evolution of the number of spacecraft launched, per mission (2000-2019)

A majority of spacecraft are now launched for telecommunication, remote sensing and technology/demonstration missions. This includes a large share of CubeSats but not exclusively. Telecommunication and remote sensing satellites also concern large satellites accounting respectively for 38% and 14% of the total mass launched in 2019. Representing a smaller share of spacecraft launched but involving heavy spacecraft, human spaceflight and navigation make up respectively 26% and 8% of the mass put in orbit last year.

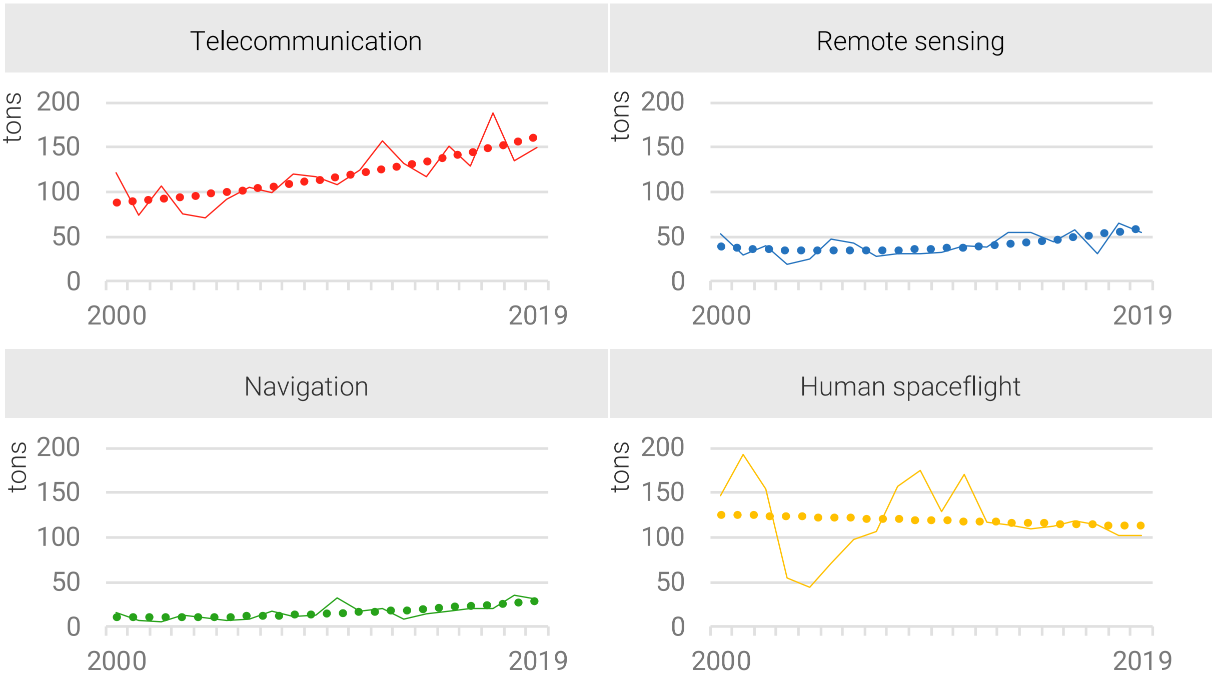

Figure 58: Evolution of the total mass launched (in tons) per mission (2000-2019) with trendline

The high number of telecommunication and remote sensing satellites launched during recent years is mostly due to the launch of constellations, including CubeSat constellations of Planet and Spire but also Starlink, OneWeb or Iridium-NEXT. The number of technology/demonstration satellites also increased substantially in 2018 and 2019 to reach a third of all spacecraft. This increase can be correlated to the rise of the CubeSat standard, as well as other factors contributing to the reduction of the cost of access to space and therefore of conducting tests and experiments directly in orbit. However, the mass of technology/demonstration satellites remains rather low. For instance, in 2018, the 148 spacecraft in this category represented only 2.5% of the total mass launched. Technology/demonstration missions mostly involve small spacecraft and in particular CubeSats, but the test of specific systems such as U.S. crew capsules (e.g. Crew Dragon, Starliner) can sometimes involve much heavier spacecraft.

The number of human spaceflight missions, mostly comprising the servicing of the ISS, remained rather steady with 15 to 20 missions per year (with the exception of the period following the Columbia disaster in 2003). Regarding the mass launched, telecommunications and human spaceflight spacecraft are the two main types of missions contributing to the total mass. Even though the mass related to human spaceflight missions decreased slightly since 2010, more than 100 tons are still launched every year to service the ISS. On the same period, the total mass launched for telecommunications missions increased and 130 to 150 tons are launched every year now, with a record high of 190 tons in 2017 due to the launch of Iridium-NEXT satellites.

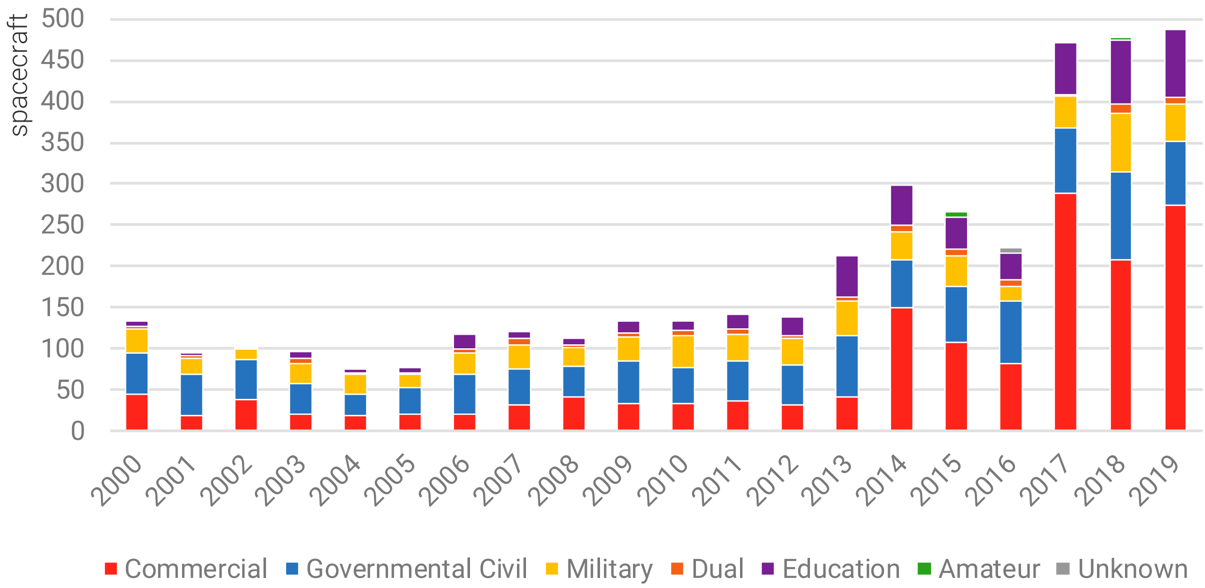

Figure 59: Evolution of the number of spacecraft launched per market (2000-2019)

Data show a steep increase of the number of commercial satellites over the last three years. More than 200 commercial satellites are now launched each year to provide commercial services, representing between 40% and 60% of the total number of satellites launched. Again, the launch of CubeSat constellations plays an important role in this trend but is not the only factor. The total mass of commercial satellites also grew, although to a lesser extent.

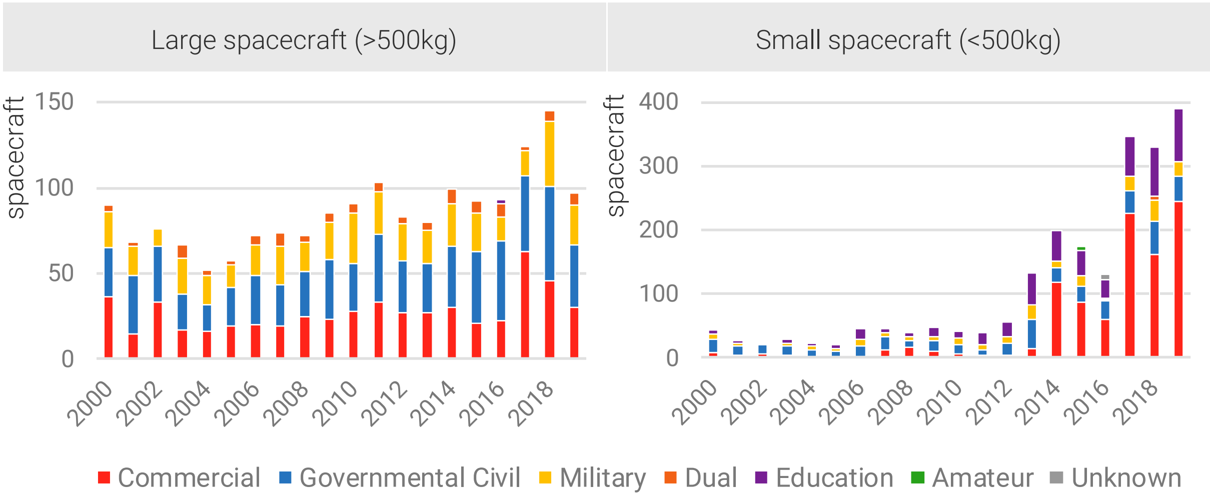

Figure 60: Evolution of the number of spacecraft launched per market and mass category (2000-2019)

While being less numerous than commercial spacecraft, spacecraft used for institutional purposes continue to make up a great share of the total mass launched, representing between two thirds and three quarters of the total mass between 2015 and 2019. The number and mass of military satellites also grew, slightly but steadily, since 2000. Various factors contribute to this growth which concerns a variety of missions, both operational and experimental. Governmental civil missions, which still represent the largest share of spacecraft in terms of mass launched, in particular because of human spaceflight missions, show a more hectic evolution profile since 2000 with several ups and downs.

The significant increase of satellites launched for educational purposes stems from the popularisation of the CubeSat standard, which allows universities to build and launch their own spacecraft more easily. In 2019, over the 82 spacecraft launched for an educational purpose, 60 were CubeSats, explaining why the mass launched for this market remains negligible.

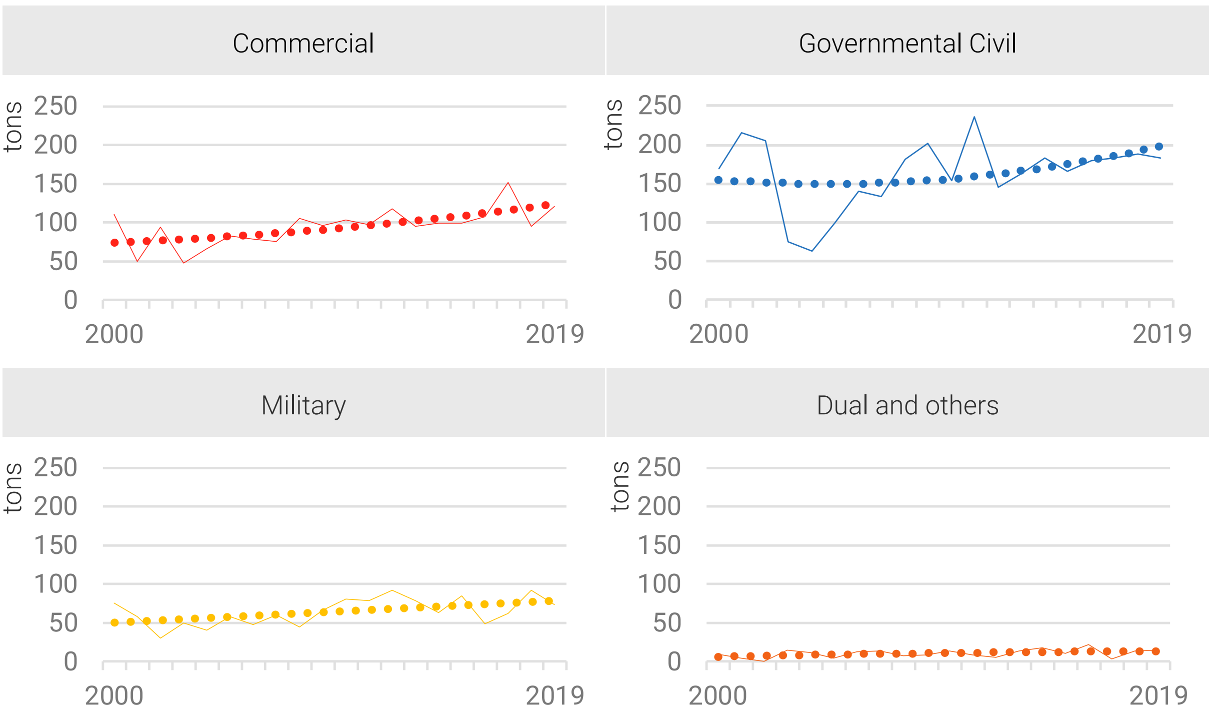

Figure 61: Evolution of total mass launched (in tons) per market (2000-2019) with trendline

4.1.4 Spacecraft manufacturing and procurement by country

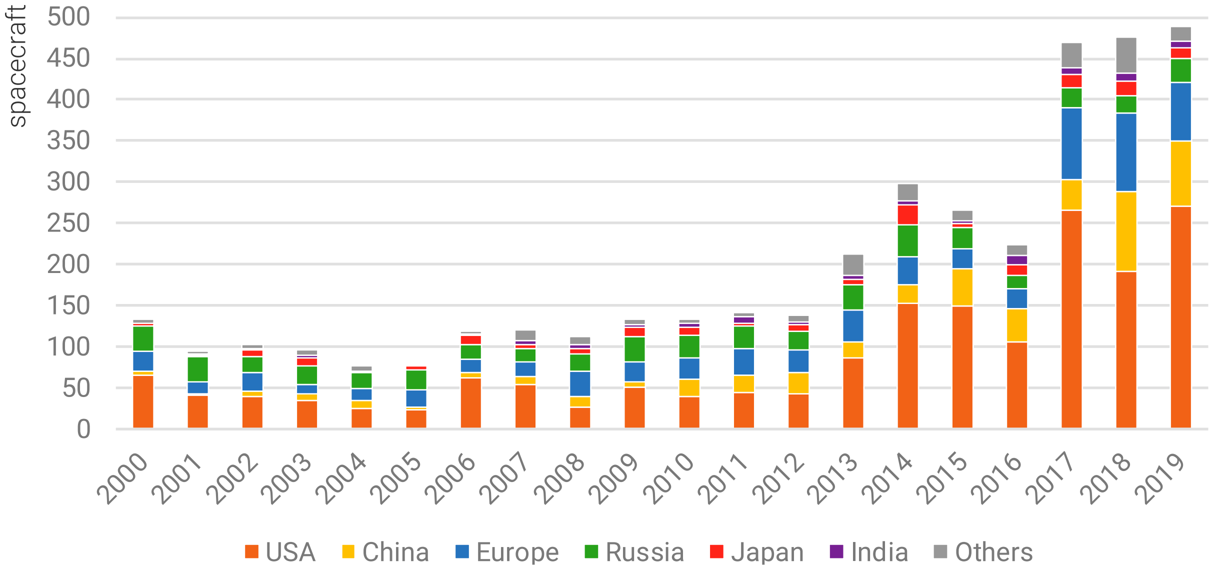

Figure 62: Evolution of the number of spacecraft per manufacturing country (2000-2019)

The manufacturing activity of the United States experienced an increase over the last decade. Over the last 3 years, 50% of spacecraft launched worldwide have been integrated in this country, corresponding to 38% of the total mass. As for the launch activity, spacecraft manufacturing in China also experienced a massive growth. Between 2017 and 2019, China produced 15% of spacecraft that were launched (17% of the total mass). The activity of Russia remained stable with a vast majority of its output concerning human spaceflight vehicles (Soyuz, Progress) and satellites for various domestic public programmes. The output of Europe has been irregular and does not allow to draw a clear trend. Over the last 3 years, Europe manufactured 18% of all spacecraft put in orbit for about 17% of the mass launched.

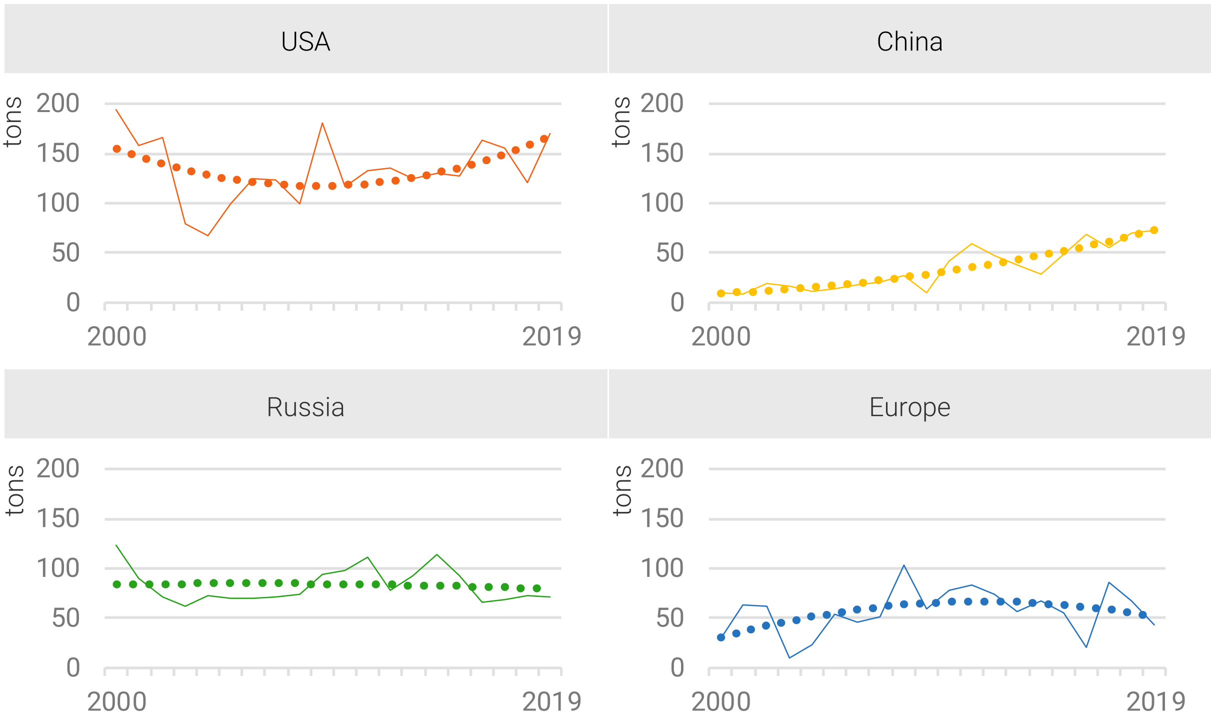

Figure 63: Evolution of spacecraft mass (in tons) per manufacturing country (2000-2019) with trendline

The spacecraft manufacturing activity is highly concentrated in a few countries but also a few companies and organisations.

Over the last 5 years, the top 10 most active organisations produced 80% of the total mass put in orbit. Yet, with the popularisation of the CubeSat standard, a growing number of countries and organisations are able to develop a spacecraft, even though very simple for most of them. Since 2015, more than 350 organisations have produced a satellite, including industries, agencies, governmental bodies, universities, research institutes and others.

This concentration is even more visible on the commercial market (mostly telecom):

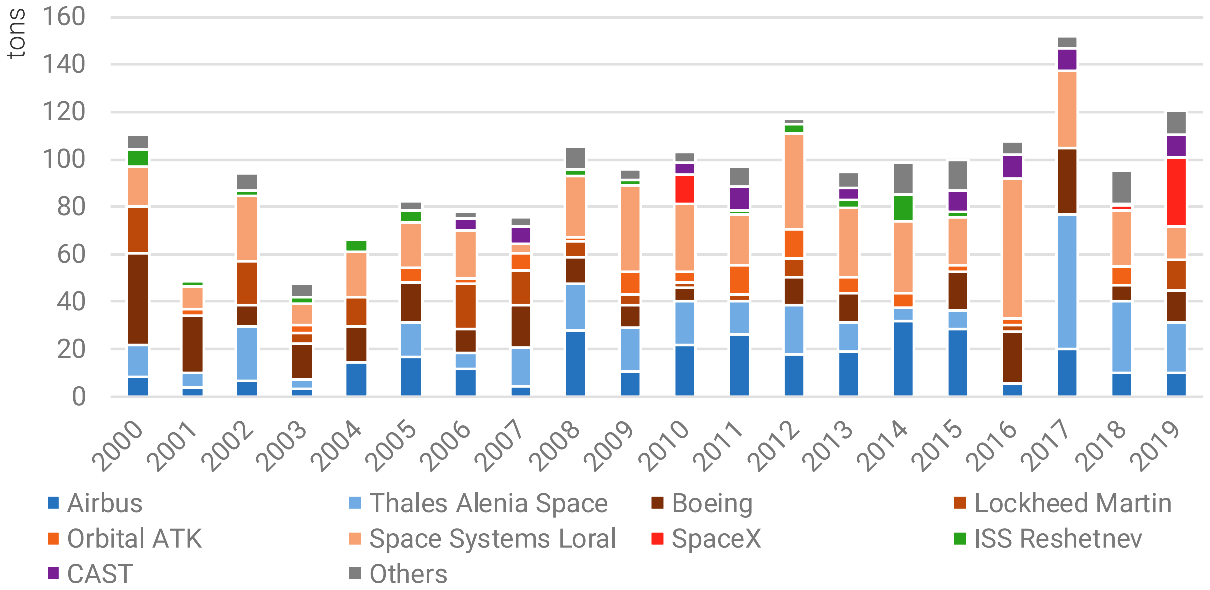

Figure 64: Evolution of the mass launched for the commercial market per year per manufacturer

A few companies and organisations compete on the international commercial satellite market and capture the vast majority of the related activity. U.S. companies, including Boeing, Lockheed Martin, Orbital ATK (now Northrop Grumman Innovation Systems), Space Systems Loral (now part of MAXAR Technologies) and SpaceX, together capture the majority of the market. European companies Airbus and Thales Alenia Space also perform very well and maintain a leading position on the market. Over the last 3 years, the two European companies delivered 150 tons of commercial satellites, corresponding to 40% of the total mass.

The commercial activity of the China Aerospace Science and Technology Corporation (CASC/CAST) remains rather limited because of difficulties to enter a large share of the market, for example due to ITAR restrictions. SpaceX put into orbit 120 Starlink satellites for commercial purpose in 2019, giving way to the first full vertically integrated activity: SpaceX is the manufacturer, operator and launch service provider of its constellation.

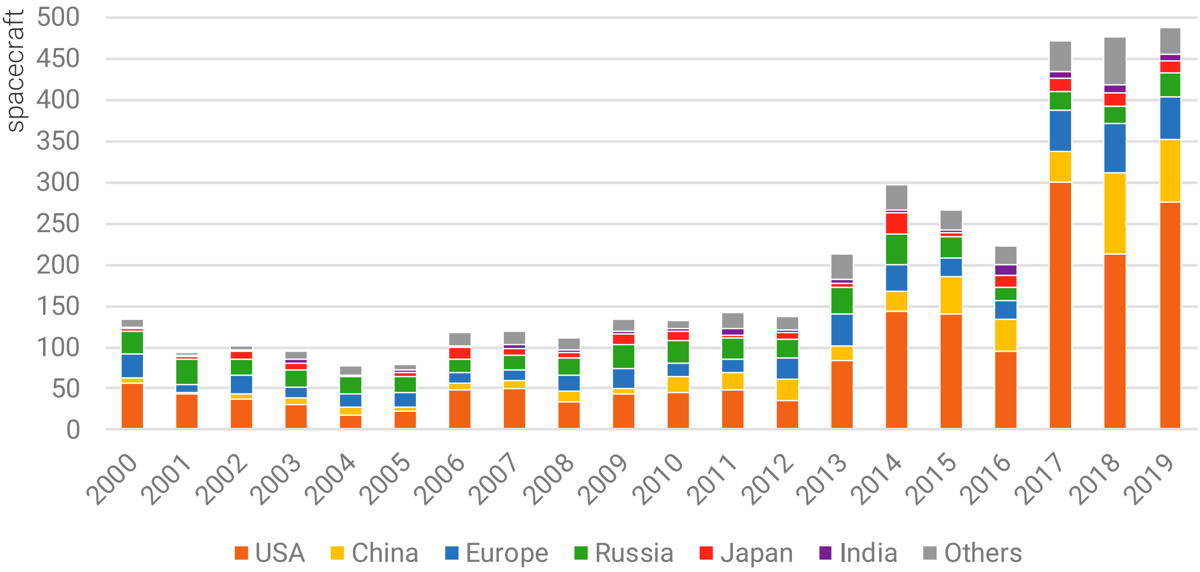

Figure 65: Evolution of the number of spacecraft per procuring country (2000-2019)

A vast majority of spacecraft are procured domestically, mostly because of procurement rules and market constrains. For this reason, the distribution of spacecraft per manufacturing and procuring country are almost identical, with a slight variation related to import/export of commercial satellites. This is the case both for the number of spacecraft and the corresponding mass. As a result, most of the spacecraft are also procured by U.S. organisations and companies. Over the last 3 years, 55% of spacecraft launched worldwide were procured by the United States, corresponding to 36% of the total mass. As a vast majority of the Chinese space activity serves a domestic need, China's growth comes first and foremost from an increase of the national investment in the space sector. The number of satellites ordered by Chinese organisations and operators multiplied by 10 since 2000 and the mass of these satellites by 7.

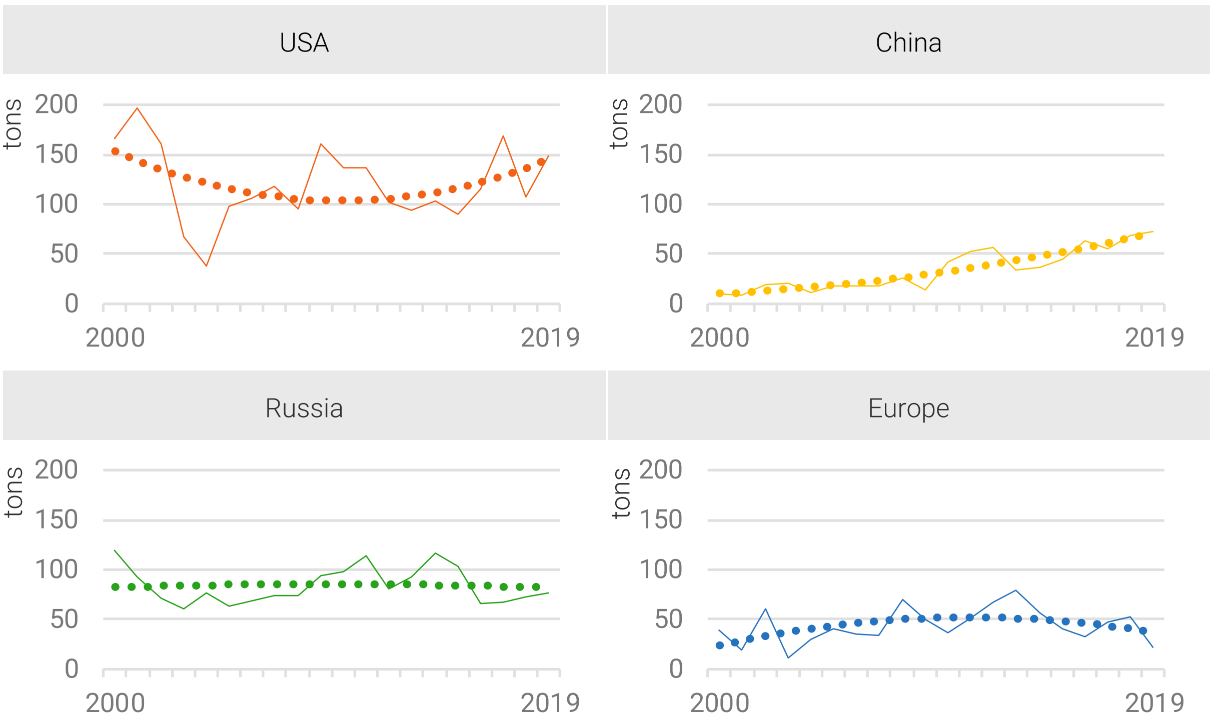

Figure 66: Evolution of total mass launched (in tons) per customer country (2000-2019) with trendline

Interestingly, Europe is the only region where the manufacturing output is higher than the domestic demand. The demand of European organisations is usually below 50 tons per year while the industry output is regularly above this threshold. Procurement statistics in Russia are somewhat biased by the human spaceflight activity, as Progress and Soyuz capsules are attributed to Russia although they may be paid for, at least partially, by other countries.

On the commercial market, leading satellite operators and customers are more diverse and include European, American, Russian, Chinese, Japanese, Canadian and Arab companies. Over the last 5 years, these satcom operators were responsible, together, for 67% of the commercial satellite market, including non-telecom markets such as remote sensing which remains, comparatively, very limited. Of course, the procurement of these operators is highly irregular, involving a few orders of large satellites.

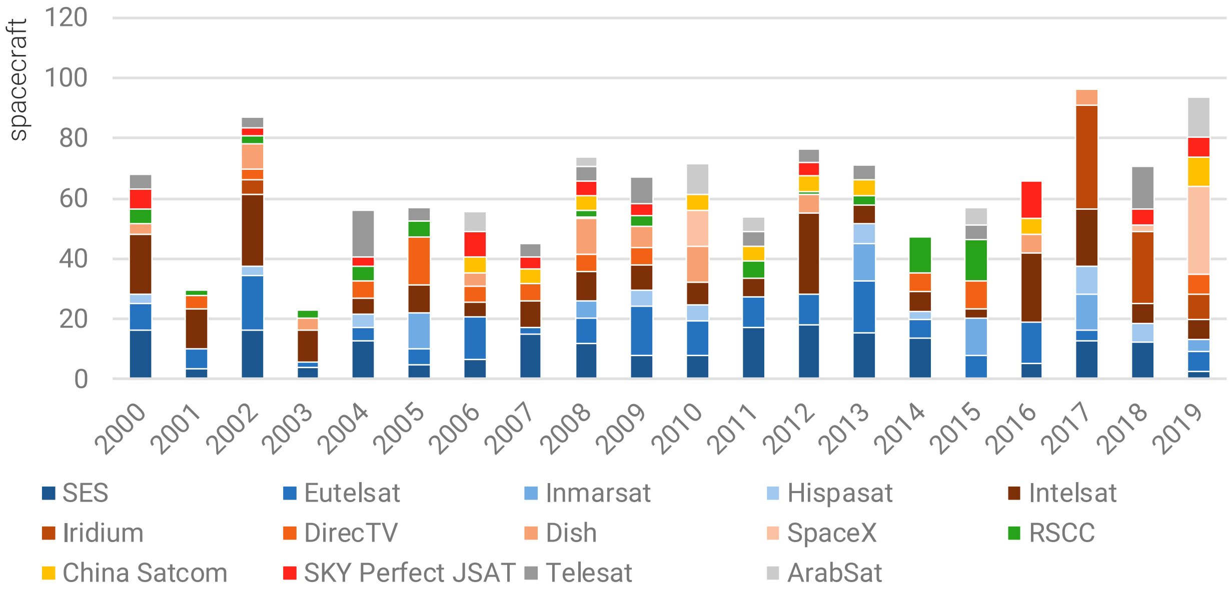

Figure 67: Evolution of the mass launched for the commercial market per year per customer (selected companies)

4.2 Global space activity in 2019

4.2.1 Launch activity in 2019

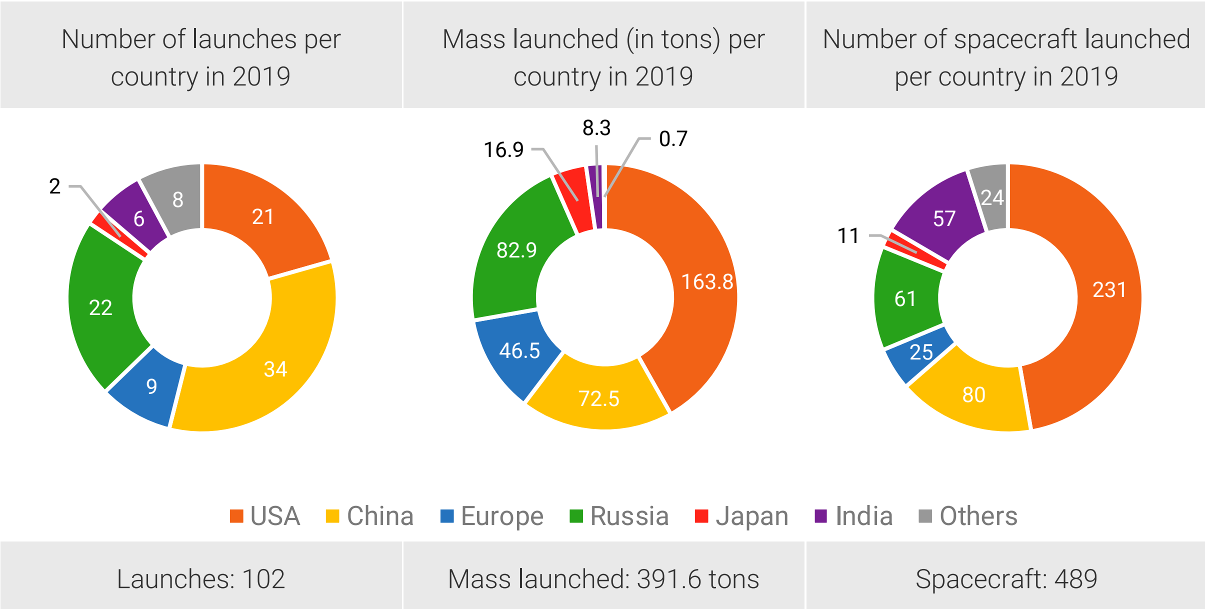

Figure 68: Number of launches, spacecraft and mass launched in 2019 per launch country

In 2019, eight countries (United States, China, Europe, Russia, Japan, India, New Zealand, Iran) launched 489 spacecraft belonging to 39 nations. Ethiopia, Sudan and Rwanda had their first satellite launched in 2019, joining the long list of 80+ countries involved in outer space activities.

For the second consecutive year, China conducted the most launches (34), below its record high of 39 launches in 2018. This number is still 50% higher than the United States and Russia who conducted 21 and 22 launches respectively. However, in terms of mass launched, China remains behind these two countries, in part because of their intense launch activity related to human spaceflight missions and involving very heavy spacecraft. Still, even excluding ISS servicing from the equation, the United States launched almost 50% more mass than China. Heavy military satellites (Keyhole, WGS, AEHF), commercial GEO satcom satellites and constellations (Iridium-NEXT, Starlink) make up most of this mass. SpaceX accounts for more than half of the U.S. launch activity.

With only 9 launches, Europe conducted the lowest number of launches since 2013. Only 46 tons were launched from Kourou, the lowest level since 2010. Nevertheless, Europe remains ahead of Japan and India, that launched respectively only 2 and 6 times.

The most active spaceport for the year 2019 is Cape Canaveral, both in terms of number of launches and total mass launched. This is especially due to the high number of launches performed by SpaceX (10). With 13 launches Baikonour remains very active but far from the 20+ launches that used to be conducted a decade ago. In China Xichang, Taiyuan and Jiuquan are all very dynamic with respectively 13, 10 and 9 launches.

With the rise of Rocket Lab, the spaceport of Onenui in New Zealand is becoming quite active marking a continuous growth: 1 launch in 2017, 3 launches in 2018 and 6 launches in 2019.

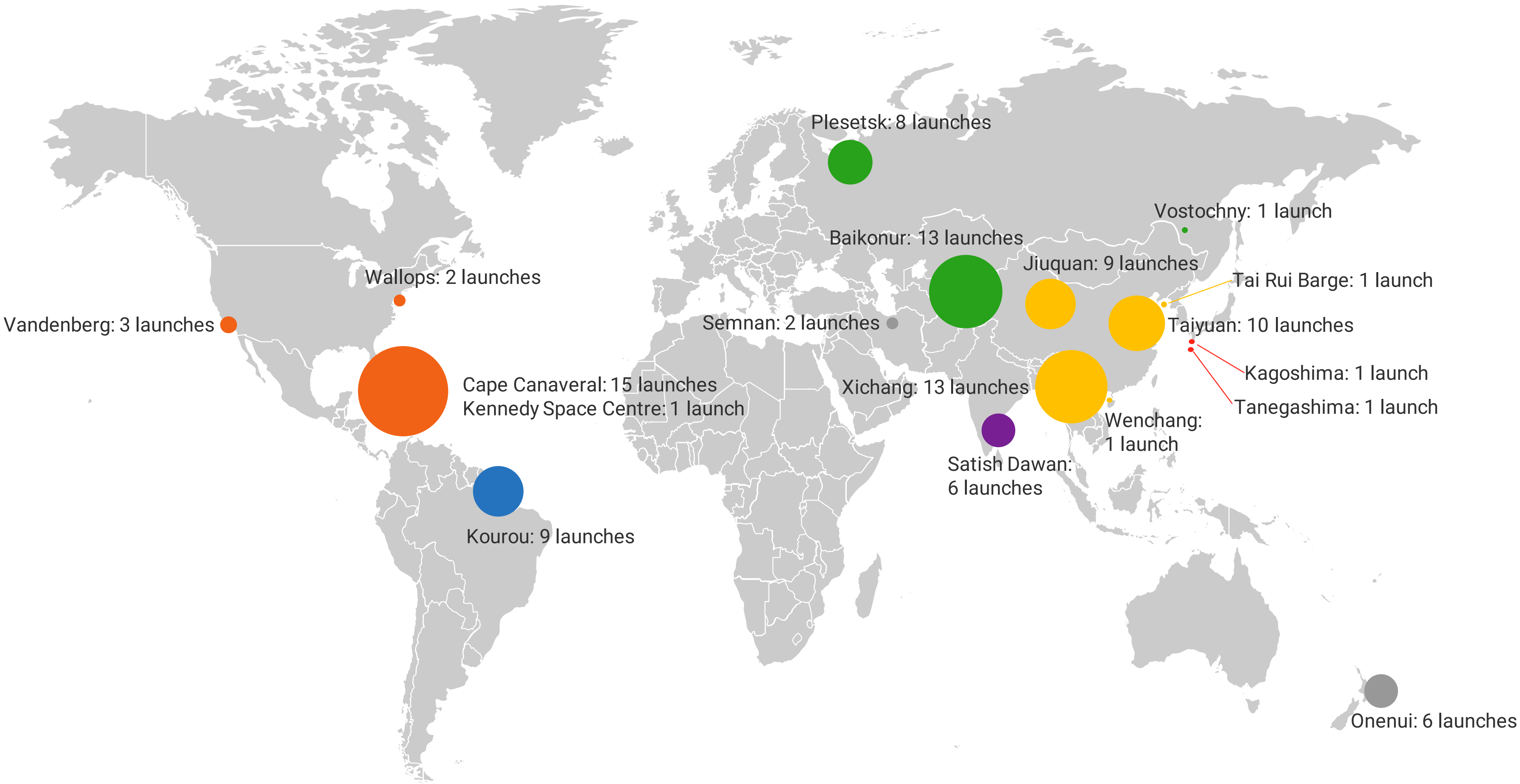

Figure 69: Number of launches per spaceport in 2019

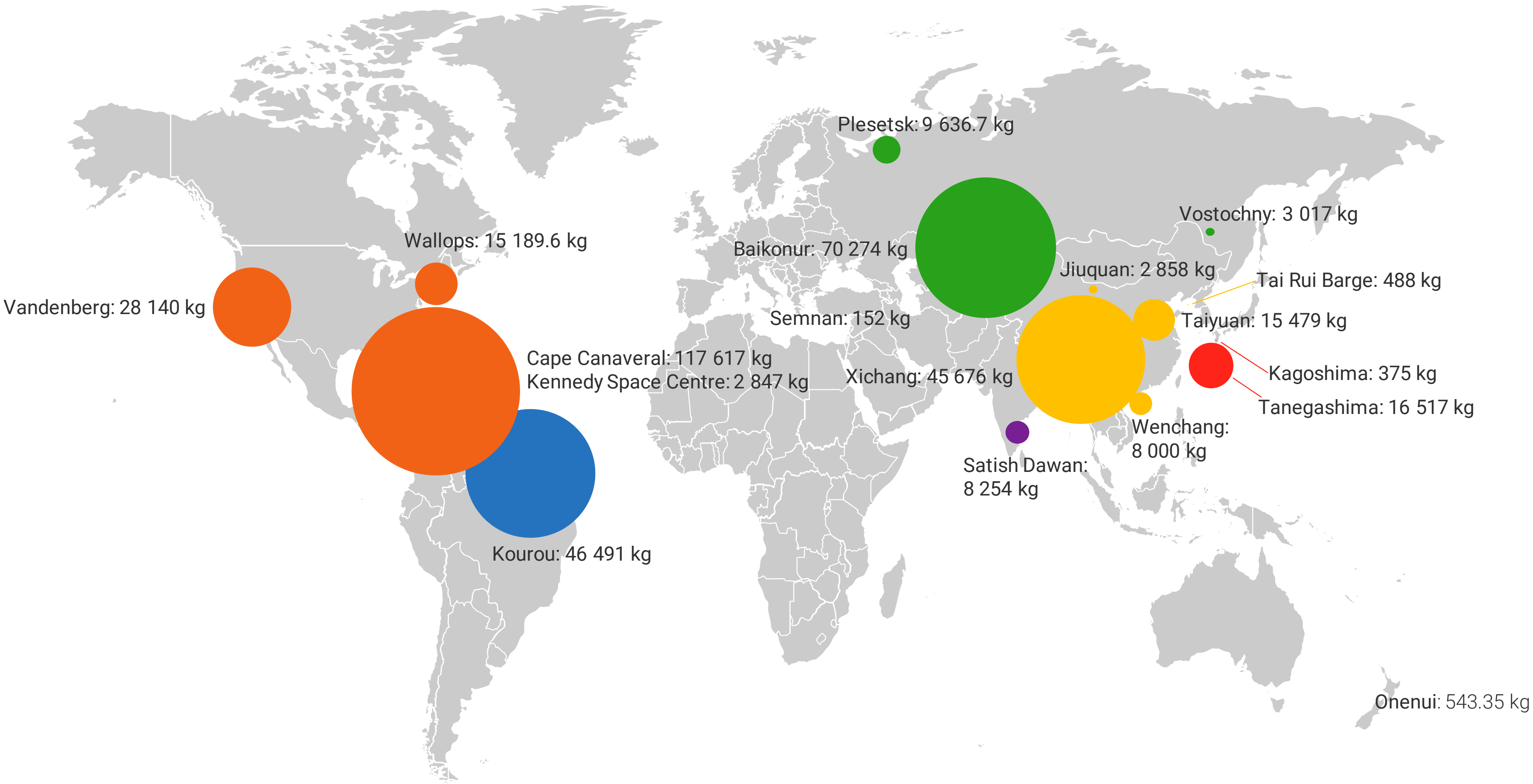

Figure 70: Total mass launched per spaceport in 2019

4.2.2 Spacecraft launched in 2019: customers and manufacturers

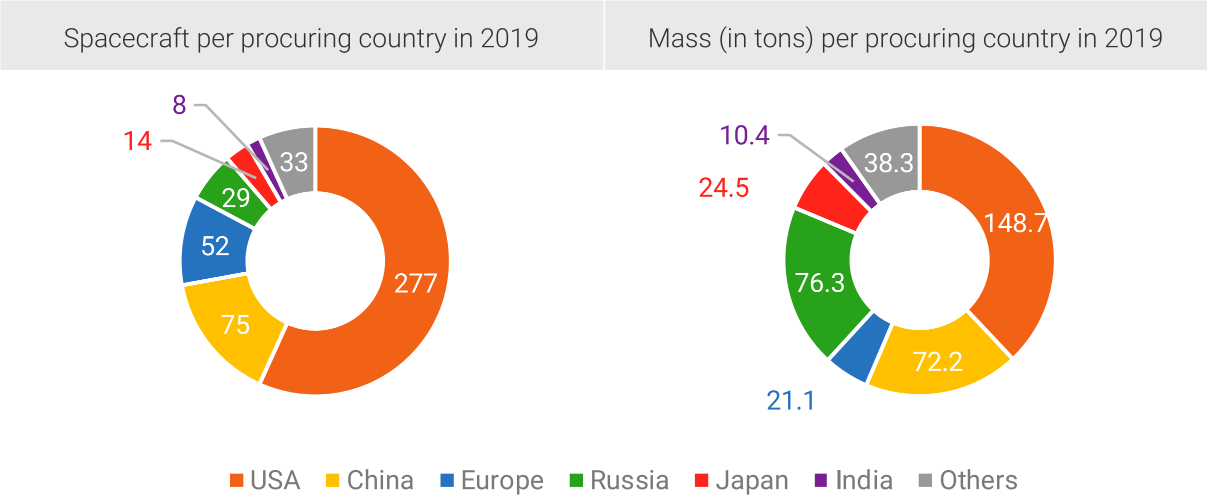

Figure 71: Number and mass of spacecraft per procuring country in 2019

The United States led the year with 277 satellites and almost 150 tons. That is three times more satellites than China, in second place, and five times more than Europe, in third place. These numbers also amount to twice the mass of Russian and Chinese spacecraft. This record number of U.S. satellites is due to the launch of U.S. constellations of CubeSats (Planet, Spire) and satcoms (Iridium-NEXT, Starlink) but also to educational and experimental CubeSats and an overall very active year across all space missions (military, science, human spaceflight…). Despite a high number of satellites (half are CubeSats), Europe had a rather quiet year in terms of procurement with only 21 tons put in orbit for European operators and organisations, for the first time less than Japan, because of the launch of the extra-heavy HTV to the ISS.

The U.S. leadership in 2019 is even more pronounced from a manufacturing perspective: the country produced 271 spacecraft for a total of 170 tons. That is 55% of all spacecraft launched in 2019 and 44% of the total mass launched. With a space activity mostly domestic, the output of Chinese and Russian satellite industries compares well to the level of procurement. On the contrary, the mass produced by the European industry in 2019 was twice more important with 71 satellites and almost 43 tons.

Japan and India produced respectively 17.5 and 10.4 tons. Other countries have a very limited industrial activity.

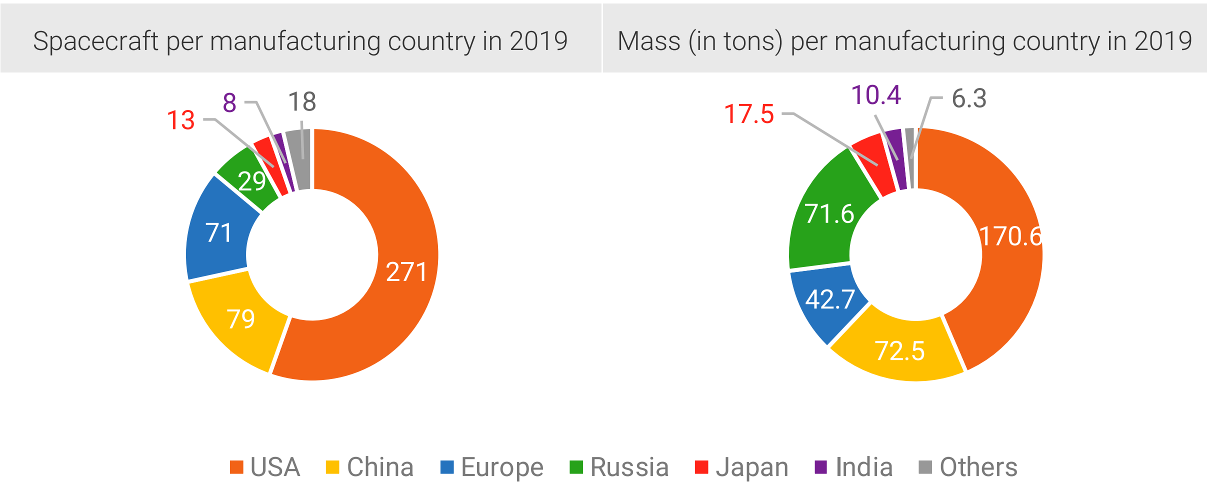

Figure 72: Number and mass of spacecraft per manufacturing country in 2019

4.2.3 Spacecraft launched in 2019: missions and markets

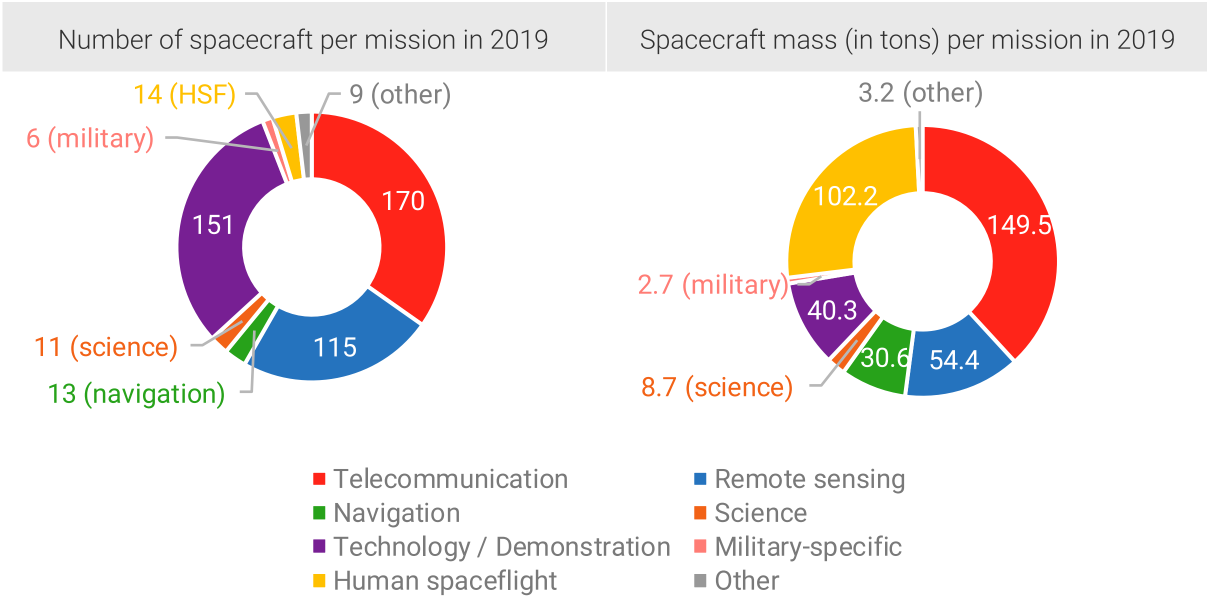

Figure 73: Number and mass of spacecraft per mission in 2019

Three types of missions accounted for almost 90% of the spacecraft launched in 2019: telecommunication (35%), technology/demonstration (31%) and remote sensing (23%). Telecommunication satellites also correspond to more than a third of the mass launched. Remote sensing and technology/demonstration represent a more modest share of this mass, although Earth Observation spacecraft still account for 14% of it. The launch of 120 Starlink satellites (30 tons) contributed substantially to satcom statistics in 2019. Human spaceflight activities (mainly cargo and crew transfer) still represent more than 25% of the mass launched. Navigation satellites also account for a significant share of the activity with only 13 spacecraft but 8% of the mass. Beidou satellites made up most of this activity. 2019 was also marked by the launch of the first in-orbit servicing mission.

While commercial satellites account for more than half of the satellites launched in 2019, most of the space activity remains public, with 47% of the mass launched for governmental civil purpose (55% of which for human spaceflight) and 19% for military purpose. Commercial satellites still account for almost a third of the mass and way more than half of the satellites.

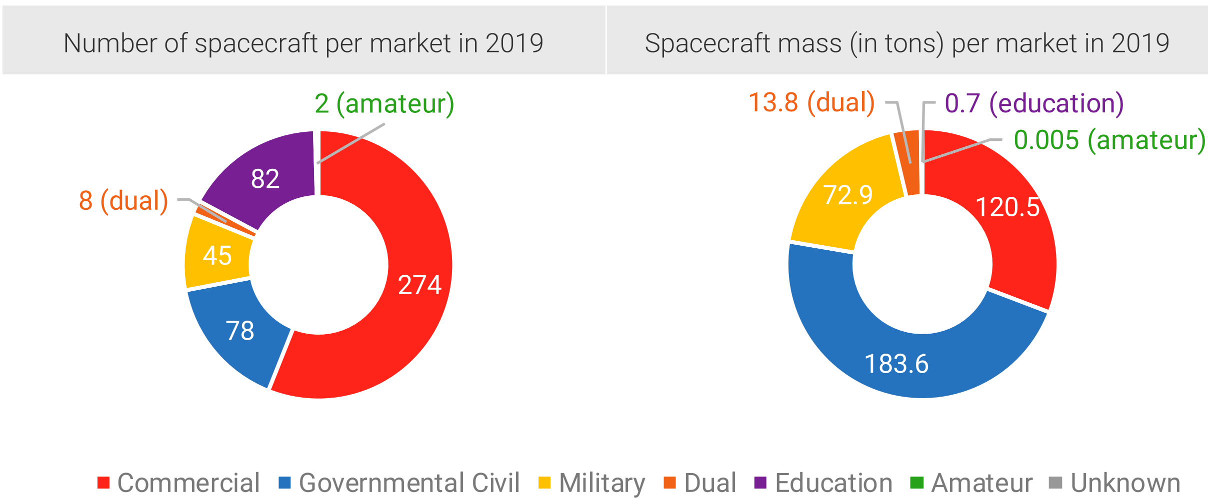

Figure 74: Number and mass of spacecraft per market in 2019

4.3 Launch log and activity highlights

4.3.1 ESPI launch log 2019

Launch date	Launch country	Launcher	Outcome	Spacecraft	Customer	Manufacturer	Mass at launch (kg)	Orbit	Mission	Market
10/01/2019	China	CZ-3B/G3	Success	ZhongXing 2D	China	China	5000	GEO	Telecommunication	Military
11/01/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Iridium-NEXT (10 satellites)	USA	France	860 (each)	LEO	Telecommunication	Commercial
15/01/2019	Iran	Simorgh	Failure	Amir-Kabir 1	Iran	Iran	100	LEO	Earth Observation	Education
18/01/2019	Japan	Epsilon-2 CLPS	Success	RAPIS-1	Japan	Japan	200	LEO	Techno/Demo	Governmental
				ALE 1	Japan	Japan	68	LEO	Techno/Demo	Commercial
				MicroDragon	Vietnam	Vietnam	50	LEO	Earth Observation	Governmental
				Hodoyoshi 2	Japan	Japan	50	LEO	Techno/Demo	Education
				Origamisat 1	Japan	Japan	4	LEO	Techno/Demo	Education
				AOBA VELOX 4	Singapore	Singapore	2	LEO	Techno/Demo	Education
				NEXUS	Japan	Japan	1	LEO	Techno/Demo	Amateur
19/01/2019	USA	Delta-4H	Success	KH-11 17	USA	USA	15250	LEO	Earth Observation	Military
21/01/2019	China	CZ-11	Success	Jilin-1 Hyperspectral-01	China	China	450	LEO	Earth Observation	Governmental
				Jilin-1 Hyperspectral-02	China	China	450	LEO	Earth Observation	Governmental
				Lingque 1A	China	China	8	LEO	Techno/Demo	Commercial
				Xiaoxiang-1 03	China	China	8	LEO	Techno/Demo	Commercial
24/01/2019	India	PSLV-DL	Success	Microsat-R	India	India	740	LEO	Techno/Demo	Military
				Kalamsat v2	India	India	1	LEO	Techno/Demo	Education
05/02/2019	France	Ariane-5ECA	Success	HellasSat 4 / SaudiGeoSat 1	Saudi Arabia	USA	6495	GEO	Telecommunication	Commercial
				GSAT-31	India	India	2536	GEO	Telecommunication	Governmental
05/02/2019	Iran	Safir-1B	Failure	Dousti 1	Iran	Iran	52	LEO	Earth Observation	Education
21/02/2019	Russia	Soyuz-2-1b Fregat-M	Partial failure	EgyptSat A	Egypt	Russia	1000	LEO	Earth Observation	Governmental
22/02/2019	USA	Falcon-9 v1.2 (Block 5)	Success	PSN 6	Indonesia	USA	4100	GEO	Telecommunication	Commercial
				Beresheet	Israel	Israel	582	Escape	Techno/Demo	Commercial
				S5	USA	USA	60	GEO	SSA	Military
27/02/2019	France	Soyuz-ST-B Fregat-M	Success	OneWeb (6 satellites)	UK	France	147 (each)	LEO	Telecommunication	Commercial
02/03/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Crew Dragon 1	USA	USA	12055	LEO	Techno/Demo	Governmental
09/03/2019	China	CZ-3B/G2	Success	ZhongXing 06C	China	China	4500	GEO	Telecommunication	Commercial
14/03/2019	Russia	Soyuz-FG	Success	Soyuz-MS 12	Russia	Russia	7080	LEO	Crew Transfer	Governmental
15/03/2019	USA	Delta-4M+(5,4) (upg.)	Success	WGS 10	USA	USA	5987	GEO	Telecommunication	Military
22/03/2019	France	Vega	Success	PRISMA	Italy	Italy	879	LEO	Earth Observation	Governmental
27/03/2019	China	OS-M1	Failure	Lingque 1B	China	China	8	LEO	Techno/Demo	Commercial
28/03/2019	New Zealand	Electron	Success	R3D2	USA	USA	150	LEO	Techno/Demo	Military
31/03/2019	China	CZ-3B/G3	Success	TianLian 2A	China	China	4000	GEO	Telecommunication	Governmental
01/04/2019	India	PSLV-QL	Success	EMISAT	India	India	436	LEO	Earth Observation	Governmental
				BlueWalker 1	Lithuania	Lithuania	8	LEO	Techno/Demo	Commercial
				M6P	Lithuania	Lithuania	8	LEO	Techno/Demo	Commercial
				Flock-4a (20 satellites)	USA	USA	5 (each)	LEO	Earth Observation	Commercial

				Lemur-2 (4 satellites)	USA	USA	4 (each)	LEO	Earth Observation	Commercial
				Astrocast 0.2	Switzerland	Switzerland	4	LEO	Techno/Demo	Commercial
				AISTECHSAT 3	Spain	Denmark	3	LEO	Techno/Demo	Commercial
04/04/2019	Russia	Soyuz-2-1a	Success	Progress-MS 11	Russia	Russia	7400	LEO	Cargo Transfer	Governmental
04/04/2019	France	Soyuz-ST-B Fregat-MT	Success	O3b FM (4 satellites)	Luxembourg	France	700	MEO	Telecommunication	Commercial
11/04/2019	USA	Falcon Heavy	Success	Arabsat 6A	Saudi Arabia	USA	6465	GEO	Telecommunication	Commercial
17/04/2019	USA	Antares-230	Success	Cygnus CRS-11	USA	USA	7492	LEO	Cargo Transfer	Governmental
				Kenobi	USA	USA	8	LEO	Techno/Demo	Governmental
				Seeker	USA	USA	8	LEO	Techno/Demo	Governmental
				EntrySat	France	France	4	LEO	Techno/Demo	Governmental
				IOD-GEMS	UK	UK	4	LEO	Techno/Demo	Governmental
				SASSI2	USA	USA	4	LEO	Techno/Demo	Education
				AeroCube (10A & 10B)	USA	USA	2 (each)	LEO	Techno/Demo	Commercial
				Swiatowid	Poland	Poland	2	LEO	Techno/Demo	Commercial
				ThinSat (9 satellites)	USA	USA	2 (each)	LEO	Techno/Demo	Education
				Bird (JPN, LKA, NPL)	Japan	Japan	1 (each)	LEO	Techno/Demo	Education
				KrakSat	Poland	Poland	1	LEO	Techno/Demo	Education
				ThinSat (1B, 1G, 1K)	USA	USA	1 (each)	LEO	Techno/Demo	Education
				VCC (A, B & C)	USA	USA	1 (each)	LEO	Techno/Demo	Education
20/04/2019	China	CZ-3B/G3	Success	Beidou 3 I1	China	China	4200	MEO	Navigation	Military
29/04/2019	China	CZ-4B	Success	Tianhui 2-01(A & B)	China	China	1500 (each)	LEO	Earth Observation	Governmental
04/05/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Dragon CRS-17	USA	USA	6650	LEO	Cargo Transfer	Governmental
				OCO 3	USA	USA	500	LEO	Earth Observation	Governmental
				STP-H6	USA	USA	300	LEO	Earth Observation	Military
05/05/2019	New Zealand	Electron	Success	Harbinger	USA	USA	150	LEO	Techno/Demo	Commercial
				SPARC 1	USA	USA	8	LEO	Techno/Demo	Military
				Falcon-ODE	USA	USA	1	LEO	Techno/Demo	Military
17/05/2019	China	CZ-3C/G2	Success	BeiDou 2 G8	China	China	4600	GEO	Navigation	Military
22/05/2019	China	CZ-4C	Failure	Yaogan 33	China	China	1040	LEO	Earth Observation	Military
22/05/2019	India	PSLV-CA	Success	RISAT 2B	India	India	615	LEO	Earth Observation	Governmental
24/05/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Starlink v0.9 (60 satellites)	USA	USA	227 (each)	LEO	Telecommunication	Commercial
27/05/2019	Russia	Soyuz-2-1b Fregat-M	Success	Kosmos 2534	Russia	Russia	1415	MEO	Navigation	Dual
30/05/2019	Russia	Proton-M Briz-M (Ph.3)	Success	Yamal 601	Russia	France	5700	GEO	Telecommunication	Commercial
05/06/2019	China	CZ-11	Success	Bufeng (1A & 1B)	China	China	150 (each)	LEO	Earth Observation	Governmental
				Tianxiang (1 & 2)	China	China	65 (each)	LEO	Techno/Demo	Commercial
				Jilin-1 03A	China	China	42	LEO	Earth Observation	Commercial
				Tianqi 3	China	China	8	LEO	Earth Observation	Commercial
				Xiaoxiang 1-04	China	China	8	LEO	Earth Observation	Commercial
12/06/2019	USA	Falcon-9 v1.2 (Block 5)	Success	RCM (1, 2 & 3)	Canada	Canada	1430 (each)	LEO	Earth Observation	Dual
20/06/2019	France	Ariane-5ECA	Success	AT&T T-16	USA	France	6350	GEO	Telecommunication	Commercial
				Eutelsat 7C	France	USA	3400	GEO	Telecommunication	Commercial
24/06/2019	China	CZ-3B/G3	Success	Beidou 3 I2	China	China	4200	MEO	Navigation	Military
25/06/2019	USA	Falcon Heavy	Success	DSX	USA	USA	600	MEO	Techno/Demo	Military
				FORMOSAT 7 (six satellites)	Taiwan	UK	278	LEO	Earth Observation	Governmental
				GPIM	USA	USA	180	LEO	Techno/Demo	Governmental
				OTB 1	USA	UK	138	LEO	Techno/Demo	Governmental
				NPSat 1	USA	USA	86	LEO	Techno/Demo	Education
				Nanosat 7	USA	USA	71	LEO	Techno/Demo	Education
				Nanosat 6	USA	USA	70	LEO	Techno/Demo	Education
				FalconSat 7	USA	USA	5	LEO	Techno/Demo	Education
				LightSail B	USA	USA	5	LEO	Techno/Demo	Education

				ARMADILLO	USA	USA	4	LEO	Techno/Demo	Education
				E-TBEx (A & B)	USA	USA	4 (each)	LEO	Techno/Demo	Governmental
				CP 9	USA	USA	2	LEO	Techno/Demo	Education
				Prometheus 2 05	USA	USA	2	LEO	Techno/Demo	Education
				PSat 2	USA	USA	2	LEO	Techno/Demo	Education
				TEPCE (1 & 2)	USA	USA	2 (each)	LEO	Techno/Demo	Governmental
				BRICSat 2	USA	USA	1	LEO	Techno/Demo	Education
				StangSat	USA	USA	1	LEO	Techno/Demo	Education
28/06/2019	New Zealand	Electron KS	Success	BlackSky Global 3	USA	USA	56	LEO	Earth Observation	Commercial
				Prometheus 2 (06 & 07)	USA	USA	2 (each)	LEO	Telecommunication	Military
				ACRUX 1	Australia	Australia	1,00	LEO	Techno/Demo	Education
				SpaceBEE (8 & 9)	USA	USA	1 (each)	LEO	Techno/Demo	Commercial
05/07/2019	Russia	Soyuz-2-1b Fregat-M	Success	Meteor-M 2-2	Russia	Russia	2700	LEO	Earth Observation	Governmental
				ICEYE (X4 & X5)	Finland	Finland	80 (each)	LEO	Techno/Demo	Commercial
				CarboNIX	Germany	Germany	30	LEO	Techno/Demo	Commercial
				Momentus X1	USA	USA	22	LEO	Techno/Demo	Commercial
				DoT 1	UK	UK	20	LEO	Techno/Demo	Commercial
				NSLSat 1	Israel	UK	8	LEO	Techno/Demo	Commercial
				AmGU 1	Russia	Russia	4	LEO	Space Science	Education
				D-Star One EXOCONNECT	Germany	Germany	4	LEO	Techno/Demo	Commercial
				D-Star One LightSat	Germany	Germany	4	LEO	Techno/Demo	Commercial
				JAISAT 1	Thailand	Thailand	4	LEO	Radio Amateur	Amateur
				Lemur-2 (8 satellites)	USA	USA	4 (each)	LEO	Earth Observation	Commercial
				SEAM 2.0	Sweden	Sweden	4	LEO	Earth Science	Education
				Sokrat	Russia	Russia	4	LEO	Space Science	Education
				UTE-Ecuador	Ecuador	Ecuador	4	LEO	Space Science	Education
				VDNH-80	Russia	Russia	4	LEO	Telecommunication	Education
				SONATE	Germany	Germany	4	LEO	Techno/Demo	Education
				BeeSat (5 satellites)	Germany	Germany	1 (each)	LEO	Techno/Demo	Education
				Lucky-7	Czech Rep.	Czech Rep.	1	LEO	Techno/Demo	Commercial
				MOVE 2b	Germany	Germany	1	LEO	Techno/Demo	Education
				ROBUSTA 1C	France	France	1	LEO	Techno/Demo	Governmental
				TTÜ101	Estonia	Estonia	1	LEO	Techno/Demo	Education
10/07/2019	Russia	Soyuz-2-1v Volga	Success	Kosmos (2535, 2536, 2537 & 2538)	Russia	Russia	200 (each)	LEO	Unknown	Military
11/07/2019	France	Vega	Failure	Falcon Eye 1	UAE	UAE	1197	LEO	Earth Observation	Military
12/07/2019	Russia	Proton-M Blok-DM-3	Success	Spektr-RG	Russia	Russia	2647	Escape	Astronomy	Governmental
20/07/2019	Russia	Soyuz-FG	Success	Soyuz-MS 13	Russia	Russia	7080	LEO	Crew Transfer	Governmental
22/07/2019	India	GSLV Mk.3	Success	Chandrayaan 2	India	India	3850	Escape	Planetary Science	Governmental
25/07/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Dragon CRS-18	USA	USA	6650	LEO	Cargo Transfer	Governmental
				IDA 03	USA	USA	526	LEO	Space Station	Governmental
				ORCA	USA	USA	8	LEO	Techno/Demo	Military
				RFTSat 1	USA	USA	4	LEO	Techno/Demo	Education
				SEOPS Quantum Radar 3	USA	USA	4	LEO	Techno/Demo	Education
				NARSScube 2	Egypt	Egypt	1	LEO	Techno/Demo	Education
25/07/2019	China	Hyperbola-1	Success	Hangtian KKG Fazhang sat	China	China	50	LEO	Techno/Demo	Commercial
				CAS-7B	China	China	3	LEO	Radio Amateur	Education
26/07/2019	China	CZ-2C(3)	Success	Yaogan (30-05-01, -02 & -03)	China	China	300 (each)	LEO	Signal Intelligence	Military
30/07/2019	Russia	Soyuz-2-1a Fregat-M	Success	Meridian-M 8	Russia	Russia	2000	HEO	Telecommunication	Military
31/07/2019	Russia	Soyuz-2-1a	Success	Progress-MS 12	Russia	Russia	7280	LEO	Cargo Transfer	Governmental
06/08/2019	France	Ariane-5ECA	Success	Intelsat 39	USA	USA	6600	GEO	Telecommunication	Commercial
				EDRS C/HYLAS 3	Europe	France	3186	GEO	Telecommunication	Commercial

06/08/2019	USA	Falcon-9 v1.2	Success	AMOS 17	Israel	USA	6500	GEO	Telecommunication	Commercial
06/08/2019	Russia	Proton-M Briz-M (Ph.3)	Success	Blagovest 14L	Russia	Russia	3227	GEO	Telecommunication	Military
08/08/2019	USA	Atlas-5(551)	Success	AEHF 05	USA	USA	6168	GEO	Telecommunication	Military
				TDO	USA	USA	20	GEO	Techno/Demo	Military
17/08/2019	China	Jielong-1	Success	Qiancheng 01	China	China	65	LEO	Earth Observation	Commercial
				Xingshidai 5	China	China	10	LEO	Earth Observation	Commercial
				Tianqi 2	China	China	8	LEO	Techno/Demo	Commercial
19/08/2019	China	CZ-3B/G2	Success	ZX 18 (ChinaSat 18)	China	China	5200	GEO	Telecommunication	Commercial
19/08/2019	New Zealand	Electron KS	Success	BlackSky Global 4	USA	USA	56	LEO	Earth Observation	Commercial
				BRO 1	France	Denmark	6	LEO	Earth Observation	Commercial
				Pearl White (1 & 2)	USA	USA	6 (each)	LEO	Techno/Demo	Military
22/08/2019	USA	Delta-4M+(4,2) (upg.)	Success	GPS-3 2	USA	USA	4400	MEO	Navigation	Dual
22/08/2019	Russia	Soyuz-2-1a	Success	Soyuz-MS 14	Russia	Russia	7080	LEO	Cargo Transfer	Governmental
30/08/2019	China	Kuaizhou-1A	Success	Taizhi 1 (KX 09)	China	China	200	LEO	Earth Science	Governmental
				Xiaoxiang 1-07 (TY 1-07)	China	China	8	LEO	Techno/Demo	Commercial
30/08/2019	Russia	Rokot-KM	Success	Geo-IK 2 03	Russia	Russia	1400	LEO	Earth Science	Dual
12/09/2019	China	CZ-4B	Success	ZY-1 02D	China	China	2100	LEO	Earth Observation	Governmental
				BNU 1	China	China	16	LEO	Earth Observation	Education
				Taurus 1	China	China	5	LEO	Radio Amateur	Education
19/09/2019	China	CZ-11	Success	OHS (3A, 3B, 3C & 3D)	China	China	90 (each)	LEO	Earth Observation	Commercial
				OVS 3A	China	China	90	LEO	Earth Observation	Commercial
22/09/2019	China	CZ-3B/G3Z	Success	Beidou 3 (M23 & M24)	China	China	1014 (each)	MEO	Navigation	Military
24/09/2019	Japan	H-2B-304	Success	HTV 08	Japan	Japan	16500	LEO	Cargo Transfer	Governmental
				AQT-D	Japan	Japan	8	LEO	Techno/Demo	Education
				RWASAT 1	Rwanda	Rwanda	8	LEO	Techno/Demo	Education
				NARSScube 1	Egypt	Egypt	1	LEO	Techno/Demo	Education
25/09/2019	China	CZ-2D(2)	Success	Yunhai-1 02	China	China	750	LEO	Earth Observation	Governmental
25/09/2019	Russia	Soyuz-FG	Success	Soyuz-MS 15	Russia	Russia	7080	LEO	Crew Transfer	Governmental
26/09/2019	Russia	Soyuz-2-1b Fregat-M	Success	Tundra 03	Russia	Russia	1500	HEO	Early Warning	Military
04/10/2019	China	CZ-4C	Success	Gaofen 10R	China	China	805	LEO	Earth Observation	Governmental
09/10/2019	Russia	Proton-M Briz-M (Ph.4)	Success	Eutelsat 5 West B	France	USA	3000	GEO	Telecommunication	Commercial
				MEV-1	USA	USA	2326	GEO	In-Orbit Servicing	Commercial
11/10/2019	USA	Pegasus-XL	Success	ICON	USA	USA	288	LEO	Earth Science	Governmental
17/10/2019	China	CZ-3B/G2	Success	Tongxin Jishu Shiyan 4	China	China	2700	GEO	Techno/Demo	Military
17/10/2019	New Zealand	Electron KS	Success	Palisade	USA	USA	20	LEO	Techno/Demo	Commercial
02/11/2019	USA	Antares-230+	Success	Cygnus CRS-12	USA	USA	7492	LEO	Cargo Transfer	Governmental
				STPSat 4	USA	USA	100	LEO	Techno/Demo	Military
				HARP	USA	USA	5	LEO	Techno/Demo	Education
				HuskySat-1	USA	USA	5	LEO	Techno/Demo	Education
				SwampSat 2	USA	USA	5	LEO	Techno/Demo	Education
				SOCRATES	USA	USA	4,2	LEO	Techno/Demo	Education
				Phoenix	USA	USA	4	LEO	Techno/Demo	Education
				RadSat-u	USA	USA	4	LEO	Techno/Demo	Education
				AeroCube (15A & 15B)	USA	USA	3,7 (each)	LEO	Techno/Demo	Governmental
				AeroCube (14A & 14B)	USA	USA	3,5 (each)	LEO	Techno/Demo	Governmental
				Argus-02	USA	USA	1	LEO	Techno/Demo	Education
				Orbital Factory 2	USA	USA	1	LEO	Techno/Demo	Education
03/11/2019	China	CZ-4B	Success	Gaofen 7	China	China	2400	LEO	Earth Observation	Governmental
				SRSS-1	Sudan	China	75	LEO	Earth Observation	Dual
				Huangpu 1	China	China	75	LEO	Techno/Demo	Education

				Xiaoxiang 1-08	China	China	8	LEO	Techno/Demo	Commercial
04/11/2019	China	CZ-3B/G3	Success	Beidou 3 I3	China	China	4200	GEO	Navigation	Military
11/11/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Starlink 1 (60 satellites)	USA	USA	260 (each)	LEO	Telecommunication	Commercial
13/11/2019	China	CZ-6	Success	Ningxia-1 (5 satellites)	China	China	180 (each)	LEO	Earth Observation	Commercial
13/11/2019	China	Kuaizhou-1A	Success	Jilin-1 Gaofen-02A	China	China	230	LEO	Earth Observation	Commercial
17/11/2019	China	Kuaizhou-1A	Success	KL-Alpha B	Germany	China	90	LEO	Techno/Demo	Commercial
				KL-Alpha A	Germany	China	70	LEO	Techno/Demo	Commercial
23/11/2019	China	CZ-3B/G3Z	Success	Beidou 3 (M21 & M22)	China	China	1060 (each)	MEO	Navigation	Military
25/11/2019	Russia	Soyuz-2-1v Volga	Success	Kosmos 2542	Russia	Russia	250	LEO	SSA	Military
26/11/2019	France	Ariane-5ECA	Success	TIBA-1	Egypt	France	5640	GEO	Telecommunication	Governmental
				Inmarsat-5 F5	UK	France	4007	GEO	Telecommunication	Commercial
27/11/2019	China	CZ-4C	Success	Gaofen 12	China	China	2400	LEO	Earth Observation	Governmental
27/11/2019	India	PSLV-XL	Success	Cartosat 3	India	India	1625	LEO	Earth Observation	Governmental
				Flock-4p (12 satellites)	USA	USA	5 (each)	LEO	Earth Observation	Commercial
				Meshbed	USA	USA	3	LEO	Techno/Demo	Commercial
05/12/2019	USA	Falcon-9 v1.2 (Block 5)	Success	Dragon CRS-19	USA	USA	6650	LEO	Cargo Transfer	Governmental
				HISUI	Japan	Japan	500	LEO	Earth Observation	Governmental
				CIRiS	USA	USA	6	LEO	Techno/Demo	Education
				SORTIE	USA	USA	6	LEO	Earth Science	Education
				CryoCube 1	USA	USA	4	LEO	Techno/Demo	Education
				QARMAN	Belgium	Belgium	4	LEO	Techno/Demo	Education
				AztechSat 1	Mexico	Mexico	1	LEO	Techno/Demo	Education
				EdgeCube	USA	USA	1	LEO	Techno/Demo	Education
				MakerSat 1	USA	USA	1	LEO	Techno/Demo	Education
06/12/2019	New Zealand	Electron KS	Success	ALE 2	Japan	Japan	75	LEO	Techno/Demo	Commercial
				NOOR 1A	USA	UK	0,75	LEO	Techno/Demo	Commercial
				NOOR 1B	USA	UK	0,75	LEO	Techno/Demo	Commercial
				ATL 1	Hungary	Hungary	0,25	LEO	Techno/Demo	Commercial
				FossaSat 1	Spain	Spain	0,2	LEO	Techno/Demo	Education
				SMOG-P	Hungary	Hungary	0,2	LEO	Techno/Demo	Education
				TRSI-Sat	USA	USA	0,2	LEO	Techno/Demo	Commercial
06/12/2019	Russia	Soyuz-2-1a	Success	Progress-MS 13	Russia	Russia	7280	LEO	Cargo Transfer	Governmental
07/12/2019	China	Kuaizhou-1A	Success	Jilin-1 Gaofen-02B	China	China	230	LEO	Earth Observation	Commercial
07/12/2019	China	Kuaizhou-1A	Success	HEAD (2A & 2B)	China	China	45 (each)	LEO	AIS	Commercial
				Tianqi (4A & 4B)	China	China	8 (each)	LEO	Techno/Demo	Commercial
				Tianyi (-16 & -17)	China	China	8 (each)	LEO	Earth Observation	Commercial
11/12/2019	India	PSLV-QL	Success	RISAT-2BR1	India	India	628	LEO	Earth Observation	Governmental
				QPS-SAR 1	Japan	Japan	100	LEO	Earth Observation	Commercial
				1HOPSat TD	USA	USA	22	LEO	Techno/Demo	Commercial
				Pathfinder Risk Reduction	USA	USA	11	LEO	Techno/Demo	Governmental
				COMMTRAIL	Unknown	USA	4	LEO	Techno/Demo	Commercial
				Duchifat-3	Israel	Israel	4	LEO	Techno/Demo	Education
				Lemur-2 (4 satellites)	USA	USA	4 (each)	LEO	Earth Observation	Commercial
11/12/2019	Russia	Soyuz-2-1b Fregat-M	Success	Glonass-M 50	Russia	Russia	1415	MEO	Navigation	Military
16/12/2019	China	CZ-3B/YZ1	Success	Beidou 3 (M19 & M20)	China	China	1014 (each)	MEO	Navigation	Military
16/12/2019	USA	Falcon-9 v1.2 (Block 5)	Success	JCSat 18/Kacific 1	Japan	USA	6956	GEO	Telecommunication	Commercial
18/12/2019	France	Soyuz-ST-A Fregat-M	Success	CSG 1	Italy	France	2205	LEO	Earth Observation	Dual
				CHEOPS	Europe	France	273	LEO	Astronomy	Governmental
				ANGELS (CNES)	France	France	27	LEO	Techno/Demo	Governmental
				Eye-Sat	France	France	7	LEO	Techno/Demo	Education
				OPS-SAT	Europe	Denmark	7	LEO	Techno/Demo	Governmental

20/12/2019	USA	Atlas-5(N22)	Partial Failure	Starliner 1	USA	USA	13000	LEO	Techno/Demo	Governmental
20/12/2019	China	CZ-4B	Success	CBERS 4A	China	China	1980	LEO	Earth Observation	Governmental
				Tianyan 01	China	China	72	LEO	Earth Observation	Commercial
				ETRSS 1	Ethiopia	China	70	LEO	Earth Observation	Governmental
				Weilai 1R	China	China	65	LEO	Techno/Demo	Commercial
				Shuntian	China	China	35	LEO	Techno/Demo	Military
				Tianqin 1/CAS 6	China	China	35	LEO	Radio Amateur	Education
				Yuheng	China	China	35	LEO	Techno/Demo	Military
				Tianyan 02	China	China	10	LEO	Earth Observation	Commercial
				FloripaSat 1	Brazil	Brazil	1	LEO	Techno/Demo	Education
24/12/2019	Russia	Proton-M Blok-DM-3	Success	Elektro-L 3	Russia	Russia	2094	GEO	Meteorology	Governmental
26/12/2019	Russia	Rokot-KM	Success	Gonets-M (14, 15 & 16)	Russia	Russia	280 (each)	LEO	Telecommunication	Governmental
				BLITS-M 1	Russia	Russia	16,7	LEO	Techno/Demo	Governmental
27/12/2019	China	CZ-5	Success	ShiJian 20	China	China	8000	GEO	Techno/Demo	Governmental

4.3.2 ESPI Database definitions

Launch outcome

- Success: launch attempt performed nominally, all spacecraft injected in the intended orbit.
- Failure: launch attempt led to the total loss of the payloads (destruction, unrecoverable orbit).
- Partial failure: launch attempt led to a recoverable harm for the payloads (damage, orbit).

System categories

- Satellite: standard spacecraft designed to orbit the Earth and comprised of a bus/platform and one or more payloads.
- Cubesat: spacecraft designed according to the cubesat standard and comprised of one or more units (U) of 10x10x10cm.
- Space Station Module: element of a space station including habitats, nodes, structure, external platforms and other permanent or temporary parts.
- Transfer Vehicle: spacecraft designed to transfer cargo or humans to a space station.
- Space Exploration System: specific spacecraft designed for space exploration purposes including probes, landers, rovers and other systems with a mission outside Earth orbit.
- Space Plane: reusable spacecraft with advanced manoeuvring capabilities including the capacity to land autonomously.
- Servicing Vehicle: spacecraft with advanced Rendezvous and Proximity Operations capabilities, designed to provide services to other satellites (e.g. life extension, refuelling, inspection).
- Dummy payload: passive object without operational payload (e.g. mockup, passive target…).
- Attached package: system remaining attached to the launcher upper stage.

Mass categories

- Large spacecraft (>500kg)
  - Extra heavy-class More than 8,000kg
  - Heavy-class Between 2,000 and 8,000kg
  - Medium-class Between 500 and 2,000kg
- Small spacecraft (<500kg)
  - Mini-class Between 100 and 500kg
  - Micro-class Between 10 and 100kg
  - Nano-class Less than 10kg

Orbits

- GEO: an orbit at an altitude of approximately 36 000 km from Earth.
- MEO: an orbit at an altitude between 2000 and 36 000 km from Earth.
- LEO: an orbit at an altitude between 100 and 2000 km from Earth.
- HEO: highly elliptical orbit, an elliptical orbit with a high eccentricity.
- Escape: an orbit beyond Earth orbit with an eccentricity higher than 1.

Missions

- Telecommunication
  - Telecommunication services by satellites
  - Automatic Identification System: detection and tracking of ships
  - Satellite Data Relay:telecommunication relay for other satellites
- Remote sensing
  - Earth Observation: observation of the Earth for an operational purpose (not scientific)
  - Meteorology: study of the Earth atmosphere with a focus on weather forecast (not scientific)
- Navigation
  - Navigation: Global Navigation Space Systems (GNSS) and Satellite-Based Augmentation Systems
- Human spaceflight
  - Cargo Transfer: transfer of supplies to a space station
  - Crew Transfer: transfer of astronauts to a space station
  - Space Station Infrastructure: supply of a space station's element
- Science
  - Astronomy: remote study of celestial bodies and phenomena
  - Biology: study of life and living organisms
  - Earth Science: study of the Earth
  - Planetary Science: study of planets, moons, asteroids, comets
  - Space Science: study of the space environment and of the functioning of the Universe
- Military-specific
  - Early Warning: detection of missile launches through infrared observation
  - Signal Intelligence: interception of electronic signals
  - Space Situational Awareness: detection and tracking of objects in orbit
- Technology / Demonstration
  - Technology / Demonstration: testing of new systems or technologies
- Other
  - In-Orbit Servicing: provision of services to another spacecraft
  - Radio Amateur: radiocommunication for amateur purpose
  - Other/Unknown: missions not falling in the above definitions

Markets

- Governmental civil: the spacecraft is primarily intended to serve the mission of an organisation providing a public service or having scientific research objectives.
- Military: the spacecraft is primarily intended to serve armed forces operational needs.
- Commercial: the spacecraft is primarily intended to serve a commercial market and to make profit.
- Education: the spacecraft is primarily intended to serve an academic or training purpose from system design to operation.
- Dual: the spacecraft is intended to serve both military and civil purposes.
- Amateur: the spacecraft is operated for private, non-for-profit actors, and usually conducts a rather basic mission (e.g. radio).

4.3.3 Space activity highlights in 2019

Finalisation of Iridium-NEXT's deployment

Iridium Communications finalised the deployment of its next-generation satellite constellation. In January, a total of 10 satellites were put in LEO on a Falcon 9, from the Vandenberg Space Launch Complex 4. This was the eighth and final launch of Iridium's campaign to replace its original constellation. The new constellation is made up of 75 satellites (66 operational and 9 spares). The programme has cost €2.7 billion over three years.

(Credit: Iridium)

Launch of Microsat-R, Indian ASAT test's target

Developed by the Indian military Defence Research and Development Organisation (DRDO), this 740 kg satellite was launched to LEO on a Polar Satellite Launch Vehicle at the end of January. It was later destroyed on purpose during "Mission Shakti", an ASAT test conducted by DRDO on 27th March using a Ballistic Missile Defence Interceptor launched from the Odisha coastal test range.

(Credit: Indian Air Force)

OneWeb's first launch a success

At the end of February, Arianespace performed the first of the planned 21 launches to put in LEO OneWeb's next generation satellites. Six OneWeb satellites were put into orbit on a Soyuz, from the Guiana Space Centre. The dispenser (purpose-built by the Swedish factory of RUAG Space and installed on the Fregat upper stage) released the first two satellites 63 minutes after liftoff, the last four remaining satellites 29 minutes later. Signal acquisition was confirmed for all satellites shortly after. The satellites are manufactured by OneWeb Satellites, a joint venture between OneWeb and Airbus DS. More than 600 OneWeb satellites were planned to be manufactured and launched in order to provide global coverage. OneWeb aimed at launching 60 satellites per launch every month, and to that end multiplied launch agreements with various providers, including Blue Origin and Virgin Orbit. However, the company filed for bankruptcy in March 2020.

(Credit: OneWeb)

The United States one step closer to independent access to ISS

(Credit: SpaceX)

Space X's Crew Dragon is a transfer vehicle designed to dock to the ISS, under the Commercial Crew Integrated Capability (CCiCap) initiative. The 12-ton unmanned capsule was launched on 2^{nd} March on a Falcon 9 from Cape Canaveral, docked to the ISS the following day, and splashed down on Earth on 8^{th} March. This marked a decisive step for the United States to recover its independent capacity to send crews to the space station. The last U.S. crewed launch dates back to the 135^{th} and last Space Shuttle mission (Atlantis), in July 2011.

First launch of SpaceX mega-constellation Starlink

(Credit: SpaceX)

On May 24^{th}, SpaceX successfully launched and deployed 60 test satellites (227 kg each) for its planned 12 000 satellites constituting the Starlink constellation. It is to be noted that the ion thrusters of the Starlink satellites use krypton-gas as a cheaper alternative to xenon – the first commercial satellites to do so. The Starlink launch was highly debated by the astronomers' community who expressed concerns about how these reflective spacecraft would affect observations but also by the space sustainability community who also expressed concerns about the impact of mega-constellations after three Starlink satellites (i.e. 5% of the first launched satellites) were declared derelict soon after launch.

First ever failure of the European Vega launcher

After 14 successful launches in a row, the European launcher Vega suffered its first failure in July during the mission VV15. The launcher was supposed to put in orbit FalconEye1, the first military optical imagery satellite of the United Arab Emirates. The anomaly occurred two minutes after the launch, which resulted in the loss of both the rocket and the satellite.

An independent inquiry commission appointed by ESA and Arianespace soon after the event revealed that the failure of the rocket was likely caused by a problem with the vehicle's second-stage motor, which failed 14 seconds after its burning because of a "thermo-structural failure". Once the error is verified and corrective actions taken, Vega will be able to launch again. This was expected to occur at the beginning of 2020, but will finally take place in summer 2020.

(Credit: ESA)

Launch of the first commercial in-orbit servicing mission

(Credit: Nathan Koga/SpaceFlight Insider)

The Mission Extension Vehicle 1 (MEV-1), developed by Northrop Grumman and operated by SpaceLogistics, one of its subsidiaries, was launched at the start of October by the only mission of ILS in 2019. This is the first-ever commercial servicing satellite spacecraft to be launched. Once launched, MEV-1 used its electric propulsion system to go to geostationary orbit, a process that took three and a half months. In February 2020, it managed to rendezvous there with the Intelsat-901 (the first-ever attempt at a docking near geostationary orbit), in order to extend its lifetime for five years. After this period, the MEV-1 will be available for other satellites.

Orbital Flight Test of Boeing's Starliner

(Credit: Boeing)

The first uncrewed orbital flight of the Boeing CST-100 Starliner took place on December 20th, after having been delayed for a few days because of technical issues with the launching pad. The test was a first for the capsule and the rocket: it was the first flight of a ULA's Atlas V with a dual-engine Centaur upper stage, and without a payload fairing. While the launch performed successfully, the capsule did not act as planned. Indeed, because of an error in the mission elapsed timing system, the attitude control thrusters on Starliner did not burn as anticipated. The spacecraft managed to reach a "stable" orbit thanks to electrical power but not the one that was planned. Moreover, this manoeuvre used too much propellant, preventing the Starliner to dock to the ISS, which was one of the mission's objectives. However, several other systems were tested and approved (space-to-space communications, navigation system…). After two days in orbit (instead of eight), the capsule performed a successful de-orbit and re-entry and landed safely on Earth.

Return to flight for the Long March 5

In the last days of December, China launched a Long March 5 rocket to send a demonstration satellite to geostationary orbit which will allow the development of very high throughput satellites. This was the third launch of the rocket, and the first launch of a Long March 5 since 2017, when it suffered technical problems and failed during its travel to space. The Long March 5 is capable of delivering 14 metric tons to geostationary transfer orbit and 8.2 tons to translunar injection, while the derivative Long March 5B will be able to deliver 25 tons to low Earth orbit. The success of the launch was important for China, as the rocket is a crucial element for its space programme. Indeed, Long March 5 will be used to launch and assemble modules of the upcoming Chinese space station, but also to conduct missions beyond Earth orbit, especially to launch a probe to Mars (Tianwen-1) and a lunar sample return mission (Chang'e 5) in 2020.

(Credit: CASC)

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