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The European Launchers between Commerce and Geopolitics

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Background

The overarching objective of this report is to provide an in-depth reflection on the medium-term prospects for Europe's access to space (i.e. over the next 10-15 year timeframe). Starting with the resolution endorsed at the 2014 Ministerial Council of the European Space Agency (ESA), the project assesses the scope, implications, opportunities and constraints of the European strategy in the launcher sector with respect to the broader and rapidly evolving international context. Indeed, the 2014 decisions were not only driven by endogenous factors (such as the deficit of commonalities between Ariane 5, Soyuz and Vega, and the dependence of a significant part of European institutional launches on Soyuz) but in particular by exogenous ones, including the increasing competition in the worldwide commercial market and the great changes expected in the upcoming years with respect to both the supply and demand conditions of the satellite launch industry.

In order to cope with these challenges, the Ministerial Council resolution called for the "availability as soon as possible of new European launch services which are not only competitive without requiring public support during exploitation, but also flexible and modular enough for responding to a wide range of needs, from institutional to commercial requirements, as well as to the uncertainties on the evolution of the commercial" market.

To achieve this objective, European ministers agreed to kick-start the development of Ariane 6 and Vega-C, and to introduce fundamental changes in the overall governance of the European launcher sector, particularly "in the relations between industry and governments in developing and operating launch vehicles". The result was a multi-pronged strategy aimed at increasing flexibility and reducing the cost of Europe's future access to space by activating a number of levers, including the utilisation of heritage hardware, a far-reaching streamlining of industrial organisation, the maximisation of common expendable elements, and the creation of synergies between different market segments. All these levers – together with the guarantee of five institutional launches per year – were essentially designed to increase the production rates so as to generate economies of scale that would ensure competitive pricing for Ariane 6 and Vega-C without the need for public support payments during exploitation.

This strategy raises a number of questions in terms of effectiveness and, more broadly, with regard to the overall prospects for Europe's access to space in the next decade.

The International Landscape: Current Dynamics and Future Trends

In order to assess how the 2014 decisions will position European future launchers at the nexus commerce and geopolitics, a detailed reference analysis of worldwide launcher programmes and an in-depth assessment of current and future trends in the sector are provided in the report. These show that a number of concurrent trends are unfolding.

All major spacefaring nations are in the process of upgrading their flagship families of launchers and launch infrastructure, primarily driven by the need to reduce cost and increase commercial competitiveness, while strengthening national autonomy and expanding existing capabilities and infrastructures to accommodate more ambitious goals. The era of international joint ventures seems to have reached an end at this stage.

Upgraded or brand new launch vehicles from all major space-faring nations will enter service over the course of the next ten years, while current launch systems will be progressively phased out. The main Geosynchronous Transfer Orbit (GTO) launchers of the 2020s, other than Ariane 6, will consist of Vulcan (U.S.) Falcon 9/Heavy (U.S.), H-III (Japan), Long March 5/7 (China), GSLV Mk-III (India) and Angara A5 (Russia). As a higher number of players will be interested in capturing a share of the market demand, there will likely be an increased degree of competition. At the same time, however, this expansion of supply will take place in a market where demand is expected to remain stable over the medium term, bar a substantial decrease in launch prices.

The Non-Geostationary Orbit (NGTO) environment will probably continue to be dominated by captive institutional demand, although the growing number of commercial applications and related constellations – as well as the exponential increase of small satellites – points to the possibility of more commercial competition for contracts for small launchers. Moreover, there will be strong competition to deliver payloads to Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) orbits between Vega-C, Epsilon (Japan), Long March 6/7 (China), Antares (U.S.), Athena III (U.S.), Falcon 9 (U.S.), PSLV (India), Soyuz 2.1v (Russia) and Angara 1.2 (Russia).

Furthermore, the trend of using launch capabilities as a geopolitical tool for foreign policy objectives is growing. While in the past it was the launcher technology itself that was to be leveraged by means of technology transfers, today several countries are offering complete packages (which include launch of a domestic-built rocket, satellite and ground support) to countries of geopolitical interest. This unfolding policy reality might have potentially disruptive effects on the future global launch industry.

Finally, after decades of complete reliance on government funding to develop launch vehicles, a new paradigm is gradually emerging in the launch industry of several countries: while access to space still remains firmly under the control of national governments, the role of private actors (and private investment) is clearly increasing, with commercial companies such as SpaceX, Airbus-Safran Launchers (ASL), Mitsubishi Heavy Industries (MHI), Blue Origin, and Virgin Galactic positioned to become even bigger stakeholders in both development and exploitation of launch vehicles.

In fact, the determination and focus of new entrepreneurial efforts to establish and commercialise game-changing launch technologies was met by success at the end of 2015, when for the first time the landing-and-reuse of a suborbital vehicle and the landing of the first stage of an orbital-capable rocket were achieved. With the technological feasibility now proven, questions remain about the economic impact of first-stage reusability, which will require a few more years to be answered. Nevertheless, the competitive edge currently gained by those actors will position them at the vanguard of reaping the expected benefits, possibly allowing them to continue to set the tempo and direction of the global space transportation sector.

The introduction of disruptive innovation technologies does not stop at rocket reusability, where Europe is perhaps lagging behind, but extends to other segments. This may give Europe leap-frogging possibilities. Additive manufacturing, a technology now in its infancy but with the potential to shake up the very foundations of the entire manufacturing industry, could have a substantial impact on reducing the production cost of launch vehicles, potentially dramatically reducing the cost of access to space. Moreover, reusable non-vertical launch system such as the Skylon Spaceplane could well be the way of accessing space in what will perhaps be a post-rocket era.

Prospects for the new European Launchers: an Assessment

Building on the above, an overall assessment on the medium-terms prospects for European launchers was performed. This revealed a number of issues of potential concern, which are summarised as follows:

- The new European strategy on access to space as defined by the 2014 ESA Ministerial Council represents a politically well-agreed compromise that follows a period of intense disagreement between ESA Member States, most notably Germany and France. However, the past disagreement might continue to have a detrimental effect on the development schedule, which is tight. Hence all efforts should be made to put the past behind and focus on the earliest possible entry into service of Ariane 6.
- From an overall perspective, the projected way forward appears to a large extent conservative rather than trend setting. The Resolution sanctions a *revolution* in terms of processes (efficiency-driven industrial reorganization and governance), but a mere *evolution* in terms of product – as the new launchers, Ariane 6 in particular, will be built upon consolidated technologies.
- The new European launchers will realize cost savings principally by virtue of modularity, common design synergies as well as industrial reorganization and streamlining. A core objective – not to say the main objective – is to eliminate the need for public support payments during exploitation while maintaining a competitive pricing policy. However, European stakeholders have not fully clarified what the overarching goals of Ariane 6 and Vega-C are in terms of the market shares that need to be achieved, or how to instrumentalise the launchers in order to provide support to the foreign policy goals of Europe.
- The success of this new launcher strategy will rely *de facto* on the guarantee of

an institutional launch business base, which might however be difficult to ensure absent a formal commitment by all European stakeholders.

- The integration of Arianespace into ASL would entail a significant market verticalisation since one of its shareholders (Airbus Defence & Space) is also a leading satellite manufacturer. Hence it is important that effective measures be put in place to ensure continued market equilibrium, as otherwise, unintendedly, market share may be lost.
- The new launcher strategy seems to project the current policy reality over a 15-year period, to some extent assuming that the current strong market situation and beneficial financial scenario (with near-zero interest rates and favourable exchange rates) will last. This may be overly optimistic. The introduction of game-changing technologies currently pursued by several launch providers, most notably first-stage reusability concepts as well as non-vertical launch systems, could dramatically affect Ariane 6's future prospects and blunt its forecast competitive edge by the time it enters into service or soon thereafter. Measures are necessary to ensure that Ariane 6 can evolve with the market – without endangering the high priority to be given to early market entry.
- While flexible enough to respond to a wide range of needs, Ariane 6 has a strong commercial focus, and it is in a certain sense almost exclusively tailored to satisfying the demand from commercial satellites operator. Such commercial focus might make it difficult to fulfil all the varied needs of the Agency's missions. Furthermore, Ariane 6 is not designed to be human-rated. Consequently, Europe will not be able to conduct autonomous human spaceflight missions in the foreseeable future.
- In terms of production costs, Ariane 6 will be less demanding than the current generation by 40%. However, there are limited margins of profit for Ariane 6. The expected launch cost of Ariane 64 is € 90/100 million while the prearranged launch price is € 115 million. This surplus however will be largely needed to cover the mismatch between the expected launch costs (roughly € 80 million) and launch price (roughly € 70 million) of Ariane 62. Crucially, the modest margins allow little room for manoeuvre in case of price war. Indeed, potential oversupply or distorted market conditions can lead to more aggressive stances on the commercial market by national actors, with governments subsiding their launchers even more than today. Should this scenario play out it might be difficult for Ariane 6 to remain competitive, unless some form of financial backing from ESA Member States is reintroduced. In the meantime, the extent of support for the exploitation of Ariane 5 for the period 2016-2023 also remains unsettled.
- The roadmap for Vega (namely Vega-C and Vega-E) appears to be more robust. However, the forecast evolution of the lightweight Vega into what will *de facto* be a medium-lift launcher (the performance envisioned for Vega-E would be up to 3,000 Kg in GTO) will enable meeting demand in the small segment of the GTO market, but leaves open the question of how to best capture the ever-growing demand for small/micro satellites in the future. Unless both Vega-C and Vega-E will be made simultaneously available, there could be some hurdles in terms of the pairing of satellites and the scheduling of launches.
- Europe is following the worldwide trend of strengthening sovereign autonomy in access to space, by realizing an all-European family of rockets and thereby overcoming the current dependence of European institutional launches on the availability and pricing of the Russian-made Soyuz. However, the decision to replace Soyuz-ST with Ariane 62 and Vega-C, while understandable from an industrial policy perspective, by implication down-prioritises the fact that the presence of Russian-made Soyuz-ST at the Guyana Space Centre (GSC) represents much more than a mere technical and economic cooperation. The eventual phase-out leaves open the issue of finding an analogue and valuable mechanism for European-Russian cooperation in space.
- Unlike other major spacefaring nations, which are putting a strong emphasis on the upgrading of their launch infrastructure through the construction of new spaceports, Europe will continue to rely on the GSC. While located in a very advantageous location, particularly for GTO launches, the GSC will remain the only spaceport for Ariane and Vega in the foreseeable future, with inherent risks.

This report sets out a variety of possible measures to overcome the issues identified as of concern:

- Enhance the commercial competitiveness of European launchers;
- Promote disruptive technological innovation in Europe;
- Boost and geopolitically leverage the strategic value of the launchers;
- Reinforce Europe's role in human spaceflight;
- Secure Europe's gateways to space.

While not all the proposed measures within these five specific – yet strongly interlinked – areas can be easily implemented, it is important to discuss the concrete steps that could be taken to ensure the long-term availability and competitiveness of an autonomous access to space for Europe. Relevant recommendations and possible concrete policy measures are as follows:

1. It is recommended that the debate on the follow-ups to Ariane 6 and Vega-C should be pursued in the very near future. Decisions on a possible Ariane 66 configuration and on Vega-E should be ideally taken as early as the ESA Ministerial Council of 2016, and those on Ariane 7 well before the Ariane 6 qualification flight in 2020. It is also recommended that these decisions become part of a unified "European Roadmap for Access to Space" that would pave the way for smoother decision-making in the future, and ultimately make Europe a more proactive and trend-setting actor vis-à-vis the rapidly evolving worldwide landscape of access to space.

2. A dedicated European-wide R&D seed-funding programme targeting disruptive technological innovation should be established, particularly for launcher technology. An actor like the European Commission (EC), which has a relatively more risk-tolerant mandate, could provide the funding and it might be possible to do so in a more stable manner than today due to the absence of geo-return constraints in Commission programmes. The overall objective would be for Europe to gain or maintain its role as a trendsetter, without being forced to play a "catch-up game" in the space transportation sector in the medium-to-long term.

3. In light of the future phase-out of Soyuz from the GSC, an alternative and symbolic instrument for European-Russian space cooperation should be identified and more firmly enshrined into the broader framework of a "European Vision for Space".

4. The creation of a "pan-European Export Credit Agency" should be considered. In this respect, the European Investment Bank could be entrusted with new, dedicated functions of support to the export of European satellites and launch services, with the ultimate goal of providing a larger launch business base both for current and future European launch systems.

5. ESA and its Member States should assess the possibility of better leveraging the existing small spaceports such as Andoya and Kiruna or the upcoming launch facility in the UK, by examining the possibility of accommodating lightweight orbital launch vehicles. Such possible decisions would ideally have to be accompanied by consideration of the introduction of an even smaller configuration of the Vega rocket or even by opening these spaceports to purely commercial launch service providers.

6. The possibility of building a second launch site for Europe's upcoming launchers – and in particular Ariane 6 – should be considered in order to ensure redundancy and cope with the potential need for increased launch frequency. At the same time, the huge financial and political efforts required suggest identifying other policy options. In view of the converging dynamics and similarities between European and Japanese launcher programmes, extending the Europe-Japan launch backup agreement to cover institutional missions would provide a greater margin for assuring Europe's access to space in case of the unavailability of Kourou.

7. The development of full spectrum capabilities for accessing space, and in particular the development of a human-rated launch vehicle and re-entry system, should not be put on the backburner, but more substantially discussed among all European constituencies within a broader vision for space exploration in the post-ISS period by *inter alia* considering the potential benefits offered by the involvement of both European institutions and European private companies in future space exploration and human spaceflight activities.

8. Finally, the potential benefits of more active involvement of other EU institutions, particularly the European External Action Service (EEAS), should be considered in terms of a more efficient exploita-

tion of launcher-related technology or services for S&T-based diplomacy. Among the possible options, but a controversial one, the provision to developing countries of "launch package agreements" through Official Development Assistance (ODA) could be a highly effective geopolitical move for providing indirect support to European space industries, expanding a launch business base for European launchers, and increasing Europe's influence on the international stage. The possibility of assisting the building of geopolitical alliances through the transfer of 'previous generation' technology to countries intent on developing their own launch capabilities should also be kept in mind, particularly at this time of generational change-over in launchers in Europe.

1. Introduction

» Earth is the cradle of humanity,
but one cannot live in a cradle forever
— K. Tsiolkovsky

1.1 Access to Space at the Nexus of Commerce and Geopolitics

More than one hundred years have passed since Konstantin Tsiolkovsky put in place the theoretical foundation for spaceflight, and the most basic equation that applies to space activities has remained unchanged: no launcher, no space programme. From Sputnik to Rosetta, through Apollo and the modules of the International Space Station, space programmes worldwide have invariably relied on the availability of launch vehicles to reach and exploit outer space.

All spacefaring nations consider launchers as a strategic good – or more precisely a strategic enabler: not a goal in itself, but a *conditio sine qua non* for the conduct of their military, civil or commercial space efforts, and thus the foundation for any comprehensive space policy and for the full utilisation of space assets. Understandably, the establishment of indigenous launch systems has been generally regarded as a crucial priority that initially responded to security needs as well as to considerations of political autonomy and national pride, but which was ultimately instrumental in providing a wide range of socio-economic benefits through the exploitation of space assets. Thus, for any nation with a minimum of strategic ambitions in space – and thus on Earth – the lack of an autonomous access to space will bear high economic and political costs.[1]

From an economic point of view, although the satellite launch industry is rather small in terms of size and revenues when compared to other space activity sectors in both the downstream and upstream segment, it nonetheless generates a variety of direct, indirect and induced benefits to society. As several analysts have pointed out, such benefits include immediate economic effects in terms of gross value added to the national economy; medium and long-term catalytic effects of enabled revenues from satellite launches (which include the downstream sector revenues of both space and non-space industries and services); as well as non-quantifiable yet significant impacts in a number of key areas. Thus, investments in space launch capabilities have indeed proved to play a crucial role in supporting overall industry, technology and research capabilities, in promoting innovation and improving competitiveness and in generating knowledge, employment and entrepreneurial capacities.[2] Hence, without autonomous access to space, many of these direct, indirect and induced benefits could not be fully reaped.

From a political and security perspective, the lack of autonomous access to space could be even more harmful, as it would cause dependency on foreign countries for space transportation needs, and thus restrict a country's political sovereignty vis-à-vis its capability to decide when and under what conditions to launch. In this respect, a major inherent risk is that a foreign launch provider could impose unacceptable conditions for launching institutional satellites – particularly military ones – or even refuse to launch on the basis of political considerations.

While the equation *no launcher, no space programme* provides a rather straightforward rationale for the establishment of national launch capacities, attaining such a goal is no easy undertaking. Quite to the contrary, the development and maintenance of an indigenous space launch system and related infrastructure is a capital-intensive process requir-

[1] This report refers to the concept of autonomy, independence and non-dependence as outlined by Jan Wouters and Rik Hansen in the book European Autonomy in Space. Autonomy is a political concept by nature and can be defined as 'possessing the power to determine one's own laws'. Strategic independence is more operational and refers to 'the capacity to take the required decisions and to execute them so as to safeguard a number of vital interests'. Autonomy could thus be understood as a formal criterion (the goal to achieve), while strategic independence is the necessary condition for effective autonomy (the means to reach the goal). Cit. Al-Ekabi, Cenan. "European Access to Space: Factors of Autonomy". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015.

[2] See Del Monte, Luca and Luigi Scatteia. "A socio-economic impact assessment of the European launcher sector". IAC-15. Jerusalem. 2015.

ing not only extremely advanced technical capabilities and large financial investments, but also the highest degree of political will and backing. In view of that, it is not surprising that only a dozen countries have been able to establish a basic launch capacity to reach lower altitude orbits. Multi-destination capabilities to reach the geostationary orbit (GTO), low and medium earth orbits (LEO, MEO) and deep space are even more concentrated, having been mastered by only six space powers: the United States, Russia, Europe, Japan, China and India.

As a direct derivative of Intercontinental Ballistic Missiles (ICBMs) technology, space carrier rockets have historically been developed under the lead of military organisations to satisfy national security purposes. In the wake of the Cold War, both the United States and the former Soviet Union, but also to a large extent China and the pioneering European space countries, France and the United Kingdom, initially conceived their launch vehicles as proxies for substantiating their military might.[3] While this military dimension – and involvement – remained significant also in subsequent stages, the development of launchers soon became understood as a tool for the development of national civil space programmes, assets and services, which would in turn ensure independent decision-making based on space data and ultimately provide a wide range of political and socio-economic benefits.

With the expansion of commercial uses for communication satellites in the early 1980s, access to space eventually evolved from a means to respond to a domestic strategic demand, to an economic activity also serving non-institutional missions. Over the past 25 years, the provision of commercial launch services has progressively taken hold, stimulating the emergence of a global market characterised by a strong dynamic of commercial competition and, in recent years, by the ever-growing involvement of private undertakings.

The market for commercial launch services, however, is not comparable to those for most customer-oriented goods or services, primarily owing to the predominant influence that non-market forces exercise on it. Key factors such as the central role played by governments in developing launch capacities irrespective of market demand, in supporting their exploitation through a variety of means, including public subsidies, and in devising regulatory actions to limit foreign competition and prevent the transfer of sensitive technology, have profoundly shaped the market conditions in which launch services are commercialised, to an extent that, arguably, these have no equivalent in any other economic sector.[4] Security and political considerations are so deeply engrained in the underpinnings of the launch industry that even for internationally competed launch contracts, the commercial launch market cannot be aptly described as a "free and fair" trade environment.

Even if the rise of private actors is now profoundly reshaping many key features of the traditional launch business model, access to space ostensibly remains a sector where market economics is constantly flanked – not to say overwhelmed – by politics. In the light of these considerations, it can be argued that dynamics in this field revolve around two overarching and closely related dimensions that the space strategies of the major space-faring nations must necessarily confront: commercial viability and geopolitics. There is a strong and visible *policy nexus* between these two dimensions and any comprehensive assessment of the sector's dynamics must thus take this mutually reinforcing relationship into proper account.

The term geopolitics needs, however, a clarification, as it is understood here to simultaneously cover two distinct aspects of the sector. The first is that access to space is an *issue-area* of strategic interaction among nation-states, and, as such, it can be analysed through the theoretical lenses provided by geopolitics as interpretative paradigms of international relations theory (state-centric analysis, relative-gains-seeker behavioural model, weak institutionalism, power as central variable, etc.), rather than through the application of a purely economic analysis.[5] The second is that launchers themselves can be understood as both elements and enablers of political power building. In this sense, the geopolitics behind access to space has a double facet: on the one hand it is a strategic

[3] Couillard, Philippe. "De Diamant à Ariane 1". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

[4] As noted by Herzfeld, "the nuclear power industry probably comes closest to having parallels to the launch industry [as to face government regulatory actions, to have defense agencies as well as civilian customers, and even to receive subsidies from governments]. However, there is a long history of successful commercial business in nuclear energy and many of the trade issues have been resolved. Nuclear power also competes with other energy sources and therefore the price for nuclear power is tied to the market price of energy in general. No such pricing baseline exists for launch vehicles and services". Cit. Hertzfeld, Henry. Williamson, Ray. Peter, Nicolas. "Launch vehicles: an economic perspective". Space Policy Institute, The George Washington University. September 2005.

[5] See Jackson, Robert, and Georg Sørensen. Introduction to International Relations. Theories and Approaches. Oxford University Press: 2007.

capability that enhances national power and prestige, in addition to securing the autonomous conduct of military, civil and commercial space programmes; on the other hand, it is a potential instrument to be leveraged (e.g. by means of technology transfer, creation of joint ventures and provision of launch package deals) to achieve diplomatic goals and support foreign policy objectives and strategies.

Only by understanding the complex interaction between the economic and geopolitical driving factors, can the underpinnings of the launcher sector be captured and assessed in the most optimal fashion.

1.2 Objectives of the Report

Access to space has by any measure been a true success story for Europe. For more than three decades, Europe has enjoyed the availability of an independent, reliable and efficient infrastructure and means for launching into space. The Ariane launchers have served a variety of institutional and commercial missions and more broadly enabled the construction of a European space programme, becoming symbols of Europe's autonomy and achievements in space.

The five different rocket generations that have succeeded one another in the Ariane family have won a considerable share of the global market, and helped turn the European Space Agency (ESA) into one of the most important actors in the international space arena, while enabling Europe to construct a robust satellite launch industry and infrastructure. More than 400 satellites have been successfully launched from Europe's spaceport in French Guiana and more than half of the commercial satellites in service today were launched by the European undertaking, Arianespace, which is indisputably the world's leading launch service provider.[6] Thanks to a remarkable launch performance of almost 70 successful launches in a row, the Ariane 5 rocket has now emerged as a global point of reference for commercial launches and a cornerstone of European institutional launches, having generated over 50 billion euros[7] of direct economic benefits in Europe.

Yet, in spite of these praiseworthy accomplishments, ensuring the long-term sustainability of an autonomous access to space and its competitiveness on the commercial market does not come as a matter of course. The satellite launch industry has been changing rapidly in recent years, with respect to both supply and demand conditions, and it is expected to experience even more profound changes in the years to come.

In response to and in anticipation of these rapid changes, the ESA Council at Ministerial level that convened in Luxembourg on 2 December 2014 took a number of strategic decisions vis-à-vis the future of European launchers. The Council's resolution, which can certainly be regarded as a decisive turning point in the history of ESA, will likely affect not only the development of Europe's access to space, but also the broader goals and directions of the European space programmes and of Europe in the international space arena for decades to come. Hence, a comprehensive assessment of the consequences of such decisions, in terms of how these will position Europe at the nexus of commerce and geopolitics, is needed.

The overarching objective of the report is to provide an in-depth reflection on the medium-term prospects for Europe's access to space (i.e. over the next 10-15 year time frame). Starting with the resolution endorsed at the ESA C/M 14, this project intends to assess the scope, implications, opportunities and constraints of the European strategy in the launcher sector with respect to the broader and rapidly evolving international context.

To this effect, the report will provide a detailed analysis of worldwide commercial and political dynamics shaping this domain, investigate key unfolding trends and their future impacts, and in turn assess the ensuing challenges and opportunities to be faced by European institutions and industry in safeguarding its future competitiveness and optimizing the political benefits of Europe's autonomous access to space.

1.3 Methodology and Structure

This study has been mainly carried out through desk research of publicly available documents, conference proceedings and bibliographic sources, spanning both sectoral and general contributions in the area of ac-

[6] With sales that have exceeded the 50% of the global launch revenues over the last ten years. See Chapter 4.

[7] See European Space Agency. "Ministerial Council 2014. Access to Space" ESA. 27 November 2014. Web. http://www.esa.int/About_Us/Ministerial_Council_2014/Media_backgrounder_for_ESA_Council_at_Ministerial_Level. Accessed 5 February 2015. Overall, it has been estimated that each euro spent by ESA in the Ariane launcher programme produces a total of 3.2 euro of value added in the economy. See Del Monte, Luca and Scatteia Luigi. A socio-economic impact assessment of the European launcher sector. IAC-15. Jerusalem. 2015.

cess to space. The research has been complemented and strengthened by a number of targeted interviews, generally off the record, with various stakeholders and space policy experts, and by participation in a number of conferences and symposia, including the 2015 ESPI Autumn Conference, the "International Conference on European Space Launchers" organised by *L'Academie de l'Air et de l'Espace* in Paris, and the "8th Annual Conference on European Space Policy", the findings of which have been incorporated into the report.[8]

The research and writing process of the report has in addition immensely benefited from the fruitful exchanges with an accompanying group of five experts that was set-up to provide competent advice and stimulate discussions on the scope and overall directions of the project. The group was composed of Peter Hulsroj, Ralph W. Jaeger, Arturo de Lillis, Nicolas Peter, and Per Tegnér, and convened at ESPI twice during the course of the project.[9] One of the main benefits of this accompanying group was that it gathered people with different backgrounds and experiences around one table to brainstorm and discuss, in an open fashion, the many issues that cluster around this highly dynamic sector.

The report provides a variety of quantitative data and analyses, which – in line with the general criteria proposed by Eisenhardt and Yin – were mainly collected to support the construction of qualitative research. It should also be highlighted that while the approach of this study is markedly empirical and its scope global, its underlying purpose is normative in nature deliberately European in perspective: the study concretely intends to *describe* and *explain* the international dynamics in the launcher sector in order to *recommend* possible policy actions and strategies to European decision-makers. This coincides with ESPI's mission to provide European stakeholders with informed analyses in the field of space policy and to facilitate the decision-making process in Europe.

The Report is comprised of six chapters. After providing an introductory overview in the chapter to hand, the next chapter will examine the decisions endorsed at the 2014 ESA Ministerial Council by, in particular, highlighting the resolution's rationales and outlining the future evolution of European launch capabilities and governance schemes.

In order to assess the international background surrounding Europe's policy on access to space, in Chapter 3 the focus will be shifted to the analysis of the most recent developments in the space transportation sector of the main space-faring nations, as well as of a number of emerging countries which have developed – or are planning to develop – their own launch vehicles. Particular attention will be paid to assessing the current strategies, and to presenting the launch capabilities and forecast evolutions. Considerations on the strategic interactions between space launch powers will also be examined within this chapter, as a means of better explaining the underlying forces shaping access to space.

On the basis of this reference analysis, Chapter 4 will put the spotlight on the major features and currents shaping the global satellite launch industry, with particular emphasis on the complex interaction between market and non-market forces. Following this, the chapter will be devoted to thoroughly identifying and discussing key unfolding trends and medium to-long term evolutions that will likely affect future supply and demand conditions of access to space.

Building upon the analysis and findings of the previous chapters, an overall assessment of the current European strategy on access to space and medium-term prospects for European launchers will be provided in the first part of Chapter 5. This will in turn be used as a basis to present and discuss a set of potential policy options to better cope with the potential areas of concern identified in the assessment. In view of the upcoming review of the Ariane 6 launcher programme and ESA C/M 2016, Chapter 6 will draw some conclusions and general recommendations on the additional measures that may be required to maintain Europe's competitiveness in the commercial market and exploit the strategic value of Europe's launchers in the best possible manner.

[8] The annual ESPI Autumn Conference took place on 21-22 September 2015 and revolved around the theme of "Access to Space and the Evolution of Space Activities". The two-day conference in Vienna gathered a large number of speakers and participants interested in debating new developments in how humans gain access to outer space, and potential new activities arising from an evolved landscape in which launch costs might decrease dramatically.

[9] Peter Hulsroj is the Director of ESPI; Ralph W. Jaeger is the former Senior VP of Arianespace; Arturo de Lillis is the former Head of ASI Launchers Unit; Nicolas Peter is a Policy Officer for the Space Policy and Research Unit, DG GROW; Per Tegnér is the former Chair of the ESA Council and the former DG of the Swedish National Space Board. They all participated in the Accompanying Group in their personal capacities.

2. Access to Space in Europe

This chapter provides an introductory overview of the European launch sector. After tracing back the historical evolution of European vehicles and policies on access to space, the chapter describes the current launch capabilities and analyses the institutional set-up behind the development and exploitation of launch vehicles in Europe. In the second part, the chapter examines the decisions endorsed at the 2014 ESA Ministerial Council, explaining their rationales as well as the foreseeable future evolution of European launch capabilities and governance schemes.

2.1 European Launchers: from Political Autonomy to Market Dominance

2.1.1 The Quest for European Independent Access to Space

In spite of national beginnings, the development of launchers was one of the very first drivers of pan-European cooperative schemes in space. Cooperation in this field predates the establishment of the European Space Agency (ESA). It originated as early as 1962 with the creation of the first intergovernmental entity devoted to space activities in Europe, the European Launcher Development Organisation (ELDO), which eventually merged in 1975 with the European Space Research Organisation (ESRO) to form ESA.[10] Although at that time European countries already had significantly different views and priorities with regard to space activities, the development of an indigenous European means of accessing space was not a point of contention. And all the pioneering European space countries agreed that nothing significant could be achieved in this field without sound European cooperation. Such necessity was later made even clearer by the well-known argument with the U.S. over the launch of the French-German *Symphonie* satellites.[11]

Within the framework of ELDO, in 1962 major European leaders agreed to develop a heavy rocket, Europa, whose first stage would be Britain's Blue Streak ballistic missile; its second stage, Coralie, was to be built in France and its third stage, Astrid, was to be provided by Germany. Italy was to provide the satellite and the fairings, while Belgium would provide the ground guidance system and the Netherlands would provide the telemetry links.[12]

However, as noted by many, these decisions were taken "at the highest political level, as a matter of bargaining and without any sound technical basis".[13] The Europa rocket, in essence, was the result of a politically imposed agenda that "was carried over into a management structure in which each partner agreed to share the tasks under the responsibility of their respective governments, leaving ELDO itself very few powers in respect of technical and financial management of the project".[14] Not surprisingly, the task of matching three stages and a satellite built in four different countries without a fully-fledged and centralised technical management of the project turned out to be an insurmountable challenge and none of the Europa launches conducted between 1964 and 1971 succeeded in putting a satellite into orbit.

After the fiasco of the Europa 2 and 3 projects and the parallel demise of ELDO, efforts were revitalised by France, which in 1973 proposed to ELDO member states to transform its Diamant-derived *Launceur a Trois*

[10] See: European Space Agency. "Launcher strategy". Web. http://www.esa.int/Our_Activities/Launchers/Launcher_strategy. Accessed 20 February 2015.

[11] With the aim of maintaining its monopoly in the field of commercial satellite communications, the U.S. initially refused to provide a launcher for the two satellites. It subsequently agreed to provide the service only on condition that Symphonie would not be used for commercial purposes, but only experimental ones. For a detailed assessment and historical analysis of the origins of the Ariane launcher, see Al-Ekabi, Cenan and Panos Mastorakis. "The Evolution of Europe's Launcher and Flagship Space Initiatives". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: pp. 2-14.

[12] Ibid. p. 6.

[13] Kriege, J. "The History of the European Launchers: an Overview". In Proceedings of an International Symposium on "The History of the European Space Agency". 11-13 November 1998, London. ESA SP-346. 1999: pp. 69-78

[14] Ibid. p. 71

Etages de Substitution (L3S) programme into a European programme, as part of a broader "package deal" with all the other European partners.[15] The Europeanization of this French launch vehicle was agreed in a ministerial meeting in July 1973[16] and work on the new launcher programme – eventually renamed the Ariane Launcher Programme – began as early as 1974 within the framework of the newly established ESA.

Unlike Europa, Ariane was conceived in a framework where European-wide management and responsibilities replaced a clear-cut division of tasks among European nations. Within the new framework, CNES was given full technical and financial delegation from ESA to manage the programme, in exchange for sustaining the largest share of the project (62.5%), assuming the risks of cost overruns, and ensuring a minimum of 80% industrial return to all participants in the arrangement.[17] Although from a financial perspective the development of Ariane encountered considerable hostility, particularly in France, from a technical point of view no major hurdles were faced. The inaugural launch of Ariane 1 eventually took place in December 1979, opening a new era in the balance of power in the international space arena.

Building on this success, in 1980, Arianespace – the world's first commercial satellite launch company – was established to manage and commercialise the operations of Ariane. Since the inception of the programme, it was rather clear that the provision of launch services to non-European customers would be necessary to amortize the development costs of the Ariane rocket. However, considering that by that time all launches into space – even those launches intended to place commercially owned and operated communications satellites into geostationary orbit – were carried out under government auspices, the decision to commercialise launch activity through a joint stock company was ground-breaking in nature. Even if it was initially intended as a supplementary source of financing for the Ariane programme, it ultimately set the stage for the emergence of a commercial launch market.

Ariane 1 successfully launched several European and non-European spacecraft, including Spacenet 1 for the first U.S. commercial customer. However, its payload capacity of 1,800 Kg to GTO soon proved insufficient to meet the growing size of telecommunication satellites. Ariane 1 thus began to give way to more powerful derivatives, the Ariane 2, with a payload of 2,200 Kg to GTO, and Ariane 3, which could carry a payload of 2,700 Kg. Ariane 3 was also designed to launch two spacecraft at a time allowing the optimization of launch configurations.[18] Interestingly, the development of Ariane 2 and 3 had already been envisaged before the entry into service of Ariane 1. By 1983, ESA also started the development of an even larger vehicle, which would become the workhorse of the European launchers' family: Ariane 4.

Altogether, 11 successful Ariane 1 launches took place between 1979 and 1986, and there were five successful Ariane 2 launches (out of 6) between 1987 and 1989. Ariane 3 made 11 flights from 1984 to 1989, all of which were successful (see Table 1).[19]

Launch Vehicle	Qualification Flight	Last Flight	Number of Successful over Total Launches
Ariane 1	24/12/1979	21/02/1986	11/11
Ariane 2	21/09/1987	01/04/1989	5/6
Ariane 3	04/08/1984	11/07/1989	11/11
Ariane 4	15/06/1988	15/02/2003	113/116

Table 1: Ariane 1-4 Launchers.[20]

Ariane 4 had its qualification flight in 1988 and soon emerged as one of the best launchers in its category, both in terms of performance and reliability. Thanks to its six variants, Ariane 4 was capable of lifting into GTO satellites weighing from 2,000 to 4,800 Kg, almost three times as much as the Ariane 3

[15] Al-Ekabi, Cenan and Panos Mastorakis. "The Evolution of Europe's Launcher and Flagship Space Initiatives". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: pp. 2-14.

[16] For a detailed description of the so-called "1973 package deal" see Krige, John, and Arturo Russo, A History of the European Space Agency 1958-1987. Volume 1. ESA Publications Division ESTEC, Noordwijk. 2000: 363- 374. Krige, John, Arturo Russo and Lorenza Sebesta. A History of the European Space Agency 1958-1987. Volume 2. ESA Publications Division ESTEC, Noordwijk: 55

[17] Sillard, Yves. "France and Launchers". In: Proceedings of an International Symposium on "The History of the European Space Agency". 11-13 November 1998, London. ESA SP-346. 1999: 69-78.

[18] Arianespace. "Milestones". Web. http://www.arianespace.com/about-us/milestones.asp Accessed 25 February 2015.

[19] European Space Agency. "Ariane 1-2-3". Web. http://www.esa.int/Our_Activities/Launchers/Ariane_1_2_3 2. Accessed 02 December 2015.

[20] Source: Arianespace. Web. http://www.arianespace.com/launch-services-ariane-heritage/ariane-heritage.asp. Accessed 25 January 2015.

launcher. It performed 116 launches, 113 of which were successful, placing a total of 182 payloads in orbit.[21] Ariane 4's technical success was accompanied by a "commercial success that far exceeded initial expectations": during its service career from 1998 to 2003, Ariane 4 captured nearly 60% of the commercial satellite market, making Arianespace the reference company for launch services worldwide.[22]

In spite of these accomplishments, the evolution of satellite technologies and characteristics forecast at the end of the 1980s, as well as ESA's plans for the development of space laboratories and an autonomous human spaceflight, necessitated reconsideration of launch requirements towards heavier payloads, suitable for launching both telecommunication satellites and modules to the International Space Station (ISS).[23]

Against this background, European ministers decided to start the development of an even more powerful launcher, Ariane 5 at the ESA Ministerial Council of 1987. Originally intended to be human-rated, Ariane 5's primary purpose was to launch ESA's crewed Hermes spaceplane. Already in 1992, however, the Hermes project was abandoned, since neither cost nor performance goals could be achieved. Ariane 5, unlike its predecessors, was designed as a two-stage launcher, making use of a single engine fuelled by liquid hydrogen, with two large strap-on solid rocket motors. The overall payload capacity of the first version (Ariane 5 Generic) was 9,500 Kg to SSO and 6,000 Kg to the GTO.[24]

The development of Ariane 5 was completed in 1996; however, it failed its first test launch as well as three other flights in the early years of operations, making it necessary to rely on Ariane 4 for some more missions before discontinuation in 2003. In spite of these uncertain beginnings, Ariane 5 was able to maintain the dominance of Arianespace in the commercial launch market (see Chapter 4.2) and, more importantly, provide autonomous access to space for Europe.

2.1.3 European Launchers: the Current Family

For more than three decades, Ariane launchers have served a variety of institutional and commercial missions, becoming symbols of Europe's autonomy and achievements in space. Today, the family of European launchers includes the heavy-lift Ariane 5, the medium-lift Soyuz-ST, and the lightweight Vega (see Figure 1).

Figure 1: Europe's launcher family.[25]

Since its introduction, Ariane 5 has been refined in successive versions, "G", "G+", "GS", "ECA", and "ES". At present, there are two operational configurations: Ariane 5 ECA, which mainly delivers communication satellites to Geostationary Transfer Orbit (GTO) with a launch capacity of 10,000 Kg, and Ariane 5 ES, which is designed for various missions to Low Earth Orbit (LEO) with a launch capacity of 20,000 Kg. The latter configuration was also used for the launches of the five ATVs to the ISS. The exploitation of Ariane 5 is supported by the Ariane Research and Technology Accompaniment (ARTA), a continuous programme designed to ensure the qualification of the vehicle for its entire lifecycle with regard to both the flight and ground segments.

Ariane 5 is launched six to seven times a year. In addition to the ESA institutional missions, a number of civil and security-related missions have been launched on Ariane 5. A total of 38 institutional missions were launched by Ariane 5 ECA between 2005 and

[21] The large majority of these payloads (139) consisted of telecommunication satellites. Arianespace. "Ariane heritage". Web. http://www.arianespace.com/launch-services-ariane-heritage/Ariane-4.asp

[22] Al-Ekabi, Cenan and Panos Mastorakis. "The Evolution of Europe's Launcher and Flagship Space Initiatives". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: pp. 2-14.

[23] Veclani, Anna Clementina, Jean-Pierre Darnis. "European Space Launch Capabilities and Prospects". In: Schrogl, Kai-Uwe, et al. Handbook of Space Security. Policies, Applications and Programs. Volume 2. Springer, 2014: p. 792

[24] European Space Agency. "Ariane 5 Generic". Web. http://www.esa.int/Our_Activities/Launchers/Launch_vehicles/Ariane_5_Generic2. Accessed 25 January 2015.

[25] Source: ESA Website.

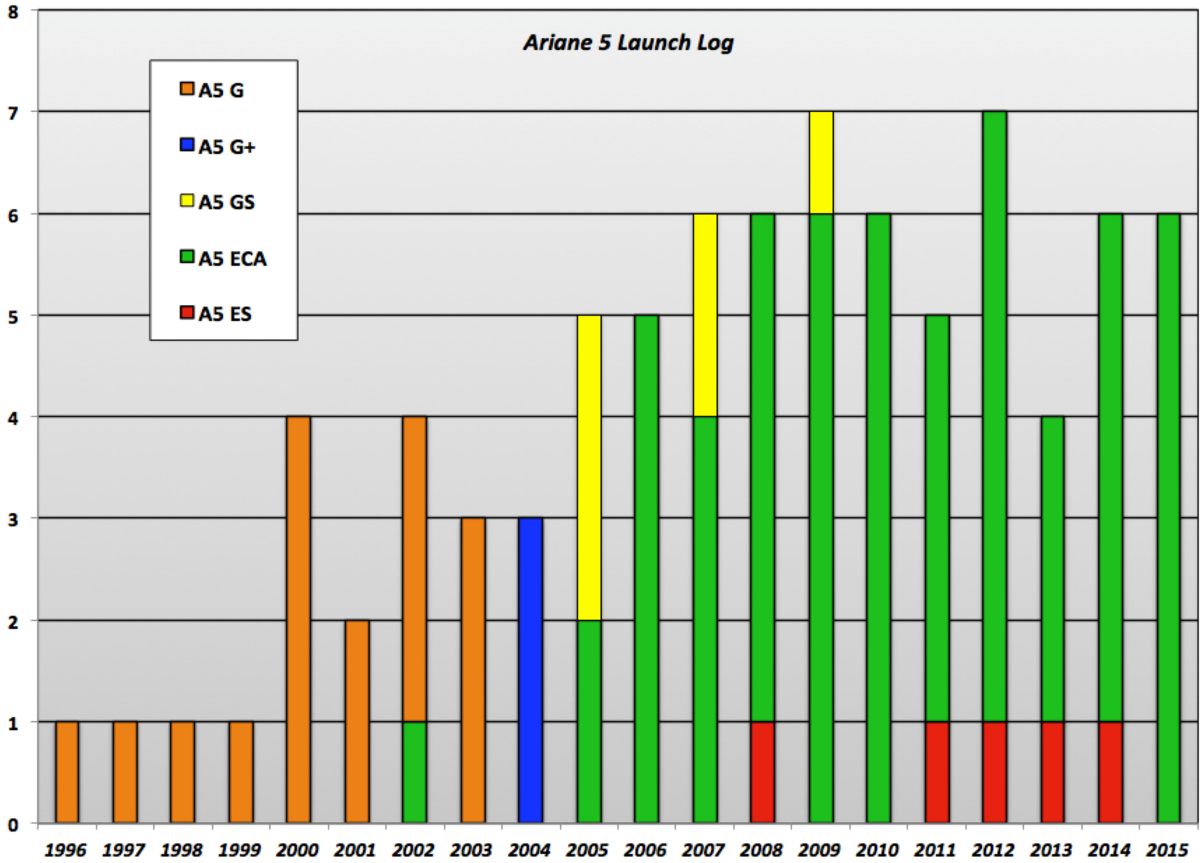

Figure 2: Ariane 5 launch log as of December 2015.[26]

2014. The majority of launches, however, has been for private customers. The largest demand has come from satellite operators such as SES (which accounted for 15% of the total number of payloads) Intelsat (12%), and Eutelsat (10%). As at December 2015, the Ariane 5 launch log stands at a total of 79 launches (see Figure 2), with contracts having been signed for launches up to 2023.[27]

The European version of the Russian-manufactured Soyuz was introduced to consolidate Europe's access to space for medium-size missions, in particular to launch satellites up to 3,200 Kg into GTO and MEO, including constellations of two or more satellites. Named Soyuz-ST, it joined the family of European launchers in 2005, following the signature of a cooperation agreement between ESA and Roscosmos, which enabled Soyuz to use Europe's spaceport in Kourou. The decision to develop a dedicated launch infrastructure at the Guiana Space Centre was of interest to both Europe and Russia, as it enabled the former to complement the performance of the ESA launchers Ariane and Vega, and the latter to benefit from improved access to commercial markets and improved performance of the Soyuz launcher when being launched much closer to the Equator.[28] At that time, it was also in the interest of both Europe and Russia to boost their relationship in general, and cooperation in the launcher sector was seen as a tool for pursuing this objective. Soyuz-ST was launched from Kourou for the first time in October 2011, and is designed for medium-weight communication satellites as well as navigation and earth observation missions. The fact that the GSC can operate Soyuz has made it easier to use it for dual-use missions, as happened with the launch of France's Pleiades constellation and ELISA satellites.[29] Since the very beginning, however, it has been questioned whether Europe should rely on Soyuz for missions having a high political-

[26] Source: ESA. Web. http://www.esa.int/Our_Activities/Launchers/Launch_vehicles/Ariane_5. Accessed 22 February 2016.
[27] Arianespace Press Release. "Arianespace and EUMETSAT announce signature of launch contract for three MTG satellites". 16 June 2015. Web. http://www.arianespace.com/news-press-release/2015/7-16-2015-EUMETSAT.asp. Accessed 02 December 2015.

[28] The agreement was preceded by the European-Russian company Starsem, which was established in 1996 to commercialise launches with Soyuz. Starsem's shareholders are EADS-Astrium (35%), Roscosmos (25%), Samara Space Centre (25%) and Arianespace (15%).
[29] Veclani, Anna Clementina, Jean-Pierre Darnis. "European Space Launch Capabilities and Prospects". In: Schrogl, Kai-Uwe, et al. Handbook of Space Security. Policies, Applications and Programs. Volume 2. Springer, 2014: pp. 783-800.

strategic value, considering that Soyuz is not a truly European launcher.

The lightweight VEGA (Vettore Europeo di Generazione Avanzata – European Advanced Generation Vehicle) was developed as a result of an Italian initiative through an ESA optional programme that began in 1998. Vega is a four-stage launcher comprising three solid motor stages (the P80, Zefiro-23 and Zefiro-9) and a liquid-fuelled fourth stage called AVUM, which is produced by Yuzhnoye in Ukraine.[30] As a small launcher, Vega is designed to seize the institutional small satellite market (300-2,000 Kg) as well as to respond to the growing demand for microsatellites. Vega is capable of placing 300-2,500 Kg into LEO and, unlike most small launchers, can simultaneously launch multiple payloads into orbit. Vega's inaugural flight took place in February 2012 from Europe's spaceport in French Guiana. Its exploitation has been supported by the Vega Research and Technology Accompaniment (VERTA) programme, which *inter alia* foresaw the procurement of five demonstration flights, for ESA's Intermediate eXperimental Vehicle (IXV), Proba-V, Aeolus, LISA Pathfinder, and two Copernicus Sentinels. By December 2015, VEGA has completed the accompaniment programme, and is now fully qualified and ready for commercial exploitation by Arianespace

With the successful introduction of Soyuz-ST and Vega, the European family of launchers has become complete, making Arianespace the only launch service provider with an integrated approach in terms of performance and flexibility. The payload segment covered by the three different launcher categories now enables the entire range of launch requirements to be covered: Ariane 5 for heavy payloads, Soyuz for medium payloads, and Vega for light payloads (see Table 2). As stressed in the ESPI book "European Autonomy in Space", this will generate "an added value for both the commercial and institutional markets. Besides the fact that Arianespace is now able to offer launch service to virtually all the customer types, [...] the possibility of launching on three different vehicles also increases versatility for the institutional payloads and might also reduce the attractiveness of launching European institutional missions on foreign launch vehicles".[31] Furthermore, the use of the three launchers from the European spaceport in French Guiana has been a clear step towards further strengthening European autonomous access to space.[32]

Operational since 1968, the Guiana Space Centre (GSC) is a strategically located facility that provides optimum operating conditions for launching thanks to its position close to the equator.[33] The GSC is governed by a longstanding agreement between ESA and France that was extended to cover Soyuz and Vega installations. On the basis of this agreement, ESA covers two-thirds of the spaceport's cost and France one-third.[34] The day-to-day activities at the GSC are managed by the French National Space Agency CNES on behalf of ESA.[35] CNES provides all needed range support requested by ESA and Arianespace for spacecraft and launch vehicle preparation and launch. The spaceport accommodates various facilities, including a common Payload Preparation Complex, where satellites are processed; a dedicated Upper Composite Integration Facility for each launch vehicle, where satellites and launcher elements are integrated; separate launch facilities for Ariane 5,

[30] See "Launcher Vega". ELV website. http://www.elv.it/en/launcher-vega/composizione-lanciatore/.

[31] Al-Ekabi, Cenan. "European Access to Space: Factors of Autonomy". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: pp. 137-155.

[32] Arianespace can, however, also operate Soyuz from the Baikonur Cosmodrome through its subsidiary Starsem.

[33] Launching near the equator reduces the energy required for orbit plane change manoeuvres. This saves important fuel, and thus reduces costs, enabling an increased operational lifetime for satellite payloads. In addition, French Guiana has a low population density and is protected from hurricanes and earthquakes, thus providing ideal operational conditions.

[34] The total amount of these costs is in the order of € 130 million per year. Nicolini, Davide A. "Launchers Operational Ground Facilities at Europe's spaceport and in Europe, and the global ground station network". ESA Launchers Directorate. Presentation at ESAC 30 June 2015.

[35] Even though France sustains a large part of the operational costs of the GSC, it has to be also stressed that the spaceport has a highly beneficial impact on the entire economy of French Guiana, which is indeed critically dependent on the operations of the GSC. As noted in a recent assessment, the GSC provides an exceptional level of high-technology activity and jobs, together with investment in the wider infrastructure of the region, incomes generated by purchases from the wider Guiana economy (by the activities at GSC and by the workers employed there and those who visit), and support for some economic development projects. It was estimated that GSC brought in around € 13 billion of goods and services inputs over 2000-12. Approximately two-fifths were brought in to support maintenance activities with the remainder being used to support launch activities. Overall, GSC generated € 1 billion of value added over 2000-12. Employment at the GSC base grew by 26% between 2005 and 2013, with little impact from the global downturn. The impact of GSC contributed to around 46% of import duty revenues over 2000-07. Value added by GSC directly contributed to 2.8% of GDP over 2000-12. This figure rises to 17.7% when accounting for indirect and induced impacts on the wider economy". Cit. Del Monte, Luca and Luigi Scatteia. "A socio-economic impact assessment of the European launcher sector". IAC-15. Jerusalem. 2015.

Launch Vehicle	Ariane 5 ECA	Ariane 5 ES	Soyuz	Vega
Height	up to 53 m	up to 53 m	46 m	30 m
Diameter	up to 5.4 m	up to 5.4 m	2.9 m	3 m
Lift-off Mass	780,000 Kg	760,000 Kg	305,000 Kg	137,000 Kg
Payload Mass	10,000 Kg (GTO)	21,000 Kg (LEO)	3,200 Kg (GTO)	1,500 Kg (LEO)
Main Propulsion	Liquid (LOX / LH_2)	Liquid (LOX / LH_2)	Liquid (LOX/Kerosene)	Solid (HTPB)
First Launch	2002	2008	2011	2012
Reliability	52/53 – 98%	5/5 – 100%	12/13 – 92%	6/6 – 100%

Table 2: Overview of current European launch vehicles.[36]

Soyuz and Vega (ELA, ELS and SLV respectively); and a Mission Control Centre (MCC).[37]

Thanks to CNES and ESA, a network of telemetry and tracking ground stations has also been set up for ensuring adequate post-launch activities. The network of tracking stations is structured around the Ariane traditional trajectory eastward, extending from Kourou to East Africa: Galliot in French Guyana, Natal in Brazil, Ascension in the South Atlantic, Libreville in Gabon, and Malindi in Kenya among the others.[38] Unlike other major spacefaring nations like the U.S., Russia and China (see Annex 3), Kourou is the only operational spaceport available to Europe.

2.1.3 The Working System: Launcher Strategy, Development and Exploitation

Ariane, Soyuz and Vega development programmes are managed by ESA on the basis of optional programmes, subscribed to by a varying number of ESA Member-States. The bulk of the contributing countries are France, Germany, Italy, Belgium and Sweden. Over the years, the overall budget for launcher-related activities has accounted for a significant share of ESA's budget, as highlighted in Table 3.

Year	Budget for launchers in M€	Share of the total budget	Position
2001	703.8	18.0%	1st budget item
2002	681.1	18.7%	2nd budget item
2003	739.2	20.0%	1st budget item
2004	557.6	20.0%	1st budget item
2005	591.0	33.0%	1st budget item
2006	539.5	18.2%	1st budget item
2007	627.7	21.1%	1st budget item
2008	651.4	21.5%	1st budget item
2009	515.6	18.3%	1st budget item
2010	566.6	15.1%	3rd budget item
2011	612.5	15.3%	3rd budget item
2012	578.0	14.4%	3rd budget item
2013	688.0	16.1%	3rd budget item
2014	617.4	15.1%	3rd budget item
2015	607.7	13.7%	3rd budget item
2016	1,051.2	20.0%	2nd budget item

Table 3: ESA budget for launcher programmes.[39]

The different launcher programmes, along with their support programmes, are run by the ESA Launcher Directorate. As the entity responsible for the overall management of Europe's launchers, ESA undertakes a number of functions, including:

[36] Reliability and launches calculated over the period 2005-2015. Source: ESA. Web. http://www.esa.int/Our_Activities/Launchers. Accessed 22 February 2015.

[37] Ariane 5 User's Manual. Arianespace.

[38] Veclani, Anna Clementina, Jean-Pierre Darnis. "European Space Launch Capabilities and Prospects". In: Schrogl, Kai-Uwe, et al. Handbook of Space Security. Policies, Applications and Programs. Volume 2. Springer, 2014: pp. 783-800.

[39] Source: ESA. See: http://www.esa.int/About_Us/ESA_Publications/ESA_Publications_Annual_Report/(archive) and http://www.esa.int/About_Us/Welcome_to_ESA/Funding. Accessed 20 January 2016.

- Defining the overall strategy for Europe's access to space and related launch system developments;
- Approving the budget, supervising the projects, and monitoring costs and developments;
- Managing the tender system and selecting contractors for the design and development of launchers;
- Concluding arrangements with CNES for the management and utilisation of the GSC and with the launch provider Arianespace for the procurement and commercialisation of launchers.

The overall European launcher strategy is driven by the necessity to ensure both the *availability* and *sustainability* of an autonomous access to space for Europe. This means ensuring that Europe has a "reliable, safe, available and competitive operational launch base on EU territory, a complete family of launch vehicles fully–developed in Europe, a European launch service provider" [able to meet institutional and commercial demands and continuous investment in R&D capabilities and] to keep European industrial capabilities and know-how at a high technological level".[40] In line with these overarching objectives, the principal axes of the European launcher strategy, as identified by ESA, are:

- To maintain the competitiveness and affordability of Ariane and Vega launchers;
- To maintain the ground infrastructure needed for launches;
- To foster the creation of a European institutional market for Ariane and Vega;
- To ensure that Europe can respond to evolving market demands by continuing the improvement of Ariane and Vega and facilitating the use of Europe's spaceport by the Russian Soyuz rocket;
- To support European industry, technology and research capabilities by improving industrial competitiveness and promoting innovation;
- To create employment;
- To develop the next generation of launchers and the related ground infrastructures to better serve the institutional and commercial markets;
- To encourage international cooperation and play a leading role in future developments.[41]

With regard to launcher development, the prime contractors and suppliers are selected by ESA on the basis of its geo-return policy, which reflects national financial participation in the project.[42] The European space launcher industry is concentrated in a relatively small number of industrial firms, with a high degree of vertical integration.[43] There are a handful of large industrial actors and approximately 40 suppliers involved in the design, development and manufacture processes, the majority of which are highly dependent on Ariane business.[44]

The working system assigns the responsibility for the whole process to a single industrial prime contractor for each launcher type. The prime contractor of Ariane 5 is Airbus Defence and Space, with Safran playing the leading role for the propulsion systems. The Soyuz prime contractor is the Russian federal space agency Roscosmos, while the European Launch Vehicle (ELV), a joint venture between Avio (70%) and ASI (30%), manages the Vega rocket (See Figure 3).

Once the launch systems are qualified, responsibility is handed over to Arianespace, which is in charge of executing the operational launcher exploitation phase, including procurement from the launcher system prime contractors, and the commercialisation and launch of the rockets. Prime contractors, however, take part in the integration of components at Europe's spaceport in Kourou together with the staff of Arianespace and CNES. While designed to avoid duplication of efforts, this framework presents a certain degree of complexity, also considering that both ELV and Airbus are at the same time suppliers and shareholders of Arianespace.

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[40] Cit. Al-Ekabi, Cenan. "European Access to Space: Factors of Autonomy". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: p. 141,

[41] Cit. European Space Agency. "Launcher Strategy". 14 October 2014. Web. http://www.esa.int/Our_Activities/Launchers/Launcher_strategy. Accessed 10 November 2015.

[42] For the development programme of Ariane 6, the "geographical return" principle was in part abandoned in favour of a "fair contribution", so that the industrial share of work would be based on best technical competence and cost-effectiveness.

[43] Hayward, Keith. "The Structure and Dynamics of the European Space Industry Base". ESPI Perspectives 55. Vienna: European Space Policy Institute (December 2011): 3.

[44] Ibid.

BOX: European prime contractors

Airbus Defence & Space, one of the leading companies worldwide in the space industry, has been involved in the development and construction of the Ariane rocket ever since the programme was launched in the 1970s. A fully owned subsidiary of the Airbus Group, the company has accumulated huge expertise in all fields that are essential for the construction and further improvement of Ariane launchers. Since May 2003, Airbus Defence & Space is the sole prime contractor of Ariane 5, in charge of coordinating some 64 companies across Europe, and the lead manufacturer, responsible for the production of all Ariane 5 stages, along with a number of subassemblies.
ELV is a company that was established by Avio and ASI in December 2000. The company's primary tasks include: managing and planning the Vega launcher design, development, qualification and production processes. Moreover, ELV coordinates the activities of the subcontractors participating in the programme, ensures the integration of the launcher in the launch facilities, and participates with a team in the final stage of the launch. ELV is a company of the Avio Group, one of the main players in the field of aerospace propulsion. Founded in 1908, it is now owned 85% by Cinven and 15% by Finmeccanica. It is present all over the world with 18 plants, over 5,000 employees and many subsidiaries. Within its space line of business, Avio is a European leader in the development and manufacture of solid propulsion and a major player in liquid propulsion systems.

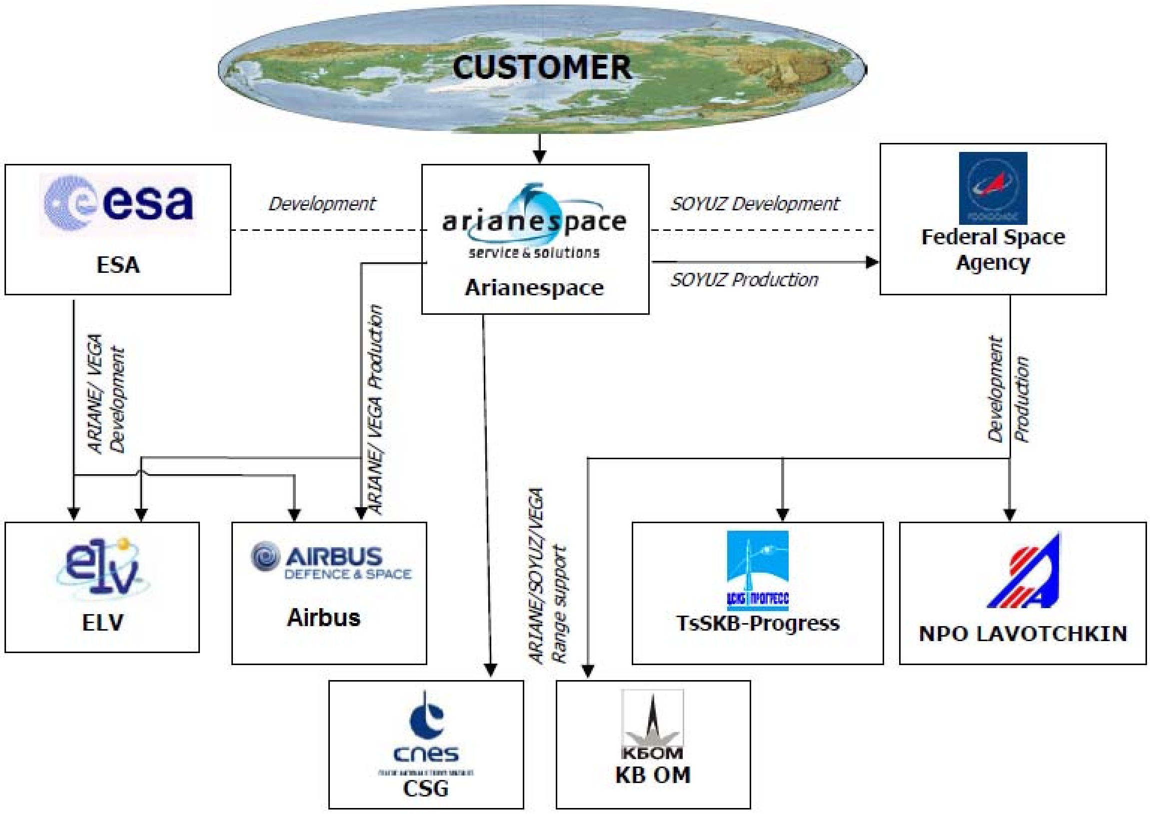


Figure 3: Launch vehicles - procurement and exploitation. [45]

[45] Source: Arianespace Ariane 5 User Manual Issue 5: p 1-15, with author's re-elaboration.

Arianespace's capital is owned by 21 shareholders from 10 different countries. France holds the largest share, controlling through its seven shareholders 64.1% of the total. Germany has the second largest share accounting for 19.8%. The remaining 16% is split among eight other countries (Belgium, Italy, Spain, Denmark, Switzerland, Norway, Sweden and the Netherlands).

In terms of shareholders, the largest stake has been traditionally held by CNES (34.68%), followed by Astrium (28.40%), Safran (10.57%) and a dozen other industrial entities. The shareholding structure of Arianespace is, however, currently undergoing a profound revision, following the creation of a Joint Venture between Airbus and Safran as a result of the decisions endorsed at the ESA Ministerial Council of 2014 (See Chapter 2.2).

As already mentioned, Arianespace is responsible for the exploitation of the Ariane, Vega and Soyuz, including marketing and sales, as well as assembly and operation from the GSC launch site. Exploitation of Ariane and Vega is, however, also supported through dedicated programmes, financed by ESA Member States on an optional basis. In addition to the ARTA and VERTA programmes, annual support payments have been provided through the European Guaranteed Access to Space (EGAS) programme and the Launchers Exploitation Accompaniment Programme (LEAP), approved respectively in 2003 and 2012 (see below).

All in all, thanks to the impressive record of more than 500 satellites successfully launched from the GSC and an order book of more than 58 launches to be performed in the coming years,[46] Arianespace has emerged as the world's leading launch service provider, with sales that exceed € 1 billion per year (approximately 40% of global launch revenues – see Chapter 4.1).[47]

2.2 Preparing for the Future: the 2014 ESA Ministerial Council

2.2.1 The Path to the Ministerial

Like other spacefaring nations, Europe has been almost constantly facing the challenge of improving and modernising its launchers in order to ensure the availability and sustainability of autonomous access to space over the long-term. Not surprisingly, the successor to Ariane 5 has been under debate since shortly after Ariane 5 entered into service in 1999. A dedicated programme, called the Future Launchers Preparatory Programme (FLPP), was launched by ESA as early as 2003. The programme was subscribed to on an optional basis by 14 ESA Member States and structured in a series of partially overlapping stages covering the 2004-2018 timeframe.

Besides fostering the development of new technologies capable of delivering improved performance and reliability as well as reducing operational costs, a major field of activity of the FLPP was the development of various launch vehicle concepts and the identification of the technologies required to make them possible. This activity was intended to form the basis for the key decision to be made on the characteristics and design of the Next Generation Launcher (NGL).[48] The objective of the FLPP was thus not the development of a new launcher itself, but the selection and maturation of technologies – the targeted Technology Readiness Level (TRL) was 5 – to pave the way for the development of a new launch system.[49] A key issue to be resolved was whether to develop another heavy-lift launcher for double launches or a medium-lift launcher for single launches that could in the long term become replace the Europeanised Soyuz-ST as well.

Notwithstanding the technical and operational considerations related to the NGL, the real issue to be addressed was how to cope with the increasing difficulties encountered by Arianespace during the exploitation of Ariane 5. These difficulties were to a large extent the direct result of two main problems: on the one hand, the fact that launch prices on the commercial market were kept lower than launch and production costs;[50] and on the other, the limited number of institutional launches performed by Ariane 5, which prevented the creation of economies of scale by spreading fixed operational costs over a higher number of launches.

[46] Arianespace's order book is worth € 5.1 billion and include 58 launches for 38 customers: 23 Ariane 5 launches, 26 Soyuz launches and 9 Vega launches. Arianespace. "Company Profile". Web. http://www.arianespace.com/service-and-solutions/ Accessed 05 December 2015.

[47] Ibid.

[48] See: European Space Agency. "European Space Technology Master Plan". 11th Edition. ESA-ESTEC: p. 323

[49] It is of interest to note that the FLPP also looked at the potential contribution offered by rocket reusability. However, it eventually concluded that the NGL could be only expendable, as otherwise it would not meet the framework conditions of the European launch sector.

[50] This situation was primarily driven by the need to cope with the sharp downturn in commercial launch demand of the early 2000s. (See Chapter 4.2)

In 2003 ESA Member States also approved the EGAS programme, with the overarching aim of making Arianespace self-sufficient. The programme covered the fixed production costs and provided around € 250 million to Arianespace for 6 years (2004-2010). The programme officially expired in December 2010. At that time, however, Arianespace was still facing financial losses and was seeking public subvention of € 120 million a year. While ESA Member States eventually agreed to continue to support Arianespace, the persistence of these issues started to call for a profound revision of the European launch model, and in particular for a reorganisation and a progressive streamlining of the whole industrial process.[51] At the same time, the need to develop a new launcher capable of sustaining itself competitively without requiring public support became even more pressing.

As a medium term solution, at the end of 2010 it was decided to begin work on the development of the Ariane 5 Midlife Evolution (ME) and to start preliminary design work on Ariane 6. Ariane 5 ME, for which preliminary activities had begun in 2009, was designed to feature a new, re-ignitable upper stage that would increase the payload-carrying capacity by 20% and thus enable the launch of an extra two tonnes to GTO, a crucial market for Arianespace's business. Ariane 5 ME was intended to replace Ariane 5 ECA and Ariane 5 ES to become Europe's new workhorse launcher until the arrival of the new Ariane 6.[52] However, in the climate of budgetary constraints imposed by the financial crisis, consensus on this pathway quickly vanished and the two hypostasized launchers started to compete against each other. The most visible disagreement was between France and Germany. While CNES started to strongly advocate a steady commitment to the development of Ariane 6, DLR showed a clear preference for Ariane 5 ME, *inter alia* because of higher German industrial involvement.[53]

Faced with the apparent trade-off between enhancing the current Ariane 5 and investing in a new Ariane 6, at the ESA Council at Ministerial level held in Naples in 2012 Member States opted to defer a decision on the new launcher until 2014. However, initial funding was secured for the activities on Ariane 5 ME as well as for a detailed definition study of the new Ariane 6, with the goal of maximising commonalities and avoiding delays in commercial exploitation of the two launchers while minimising costs for Ariane 6. At the Ministerial Council, funding was also provided to set up the Launchers Exploitation Accompaniment Programme (LEAP), with the aim of providing a stable and comprehensive frame to support the exploitation of Vega and Ariane.[54] The financial envelope agreed on amounted to € 540 million, financed by 10 ESA Member States (Austria, Belgium, Germany, France, Italy, Ireland, Norway, Netherlands, Sweden, and Switzerland).[55]

Between 2013 and 2014, a number of proposals regarding the reorganisation of the European launch sector and the selection of the future launch vehicle were discussed, but divergences between the two major European countries involved remained and decisions were complicated by the political and industrial implications of such a programme.[56] In an attempt to remedy this difficult situation, on 16 June 2014 Airbus and Safran surprisingly advanced a new proposal for the development of Ariane 6 and announced the creation of a joint venture to lead the rocket's

[51] Various solutions and initiatives have been advanced over the last few years to reduce costs. See for instance the rationalisation of the propulsion sector advanced by Astrium; the establishment of a direct link between Astrium and ESA, without Arianespace as intermediary proposed by the Academie de l'Air et de l'Espace; and the introduction of a tax on satellite operators to finance the European launch sector. Another interesting initiative was the New European Launch Service (NELS) feasibility study launched by ESA. The study was intended to investigate options for a new access to space model economically self-sufficient, with no need for public support to launcher exploitation. The innovative principle behind NELS was that ESA Member States participating in a future optional programme for development would contribute on the basis of "fair contribution" rather than of "geographical return". As a result, the industrial share of work would be based on best technical competence and cost-effectiveness. See Veclani, Anna Clementina, Jean-Pierre Darnis. "European Space Launch Capabilities and Prospects". In: Schrogl, Kai-Uwe, et al. Handbook of Space Security. Policies, Applications and Programs. Volume 2. Springer, 2014: pp. 783-800.

[52] Cit. European Space Agency. "Adapted Ariane 5 ME". 14 October 2014. Web. http://www.esa.int/Our_Activities/Launchers/Launch_vehicles/Adapted_Ariane_5_ME .

[53] De Selding, Peter. "DLR's Wörner Remains Unconvinced Just-unveiled Ariane design Is Right Way to Go". Space News. 12 July 2013.

[54] European Space Agency. Press Release N° 37–2012: European Ministers decide to invest in space to boost Europe's competitiveness and growth".

[55] The typical activities covered by LEAP included the monitoring of the qualification status of Vega and Ariane launcher, enhancing the knowledge of launcher performance and reducing the system qualification reservations Activities related to maintaining ESA-owned facilities in Europe and French Guiana in operational condition are also covered by LEAP. These include engine-related test facilities, facilities required to manufacture, integrate and accept the launch vehicle components up to stage level, and the launch complex where integration and launch operations activities are performed. See: ESA Bulletin 156: pp. 32-33.

[56] See: Al-Ekabi, Cenan. "European Access to Space: Factors of Autonomy". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: p. 153.

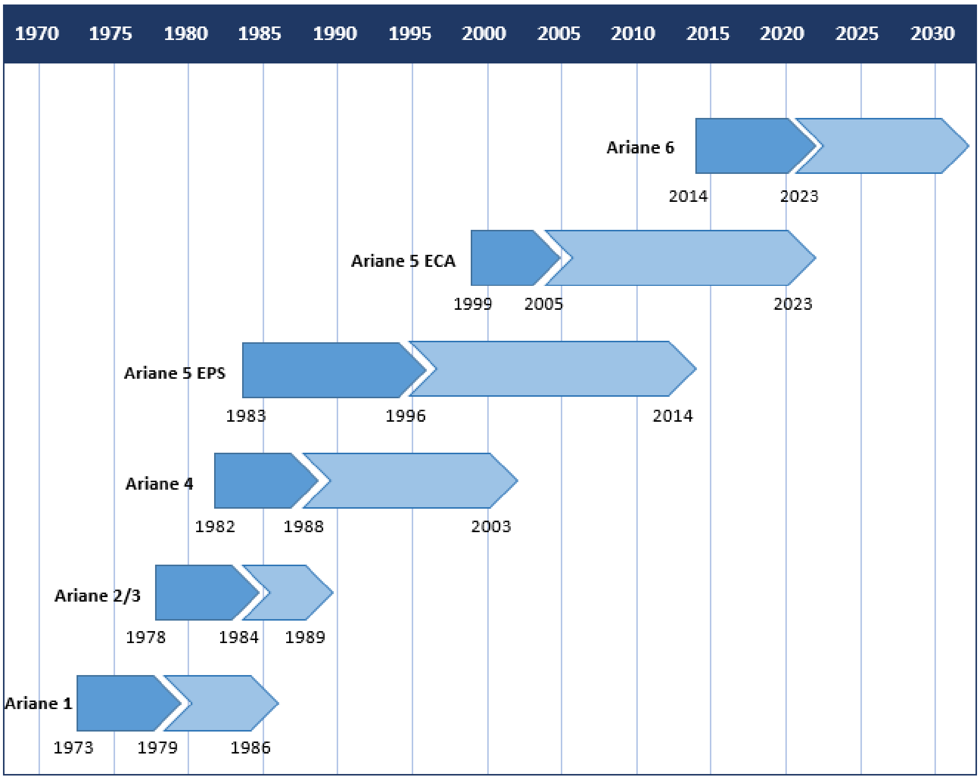


Table 4: Ariane Family: historical timeline of development and exploitations phases, as presented in November 2015.[57]

development.[58] Building on this, in October 2014 the ESA Director General sent ESA Member States a policy proposal on new industrial governance, and the parallel development of Ariane 5 ME and Ariane 6, both considered as complementary – not competing – projects.[59]

The disagreement was eventually resolved on the eve of the Ministerial Council Meeting in 2014, with Germany and France agreeing to skip the planned upgrade of Ariane 5 and proceed directly to the development of a substantially reconceived Ariane 6 – making it palatable to Germany. At the same time, Airbus Defense and Space and Safran proposed to create a joint venture to lead the development and production of Ariane 6 in order to streamline industrial organisation, overcome the inefficiencies of the industrial cycle and thus reduce the costs to be borne by Member States.[60] In response to this proposal, major stakeholders from ESA Member States and industry worked together to define a joint ESA–industry scheme for the development of Ariane 6, based on balanced responsibility, and cost and risk sharing between Agency and the industrial Joint Venture.[61]

The official sanctioning of the new industrial scheme and the final decision regarding the complete development of Ariane 6 was taken at the ESA Ministerial Council on 2 December 2014, in the context of the overall launcher strategy for the next 10 years.

The Ministerial Resolution

The *Resolution on Europe's Access to Space* acknowledged the difficulties faced by the European launch sector (*inter alia*, the account balance of Ariane 5 on the commercial market; the dependence of a significant proportion of European institutional launches on the Soyuz launcher; the deficit of commonalities between Ariane 5, Soyuz and Vega, which limits synergies in exploitation; and

[57] Development phases are indicated in dark blue, exploitation in light blue. For Ariane 6, dates are indicated as presented at November 2015. Source: Albinger, Jürgen. "MT Aerospace at a Glance". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

[58] Safran Group. Press release. "Safran-Airbus Group launcher activities agreement". 16 June 2014. Web. http://www.safran-group.com/media/20140625_safran-airbus-group-launcher-activities-agreement. Accessed 28 September 2015.

[59] See Dordain, Jean-Jacques. "Answer to Questions of Germany". Paris. 29 October 2014: pp. 17-18. The concepts developed for Ariane 5 ME were intended to be applicable to Ariane 6 as well, thereby reducing costs and risks associated with Ariane 6.

[60] Cit. European Space Agency. "Ariane 6". Web. http://www.esa.int/Our_Activities/Launchers/Launch_vehicles/Ariane_6 . Accessed 2 January 2016.

[61] See: ESA Council at Ministerial Level. "Resolution on Europe's Access to Space". ESA/C-M/CCXLVII/Res. 1 (Final). 2 December 2014.

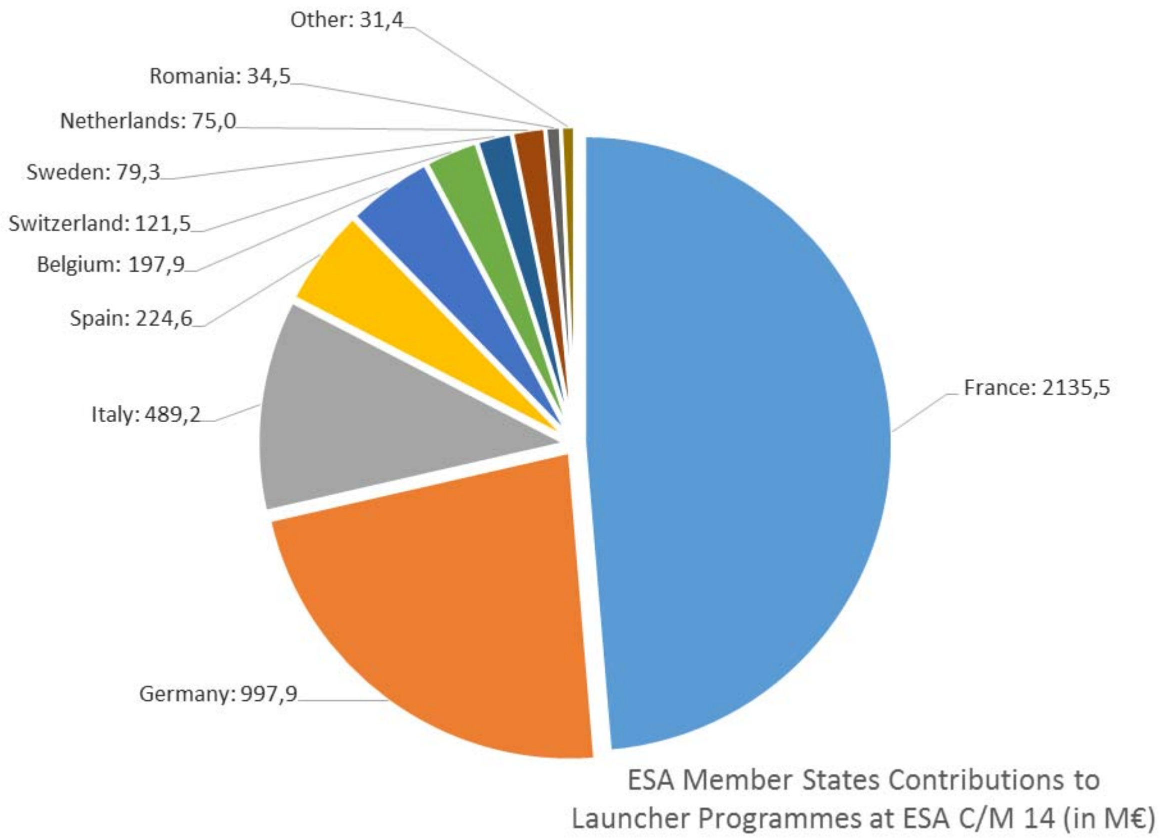


Chart 1: ESA Member States contributions to launcher programme at ESA C/M 14, in M€.[62]

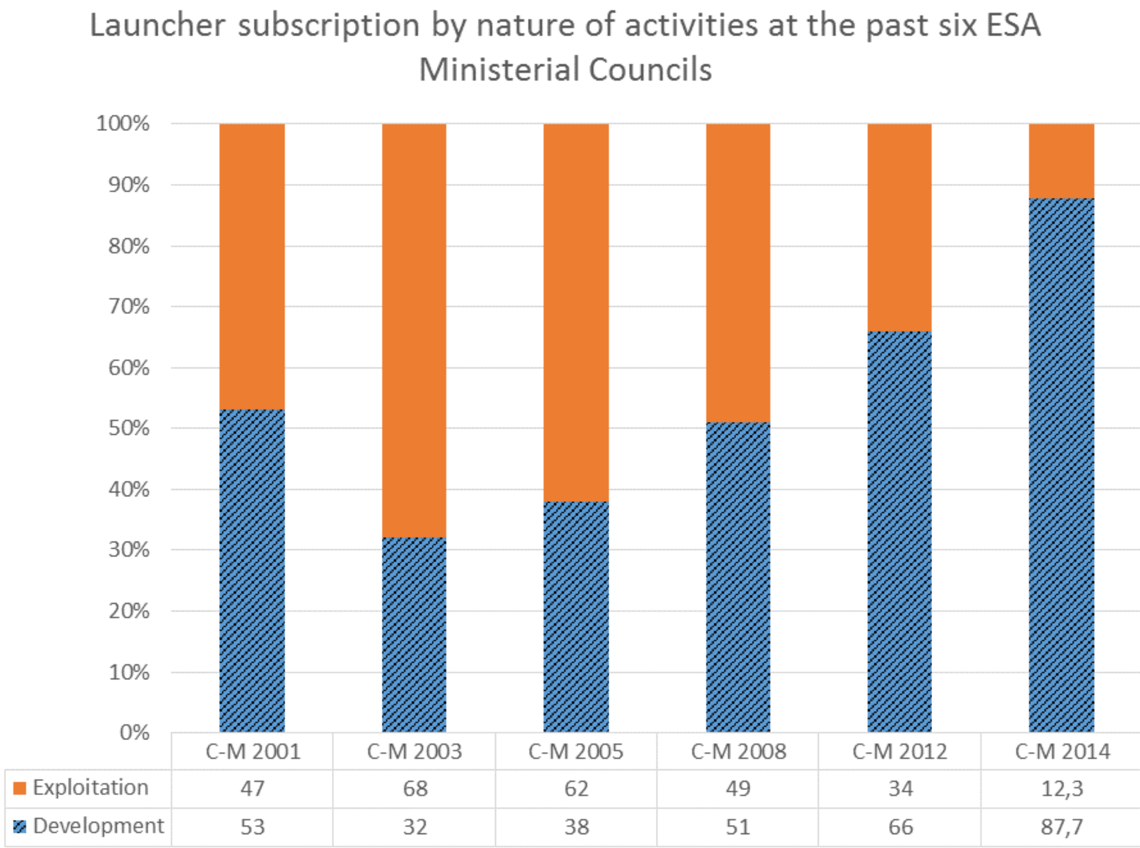
increasing competition in the worldwide commercial market) and called for the "availability as soon as possible of new European launch services which are not only competitive without requiring public support during exploitation, but also flexible and modular enough for responding to a wide range of needs, from institutional to commercial requirements, as well as to the uncertainties on the evolution of the commercial requirements".[63]

To achieve this objective, European Ministers not only agreed to begin the development of Ariane 6 and Vega-C, but also decided to introduce fundamental changes in the overall governance of the European launcher sector. In addition, Ministers agreed to fund the Launchers Exploitation Accompaniment Programme (LEAP) for 2015–16, the Future Launchers Preparatory Programme (FLPP) and the Programme for Reusable In-orbit Demonstrator in Europe (PRIDE) – the successor to the experimental IXV re-entry vehicle.[64] Finally, funding was secured for the necessary launch pad upgrades to accommodate Ariane 6 at the Kourou spaceport.

The overall proposed subscription to launcher programmes amounted to € 4.8 billion, 95% of which was subscribed at the Ministerial Council (see Chart 1).

It is noteworthy that, unlike previous Ministerial Councils, the largest portion of subscriptions endorsed at the C/M 2014 was devoted to development activities and not to exploitation accompaniment actions. The evolution of the ratio between development/exploitation activities from the ESA Ministerial 2001 is represented in Chart 2.

[62] Chart built on the data from: Bianchi, Stefano. "The European decisions of December 2014". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.
[63] Ibid.
[64] Ibid.



	C-M 2001	C-M 2003	C-M 2005	C-M 2008	C-M 2012	C-M 2014
Exploitation	47	68	62	49	34	12,3
Development	53	32	38	51	66	87,7

Chart 2: Launcher subscription by nature of activities at the past six ESA Ministerial Councils.[65]

2.2.2 A Look at Europe's Future Launchers and Infrastructure

Ariane 6

Ariane 6 is conceived as a modular three-stage (solid–cryogenic–cryogenic) launcher with two different variants using either two boosters (A62) or four boosters (Ariane 64) (See Figure 4). The main features of the Ariane 6 concept are: [66]

- The total length of the vehicle is around 63 metres.
- The external diameter is about 4.6 metres.
- The mass at lift-off is about 500,000 Kg for Ariane 62 and 800,000 Kg for Ariane 64.
- The payload capacity of Ariane 62 is 5,000 Kg to GTO.
- The payload capacity of Ariane 64 is 11,000 Kg to GTO. (single payload) or 10,000 Kg with dual payload.

As emphasised by ESA Director General Jean Jacques Dordain in the abovementioned policy proposal, the new Ariane relies upon a substantial heritage that has no equivalent in any previous launcher programme. As a matter of fact, the architecture (and in particular the staging) is the same as for Ariane 5. The main stage, which will burn liquid oxygen and hydrogen, is based on the Vulcan engine of Ariane 5 ECA, while the cryogenic upper stage will be powered by a Vinci engine, which relies on work done for the Ariane 5 ME upper stage. As for the P120 solid rocket booster, this is directly derived from the first stage of the Vega rocket, the P80, and will also be utilised as the first stage for the upcoming Vega-C (see below). With regard to scheduling, the upper stage and the P120 boosters will be ready in 2018. The qualification flight is expected in 2020 and the entry into commercial operation (provision of services) around 2022-2023.

[65] Source: Bianchi, Stefano. "The European decisions of December 2014". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.
[66] Cit. European Space Agency. "Ariane 6". Web. http://www.esa.int/Our_Activities/Launchers/Launch_vehicles/Ariane_6

Figure 4: Artist's view of Ariane 62 and 64.[67]

The general architecture of Ariane 6 will enable it to cover a wide range of missions in GTO, LEO, and MEO and to respond to different market needs in a cost-effective way thanks to the possibility of varying the number of boosters in the configuration. This double configuration is indeed a key element in the new launcher strategy and responds to precise goals with respect to both the commercial and the institutional dimensions of Europe's future access to space. Two points deserve particular attention: first, this decision facilitated overcoming the apparent trade-off between developing another heavy-lift launcher for double launches or a medium-lift launcher for single launches. While Ariane 64 will retain the double launch capability, Ariane 62 will ensure flexibility in availability since its exploitation will be based on single launch. Thus, it will not require so much effort in terms of pairing satellites and scheduling of launches.[68] Together, Ariane 62 and 64 will provide the modularity required to adapt to the uncertainties of the future commercial market.[69] In addition to that, because Ariane 62 and Ariane 64 are two configurations of the same launcher that are intended to be exploited together, this will enhance the cadence of the production rate and thus contribute to cost reduction of Ariane 64. All in all, "Ariane 64 will make the overall exploitation of Ariane profitable thanks to the revenues of double launches and provide the margins for a more competitive pricing policy of Ariane 62".[70]

In 2014 economic conditions, the expected launch cost of Ariane 64 is € 90 million while the launch price is € 115 million for a dual launch. In comparison with the Ariane 5 launch price of € 165 million there is thus an estimated saving in the order of € 50 million for the full Ariane 64 and of € 25 million for each passenger of a dual launch. As for Ariane 62, the expected launch cost is € 78 million, while the launch price has been fixed at € 70 million (one satellite). This mismatch during the exploitation of Ariane 62 is expected to be covered by the profitable exploitation of Ariane 64.[71] Compared to a Soyuz launch, which has a price of € 78-85 million at 2014 economic conditions, the estimated saving for an Ariane 62 launch is in the order of € 10 million. It is expected that the total savings (to be generated by Ariane 6 in comparison to Ariane 5, against the boundary conditions defined in the abovementioned document) between 2021 and 2024 for institutional missions will amount to € 345 million (see Table 5).[72]

In tandem with its commercial logic, the decision to proceed with a double configuration for Ariane 6 responds to political considerations as well, particularly the perceived need to overcome the current dependence of European institutional launches on the availability and prices of Soyuz. As a medium-lift launcher, Ariane 62 will cover the payload segment as amply as Soyuz and will thus

[67] Source: ESA Website.

[68] Thus overcome the pitfalls related to the double launch concept of Ariane 5 that has proved inefficient. Indeed, although the double launch capability has allowed to apply lower prices to customers, they require greater efforts in terms of the pairing of satellites and the scheduling of launches.

[69] See Dordain, Jean-Jacques. "Answer to Questions of Germany". Paris. 29 October 2014: pp. 6-7. Web: http://www.spacenewsinc.com/pdf/dordainfile.pdf. Accessed 10 February 2015. See also: de Selding, Peter. "To Win Over Germany, ESA Maps out How Ariane 6 Would Save Everyone Money". SpaceNews. 6 November 2014. Web. http://spacenews.com/42472to-win-over-germany-esa-maps-out-how-ariane-6-would-save-everyone-money/. Accessed 10 February 2015.

[70] Ibid: pp.6-7

[71] As explained by Jean-Jacques Dordain, even though the launch costs of Ariane 62 might be higher, the target price has been fixed to industry at € 70 million in order to take into account the result of exploitation of Ariane 62 and Ariane 64 together, as the exploitation of a single launcher. See Dordain, Jean-Jacques. "Answer to Questions of Germany". Paris. 29 October 2014: pp. 17-18.

[72] Ibid.

Year	Missions	Launcher	Savings per mission (M€)	Savings per year (M€)
2021	MTG S1 SL-1C MetOp SG Galileo SG	Ariane 64 Ariane 62 Ariane 62 Ariane 62	25 10 10 10	55
2022	MTG Skynet Juice SL-1D MetOp SG Galileo SG	Ariane 64 Ariane 64 Ariane 64 Ariane 62 Ariane 62 Ariane 62	25 25 50 10 10 10	130
2023	Sicral Skynet Cosmo Galileo SG Galileo SG	Ariane 64 Ariane 64 Ariane 62 Ariane 62 Ariane 62	25 25 10 10 10	80
2024	Plato CSO INSPIRE Galileo SG	Ariane 62 Ariane 62 Ariane 64 Ariane 62	10 10 50 10	80
Total savings over the four year period (M€)				**345**

Table 5: Prospected savings for Ariane 6 institutional launches from 2021 to 2024.[73]

offer the possibility of replacing the Russian-manufactured rocket with a truly European launcher. Indeed, although not officially formalised, ESA's commitment to its development suggests that "Soyuz in Guiana" will ultimately remain only a transitional solution in Europe's strategy for access to space.[74]

Besides ensuring autonomy in a strategic payload segment, the key "political driver" behind the development of Ariane 62 is to help sustain industrial activities and research capabilities in ESA Member States rather than in Russia. In this regard, it is important to note that supporting the maintenance of a solid industrial base, improving its competitiveness and promoting innovation in space transportation technologies are in the final analysis the key elements for ensuring the availability and sustainability of autonomous access to space also in the future (See Table 6).

Ariane 6 Objectives	
Guaranteed access to space for Europe	• Family of launchers addressing both institutional and commercial markets
No public funding supporting commercial exploitation	• Advanced launch service procurement for European institutional missions • Half the costs per Kg of Ariane 5, and target launch service prices for institutional missions as defined in 2014
Time-to-market: • Qualification flight in 2020 • Fully operational in 2023	• Fast track development plan and simplified management rules for minimised decision time
Maximising commonalities within the European Launcher Family	• Vulcain main stage engine flight proven on Ariane 5 • Vinci upper stage extensively ground tested • Common Solid Rocket Motor P120C with Vega-C as extension of Vega flight proven P80, to be flight qualified in 2018 on Vega-C
Proven reliability to customers	• Progressive phasing in of Ariane 6 and phasing out of replaced launch systems – first Soyuz (for institutional customers) and then Ariane 5 (for commercial customers)

Table 6: Ariane 6 programme main objectives.[75]

[73] Ibid.
[74] It is however likely that Arianespace will continue to commercialise Soyuz from the Baikonur launch site, as evidenced by the signature in June 2015 of a commercial launch contract with OneWeb (a contract to launch roughly 700 LEO satellites aboard the Russian Soyuz from the cosmodrome of Baikonur). See de Selding, Peter "Launch Options were key to Arianespace's One-Web Win". Space News. 25 June 2015.

Vega-C

At the Ministerial, investments were also secured for the development of an upgraded version of the Vega launch system, the Vega-C (Consolidated), with an inaugural flight scheduled for 2018. Originating from the "VEga Consolidation and Evolution Preparation Programme (VECEP)" programme approved at the previous Ministerial (ESA C/M 12), the main drivers behind the Vega-C decision, as outlined by AVIO CEO Pier Luigi Lasagni, are:[76]

a. To strengthen and enlarge Vega's market position in the short/medium term
b. To decrease dependency on non-European sources
c. To contribute to safeguarding European industrial engineering capabilities
d. To be in a position to better respond to long term institutional needs

Regarding the first item, in terms of performance Vega-C High Level Requirements are set to 2,200 Kg in a single launch to a 700 Km circular polar orbit, and 1,800 Kg at an 800 Km Sun-synchronous orbit. This implies a 700 Kg increase on the nominal Vega performance, enabling balancing and compensation for losses related to additional operational constraints (e.g. French Space Operation Act, Space Debris Policy), as well as providing an additional margin for complex missions requiring significant flexibility, without any increase in the recurring costs. The Vega-C upgrade then is intended to pursue a limited increase in performance, in order to remain competitive in the evolving market and have greater flexibility to better accommodate multiple payload configurations. In fact, a new payload adapter is being developed to enable the launch of a main payload plus a small payload as well as additional cubesats.

Vega-C, similarly to Vega, will be a three-stage all-solid launch vehicle with an optional liquid fuelled fourth stage for re-start and precise injection capability. One of the major features of Vega-C will be the utilization of the P120 engine as the first stage, replacing the P80. In addition, the second stage Zefiro 23 will be replaced by Zefiro 40 (which will have roughly 17,000 Kg more propellant loading and an increased diameter). The third stage will remain Zefiro 9 while the AVUM (Attitude Vernier Upper Module) fourth stage will also see slight modifications (mainly larger propellant tanks) and will be called AVUM+. It must be noted that the current Vega launcher includes non-European elements (namely, the Ukrainian-made RD-869), so a major element of the new Vega Consolidation strategy is to fully 'Europeanise' the new European launchers. Nevertheless, the Vega manufacturer has underlined that *"the implementation of European components will be pursued taking into account the constraint not to increase the launcher recurring cost"*.[77]

As noted, the Vega-C first stage solid motor, the P120, will also serve as a strap-on booster for the first stage of Ariane 6. This common element is considered the first true common block in the European Launcher Families, and is thus a key factor for the successful commercialisation of Europe's future launchers, as it will allow significantly enhanced production rates and thus decrease the costs for both Vega and Ariane. To this effect, the Ministerial Resolution underlined the mutual benefit of preparing the exploitation of Ariane 6 and Vega-C together, so as to ensure that the overall competitiveness of the future launchers will be enhanced.[78]

As for the launch costs and prices of Vega-C, these are expected to directly benefit from the cadence of the production of the P120 but are yet to be consolidated. It is, however, assumed that the launch cost will remain in the order of € 26 million. Also the price of Vega-C is expected to remain in the range of today's prices (€ 35 - 45 million). Finally, it is worth noting that the decision to adopt the P120 as a booster of Ariane 6 has contributed to further alter the geopolitical balance of launcher policy in Europe, breaking the previous Franco-German duopoly and creating a higher degree of interdependence, in which Italy has increased weight.

With regard to the Vega programme it is worth noting that a further upgraded version of Vega for the mid-2020s is currently being studied: the Vega-E (Evolution). At present, Vega-E is designed to feature:

- P120 as first stage;
- Zefiro 40 as second stage;
- A Cryogenic upper stage (LM-10 MYRA) replacing both the Zefiro 9 and AVUM+.

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[75] Source: Bianchi, Stefano. "The European decisions of December 2014". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.
[76] See: Lasagni, Pier Giuliano. "Vega C". Presentation at the "International Conference on the European Space Launchers". Paris, 3-4 November 2015.
[77] Ibid.
[78] See ESA Council at Ministerial Level. "Resolution on Europe's Access to Space". ESA/C-M/CCXLVII/Res. 1 (Final). 2 December 2014.

If this configuration is eventually adopted, Vega-E would become a three-stage launcher, with no optional fourth stage. Activities to replace the current third and fourth stages with a single cryogenic upper stage featuring a new guidance system are being conducted within the context of the LYRA programme. Primarily financed by ASI, the LYRA programme responds to the overall objective of upgrading the performance of Vega by about 30% without a significant price increase. A full-scale demonstrator of the new MYRA cryogenic propulsion system has already been produced and tested, but a final decision remains to be taken.

Parallel to LYRA is the VENUS programme, a DLR effort to study possible German contributions to the future evolution of Vega. Two main options have been addressed: one option consists of replacing the Z9 third stage and AVUM with a storable upper stage using the Aestus engine, today used for Ariane 5 ES.[79] The other option being considered by Germany is to stay with a four-stage configuration but to replace the Ukrainian RD-869 engine on the AVUM fourth stage with a Europeanized stage. This option seems currently to be the preferred solution within the VENUS programme. In that way, *"all components of the rocket would be built inside Europe"* and autonomy from foreign sources would be ensured.

Guyana Space Centre

The development of Ariane 6 will be accompanied by the necessary upgrades and adaptations for its main launch base, the Ariane 6 Launch Complex and Launch Range located at the Guyana Space Centre in Kourou, French Guyana. Relevant funding for the base upgrades was secured at the Ministerial Council, with contracts signed between ESA and CNES – Prime Contractor for the launch base – in August 2015 valued at € 600 million. A key feature of Ariane 6 is the horizontal integration,[80] which, while at first will require additional capital investment to accommodate and build the new structures, in the long run will lead to lower recurring costs during the exploitation phase, and thus ultimately offset the higher initial expense.

2.2.3 A Revolution in Governance

In addition to the numerous synergies between Ariane 62, 64 and Vega-C, the successful exploitation of future European launchers on the commercial market will also be supported by important changes in governance, particularly *"in the relations between industry and governments in developing and operating launch vehicles"*.[81]

The necessity to introduce such changes stemmed from the recognition that the European launch model, despite being successful for 30 years, will no longer be financially sustainable. In addition to the deficit of commonalities between Ariane 5, Soyuz and Vega, which has limited synergies in their exploitation, and the lack of a solid institutional launch business base, the industrial cycle, in particular, has shown numerous inefficiencies due to the excessive number of layers produced by ESA's geo-return principle and the overall management scheme. Indeed, while encouraging specialisation and thus being a quality enhancer, the principle of geographical return ultimately generated a scattered industrial landscape for both development and production activities, which inevitably drove costs up. Although the streamlining of the industrial processes started as early as 2005 with the launch of the Ariane 5 Recovery Plan, its limited success made it apparent that overall reorganisation of the launch sector based on a clearer division of tasks between the main actors had to be undertaken if Europe wanted to eliminate the need for public support payments while at the same time retaining the competitiveness of European launchers in the marketplace.

In order to achieve this overarching goal, the 2014 Ministerial Resolution emphasises that decisions on the development of Ariane 6 are to be closely associated with a change in governance of the European launcher sector, based on a balanced responsibility and cost and risk-sharing scheme between ESA and the industrial Joint Venture (See Table 7). In more concrete terms, it stresses that within this new governance, the newly established Airbus Safran Launchers (ASL) joint venture[82] *"will bear all commercial market risks during exploitation without support from Member States under the understanding that the Joint Venture will control the commercial exploitation of the launch service and that a number of launches will be contracted per year by different institutional actors in Europe that*

[79] Veclani, Anna Clementina, Jean-Pierre Darnis. "European Space Launch Capabilities and Prospects". In: Schrogl, Kai-Uwe, et al. Handbook of Space Security. Policies, Applications and Programs. Volume 2. Springer, 2014: pp. 783-800.

[80] Ariane 5 is vertically integrated.

[81] ESA Council at Ministerial Level. "Resolution on Europe's Access to Space". ESA/C-M/CCXLVII/Res. 1 (Final). 2 December 2014.

[82] The ASL started operations in January 2015 with an operational workforce of 450 employees, though it will be fully operational at the end of 2015 after Safran's payment of € 800 million for having an equal stake in the joint venture. See de Selding. Peter. "Safran to pay Airbus 1 billion for equal stake in joint rocket venture". Space News. 27 February 2015.

consider as a collective priority and an individual benefit to use competitive European-developed launchers".[83]

With the new arrangements, the Member States and ESA will have responsibility for guaranteeing five launches per year for Ariane 6 – so as to provide a stable and predictable institutional launch business base over which to amortize fixed operational costs – while for the commercial market, ASL will be on its own, since Member States will no longer provide public support payments to cover the annual losses incurred by Arianespace, as was done in the past.[84]

Thus, the success of the ASL joint venture will rely, *de facto*, on an ESA/EC-guaranteed market of five institutional launches, but – as also stressed in an interview with the ESA Director Advisor to Director General, Antonio Fabrizi – "this is not ESA's own market. It is a market from ESA, from France, from the European Commission, from Eumetsat and others. Whether this all can be put together into a single bowl, a single agreement, is uncertain".[85]

Regardless of how this issue is addressed in the coming years, what needs to be highlighted is that the change in responsibilities flowing from the creation of the ASL joint venture involves far more than a mere streamlining of industrial processes and reduction of the number of layers. There is an entire paradigm-shift in the overall governance of the European launch sector, with far-reaching implications. For industry, the ultimate objective behind the regrouping of industrial capacity is to assume full control of the entire lifecycle (including design, production, operations and commercial sales) of the new Ariane 6.

As clearly explained by Marwan Lahoud, president of the French Aerospace Industries Association: "the launcher business in Europe in the beginning of 2014 was one in which the vehicles were designed by government agencies, commercialized by a company called Arianespace, produced by an ensemble of companies, and then launched by Arianespace. This is not an optimal situation […]. The optimal solution is to industrialize the process, with one prime contractor that designs, builds, sells and operates the launchers, with a supply chain – much as we do with Airbus today".[86] In short, the production of Ariane 6 should be fully entrusted to ASL, and no longer through the multi-layered ensemble of stakeholders that has so far been pursued in Europe.

The ASL joint venture has already planned to take steps in this direction and, as an essential element in this process, has expressed the intention to ultimately acquire direct control over Arianespace and launcher commercialization. Since its creation in January 2015, the ASL joint venture – which is already the biggest shareholder of Arianespace, holding almost the 39% of the company's shares – has been planning to acquire the roughly 34% share of CNES. After the agreement with the French government and the completion of all regulatory consultation and approval procedures, ASL will then hold 74% of Arianespace's share capital.[87]

According to Alain Charmeau, CEO of ASL, "the project represents a key step forward following the creation of ASL. [While] Arianespace will remain legally an independent company based in Evry and will maintain all the assets that have made it a world leader in launch services, launch service customers will directly benefit from this change of control, because of:

- An increased focus of Arianespace on the commercial market;
- An optimization of Ariane 6 costs and cycles;
- A shorter loop between operators and the launcher industry, already evidenced by the successful creation of the first "Ariane User Club".[88]

Notwithstanding that in June 2015 the French government and ASL signed a protocol to govern the purchase of CNES shares, there still appears to be a certain resistance from the institutional side to entrust industry with full control of Ariane 6. Indeed, both ESA and CNES, while clearly in favour of increased responsibility on the industrial side, have at the same time made clear their intention to *de facto* remain project managers, by maintaining a seat at the design and development

[83] Cit. ESA Council at Ministerial Level. "Resolution on Europe's Access to Space". ESA/C-M/CCXLVII/Res. 1 (Final). 2 December 2014.
[84] Space News 3 April 2015. "Desire for Competitive Ariane 6 Nudges ESA towards Compromise".
[85] The Commission can provide comfort through a certain degree of preference, but not a guarantee they will use Ariane 6. See de Selding, Peter. "Profile: Antonio Fabrizi". Space News. 27 January 2015. Web. http://spacenews.com/profile-antonio-fabrizi-director-adviser-to-the-director-general-european-space-agency/. Accessed 2 December 2015.
[86] de Selding, Peter. "New Airbus Safran Venture eyes full control of Arianespace". Space News. 8 January 2015. Web. http://spacenews.com/new-airbus-safran-venture-eyes-full-control-of-arianespace/. Accessed 2 December 2015.
[87] Airbus-Safran Launchers Press Release. 16 June 2015.
[88] Charmeau, Alain. "European Space Launchers from Diamant to Ariane 6". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

table.[89] As the President of CNES Jean-Yves LeGall quipped at a press conference: *"European governments didn't approve spending 4 billion euros of taxpayer money [on Ariane 6] only to surrender [to industry] all control".*[90]

Ariane 6 New Governance Principles in Development and Exploitation – New exploitation cost and risk sharing scheme	
Industry	Public Sector
• Industrial investment > 10% of development costs • Only high level contractual requirements (HLR) • Industry is Design Authority for launcher • Bearing risks in development and on commercial exploitation • Competitive launch service prices for commercial missions and target launch service prices for institutional missions as defined in 2014	• Only high level contractual requirements (HLR) • No public funding in commercial exploitation • Preserving the interests of all Participating States in the launcher development programmes and their respective industry • Minimum number of launch services contracted per year by European Institutional Users

Table 7: An overview of the new industrial governance scheme.[91]

In light of these brief considerations, it appears quite evident that "getting ESA, CNES and industries to agree on a new working relationship will be as problematic as the process of reaching consensus among member states on the development of the new Ariane".[92] A dialogue between governments and industry on the scope of the overall reorganisation of the European launch sector is currently ongoing. While launch development contracts have already been awarded and the ASL has agreed to contribute € 400 million of industrial investment to the development of the new Ariane (roughly 10% of the development cost),[93] the new industrial organisation still needs to be fully consolidated. Accordingly, the decisions endorsed at the Ministerial 2014 will be subject to the outcome of the Programme Implementation Review in June 2016, which will indeed be a crucial milestone in the construction of the new governance.[94]

What future for European Launchers?

The 2014 Ministerial meeting adopted a multi-pronged strategy aimed at increasing flexibility and reducing the costs of its future access to space through a number of levers, including the utilisation of heritage hardware, the streamlining of industrial organisation, the maximisation of common expendable elements and the creation of synergies between different market segments. All these levers – together with the guarantee of five institutional launches per year – are essentially designed to increase production rates so as to generate economies of scale that will ensure competitive pricing for Ariane 6 and Vega-C without the need for public support payments during exploitation.

These features inevitably raise a number of questions with regard to the effectiveness of this strategy and, more broadly, with regard to the overall prospects for Europe's access to space in the coming decade. Whereas at this point some conclusions can already be drawn, an investigation of the international dynamics surrounding the European launcher sector should be provided first. Accordingly, the next chapter will broaden the perspective, by providing a reference analysis of the space transportation sector outside Europe, its structure and the most recent developments in terms of policies, capabilities and practices.

[89] de Selding, Peter. "Full industry control of Ariane 6 non-negotiable". Space News. 9 April 2015. Web. http://spacenews.com/full-industry-control-of-ariane-6-nonnegotiable-exec-says/. Accessed 2 December 2015.
[90] de Selding, Peter. "New Airbus Safran Venture eyes full control of Arianespace". Space News. 8 January 2015. Web. http://spacenews.com/new-airbus-safran-venture-eyes-full-control-of-arianespace/. Accessed 2 December 2015.
[91] Source: Bianchi, Stefano. "The European decisions of December 2014". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.
[92] Ibid.
[93] The contract, signed on 12 August 2015 and worth € 2.4 billion, finances the development and industrialization of the Ariane 6 launcher in its two versions until the full operational level set for 2023. The contract includes a commitment of some € 680 million for initial development activities up to the Preliminary Design Review scheduled for mid-2016. The total amount for the development of the launcher will be approximately € 3 billion, including € 400 million of industrial capital. Airbus-Safran Launchers Press Release. 12 August 2015.
[94] de Selding, Peter. "Desire for Competitive Ariane 6 Nudges ESA towards Compromise". Space News. 3 April 2015.

3. World Outlook in 2015: Analysis of Launcher Policies, Programmes and Developments

Since the onset of the space race only a handful of countries have developed expendable launch vehicles that can grant them complete and autonomous access to space, from Low Earth orbits (LEO) to Medium Earth orbits (MEO), Geostationary Transfer Orbits (GTO) and Earth escape trajectories. Such countries are the United States, Russia, the Member States of ESA, China, Japan and India.

A few more countries, such as Ukraine, Israel, South Korea, North Korea and Iran have developed capabilities to reach LEO, either autonomously or through technology transfer programmes. Furthermore, two countries, Argentina and Brazil, are currently in the process of developing their own first LEO vehicles.

This chapter gives a global overview of national capabilities in the space launch sector. The most recent policies and programmes of each established and emerging spacefaring nation are presented, focusing on present-day challenges and issues at stake, including a forecast of their position in the worldwide launcher sector with a medium-term perspective.[95]

For each major spacefaring nation, current orbital launch vehicles are presented and detailed in Annex 1. Orbital launch vehicles currently under development are described in Annex 2.

3.1 United States

Policy

The United States space transportation policy is aimed at guaranteeing *"robust, responsive and resilient"* access to space, with the ultimate purpose of protecting its national security, foreign policy, civil, and commercial interests through its own capabilities.[96] The Secretary of Defense and the NASA Administrator are responsible for assuring U.S. access to space, which is governed at the highest political level to serve three main goals: independent access to space, worldwide U.S. leadership and redundancy of procurement sources.

The way space transportation policy is established in the U.S. is twofold: as legislation from the Congress of the United States and as policy statements and directives from the Executive Branch.

Aligned with the objectives stated in the broader 2010 National Space Policy,[97] the most recent guidelines for the space transportation sector are laid out in the National Space Transportation Policy of November 2013. Its main objective is assured access to space, to be achieved through U.S.-manufactured launch vehicles developed and exploited by private entities with continued public support. The most relevant additions in this new policy are the provisions for new entrants to launch U.S. government payloads, encouraging hosting such payloads on commercial spacecraft, and ultimately spurring innovation and entrepreneurship in the commercial space transportation sector, still backed by public support in the form of a large, captive domestic market, as well as access to government launch infrastructures and other incentives.

More recently, in November 2015, the United States updated its commercial space legislation with the signature of the "U.S. Commercial Space Launch Competitiveness Act" (also known as the SPACE Act, "Spurring Private Aerospace Competitiveness and Entrepreneurship"*)*.[98] This updated law explicitly allows "*U.S. citizens to engage in the commercial exploration and exploitation of 'space resources' [including ... water and minerals]*".[99] Furthermore, it paves the way for an

[95] The content of this chapter mainly builds on publicly available sources and documentation provided by the members of the Accompanying Group.

[96] "National Space Transportation Policy". 21 November 2013. Web. http://www.nasa.gov/sites/default/files/files/national_space_transportation_policy_11212013.pdf. Accessed 2 December 2015.

[97] "National Space Policy". 28 June 2010. Web. https://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf. Accessed 2 December 2015.

[98] "Spurring Private Aerospace Competitiveness and Entrepreneurship Act of 2015 or the SPACE Act of 2015". Web. https://www.congress.gov/bill/114th-congress/house-bill/2262. Accessed 2 December 2015.

[99] For a detailed overview, see: Foust, Jeff. "Congress launches commercial space legislation". The Space Review. 26 May 2015. Web.

increased presence of commercial companies, both for launch and space services, in LEO and beyond, as NASA's focus shifts toward its Mars programme.

In order to support its space transportation policy, the U.S. has over time made use of several additional tools that have had and continue to have a deep impact on the international trade in launch services. An example of these is a series of protectionist regulations enacted in the field of space transportation, such as the Buy American Act (first enacted in 1933) applied to procurement in the launchers sector. These measures restrict public U.S. entities from purchasing goods and services from foreign sources. As a consequence, the U.S. has excluded launchers from the World Trade Organization Agreement on Government Procurement, with both NASA and DoD explicitly mentioned. Even more so, the ITAR Regulations (see Box 2) considerably impact the global trade and export of space technology, including launchers. Furthermore, Presidential Directive NSPD-2 of 1990, prohibits U.S. government payloads to be launched on foreign launch service providers[100] – unless specifically exempted by the President under a number of limited exceptions. Other measures in place are the Iran, North Korea and Syria Non-Proliferation Act (INKSNA), through which the U.S. sanctions a number of entities, both private and governmental, that engage in proliferation activities.[101] More recently, the 2015 Defense Authorization Act, which was heavily influenced by the Russian-Ukrainian Crimean crisis, prohibits the contracting of Russian engines for U.S. ELV vehicles (excluding the order already placed in the 2013 EELV block buy contract) involved in launching national security-rated payloads (see below).[102]

With respect to the launcher fleet in the post-Space Shuttle era, NASA has established a two-phased approach to meet the need for ISS logistics and resupply missions. The first phase, called "Commercial Orbital Transportation Services (COTS) Demonstrations", started in 2005. Under COTS, NASA helped industry develop and demonstrate its own cargo space transportation capabilities, including launch vehicles. Industry led and directed its own efforts while NASA provided technical and financial assistance.[103]

The first COTS competition lasted 10 months and was completed in August 2006. Two COTS Commercial Partners (CPs) were selected to participate in the ensuing Phase 1 of the programme: Space Exploration Technolo-

BOX: ITAR

The International Traffic in Arms Regulations (ITAR) is a far-reaching set of U.S. Government regulations that began to form in 1976. They encompass most areas of technology and limit the export and import of defence related articles and services. ITAR regulations define "export" to include the entire spectrum of technical activities, from design, development, and production to operation, repair, and maintenance.

To prevent unauthorized export of technology to foreign nations and individuals, the Regulations require that whenever a defence article, its technical data or related services that appear on the ITAR USML (United States Munitions List) are exported, the manufacturer or exporter must obtain a license from the DDTC (Directorate of Defense Trade Controls).

ITAR regulations have been subject to intense debate for decades, with criticism highlighting their whole cumbersome framework, and the potential harm they are causing to U.S. commercial interests worldwide (see for example the initiatives on "ITAR-free" satellites). Following a lengthy re-assessment process by the U.S. Government on whether the regulations were damaging U.S. exports in the global space industry (with some studies estimating the loss in sales to be up to $ 2 billion in recent years), a major change came into effect in 2014, when commercial satellites were removed from the U.S. Munitions List and are no longer classified as military exports. Furthermore, many satellite components were also delisted and are no longer part of a blanket ban.

However, the reformed rules relate to satellite systems and not launchers, which continue to be tightly controlled by ITAR given that the technology can be directly related to offensive military missile systems.

http://www.thespacereview.com/article/2759/1. Accessed 2 December 2015.

[100] The NSPD-2 policy has been codified as statutory law in the 1998 Space Commercialization Act. See: "Commercial Space Act". 28 October 1998. Web. http://www.nasa.gov/offices/ogc/commercial/CommercialSpaceActof1998.html. Accessed 2 December 2015.

[101] See: "Iran, North Korea, and Syria Non-proliferation Act Sanctions (INKSNA)". Web. http://www.state.gov/t/isn/inksna/. Accessed 2 December 2015.

[102] "National Defense Authorization Act for Fiscal Year 2015". Web. https://www.congress.gov/bill/113th-congress/house-bill/4435. Accessed 2 December 2015.

[103] NASA invested approximately $ 800 million from 2006 through 2012 toward cargo space transportation flight demonstrations.

gies (SpaceX) and Rocketplane-Kistler (RpK), although the agreement with RpK was later terminated after it failed to complete financial and technical milestones. A second competition was then held to select a new commercial partner, which resulted in the selection of Orbital Sciences Corporation (today Orbital ATK) in February 2008. The "*unprecedented efficiency*" of the COTS investment resulted in "*two new U.S. medium-class launch vehicles and two automated cargo spacecraft*".[104]

The second phase consists of competitive procurement for cargo services to support the ISS using the newly developed vehicles. The first Commercial Resupply Services (CRS) contracts were signed in 2008 and awarded around $ 1.6 billion to SpaceX for 12 cargo transport missions and $ 1.9 billion to Orbital ATK for 8 missions, nominally covering deliveries to 2016. The second round of contracts, CRS2, will cover deliveries from 2017 until 2024, and were awarded in January 2016 to SpaceX, Orbital Sciences and Sierra Nevada Corporation (with its Dream Chaser vehicle)[105].

With the role of NASA redirected towards the study of transportation systems such as SLS and Orion for beyond-LEO exploration, in the last five years the private sector has been granted the possibility to compete in unprecedented ways in the U.S. space transportation sphere, including areas that were previously an exclusive government domain, as was the case of manned spaceflight.

Current Status

The U.S. benefits from several remarkable advantages in the field of space transportation. Some of them are the comprehensiveness of its fleet of launch vehicles (with the notable current exception of human-rated spaceflight vehicles), redundant options for the same launch requirements, the world's largest captive institutional payload manifest, and a favourable political and financial environment supporting the appearance of new actors in the space transportation sector.

Nevertheless, in recent years the U.S. has also seen some critical developments that have affected its space transportation sector. The global financial crisis caused budget cuts and a series of freezing measures that led to a decrease of institutional payloads launched. Additionally, the U.S. has seen a high-profile limitation in its otherwise comprehensive autonomy in access to space: first, the phase-out of the Shuttle Programme led the U.S. to become dependent on Russian Soyuz capsules and launches for human spaceflight and access to the ISS; then, reliance on foreign engine suppliers even for national payload launches was highlighted in the wake of the Crimean crisis.

With the National Defense Authorization Act of 2015, the U.S. Congress banned the use of Russian-built RD-180 engines in national security missions starting from 2019, in response to Russia's occupation of Crimea. The RD-180 is the main engine of Atlas V, the launch vehicle used to put in orbit the majority of U.S. national security satellites. The decision was subjected to intense criticism by the U.S. industrial sector as well as the Air Force, the latter in particular being concerned about the risk of creating a gap in assured access to space and redundancy options for national security payloads. Among the other consequences of the 2015 policy decision, in November 2015 ULA stated that, because of the ban, it had been impeded in its bid to launch a U.S. Air Force GPS satellite scheduled for 2018, effectively ceding the contract to SpaceX, the only other viable competitor. This was seen as a setback for DoD efforts to introduce competition into a national security launch market after years of *de facto* monopoly).[106] In December 2015, the new U.S. government spending bill effectively ended the ban on the RD-180, stating that the Air Force could award a launch contract to any company "regardless of the country of origin of the rocket engine that will be used on its launch vehicle, in order to ensure robust competition and continued assured access to space".[107]

Notwithstanding the recent termination of the RD-180 engine ban, the issues highlighted above have been instrumental in leading to policy decisions that could ensure a long-term, positive upturn for the U.S. space

[104] "Commercial Orbital Transportation Services, A New Era in Spaceflight" NASA/SP-2014-617. Web. https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf. Accessed 2 December 2015.

[105] Gebhardt, Chris and Bergi, Chris. "NASA awards CRS2 contracts to SpaceX, Orbital ATK, and Sierra Nevada". NASA Spaceflight.com. Web. http://www.nasaspaceflight.com/2016/01/nasa-awards-crs2-spacex-orbital-atk-sierra-nevada/. Accessed 20 January 2016.

[106] For an overview of the 2015 RD-180 debate, see: Ferster, Warren. "Defense Bill Curbs ULA Use of Russian Engines but Draws Veto Threat". Space News. 30 September 2015; Shalal, Andrea. "U.S. Air Force official sees issues with space launch priorities". Reuters. 25 November 2015; Gruss, Mike. "McCain Urges Appropriators To Uphold RD-180 Ban". Space News. 23 November 2015; Young, John. "Stay the Course on Launch Competition". Space News. 11 December 2015.

[107] Gruss, Mike. "Spending Bill Lifts RD-180 Ban, Puts ULA Back in Competitive Game". Space News. 16 December 2016. Web http://spacenews.com/spending-bill-lifts-rd-180-ban-puts-ula-back-in-competitive-game/. Accessed 19 January 2016.

transportation sector. Budget cuts have triggered a more active search for cost reduction measures, and have spurred competition between U.S. launch providers, from which SpaceX has benefited the most. Similarly, the lack of autonomous human spaceflight capabilities and U.S.-manufactured engines has encouraged more political pressure to reassert national independence, with the involvement of private companies in the development of U.S.-made engines for human-rated spaceflight vehicles and manned capsules for LEO and possibly beyond.

As of 2015, the U.S. was developing or upgrading a series of orbital and suborbital launch systems that will enter service and commercialization in the upcoming decade. The main actors involved are NASA, ULA, SpaceX, and Orbital ATK for orbital vehicles, as well as Blue Origin, Virgin Galactic and XCOR Aerospace for suborbital vehicles and engine development. Additionally, several small U.S. companies are pursuing the development of small launchers (see Chapter 4.3.5).

The Space Launch System (SLS) and Orion/MPCV (Multi-Purpose Capsule Vehicle) is a NASA-led effort aimed at developing a very heavy-lift manned spaceflight capability, in accordance with its new mandate to focus on beyond-LEO exploration. SLS rises from the ashes of the cancelled Constellation programme, thus drawing heavily on the Ares V concept, with the J-2X engine derived directly from Saturn V and boosters derived from the Space Shuttle SRBs. Following an initial plan for a modular vehicle with a performance of 70,000 to 130,000 Kg to LEO, budgetary constraints and no small amount of criticism led to the adoption of a "block upgrade approach" which envisages a 70,000 Kg (SLS Block 1 Initial Capability) version by 2018, and ongoing studies for an expanded 130,000 Kg version (SLS Block 2 Evolved Capability), to be made available in time for the NASA Mars manned exploration programme planned for the 2030s. Criticism of the SLS and Orion programme revolves around the necessity of such a vehicle, at least in its Block 1 version. Indeed, some critics noted that ULA and SpaceX future heavy-lift vehicles (Vulcan Step 3 and Falcon Heavy) could be human-rated and able to serve as carriers for commercial crew capsules, fulfilling most if not all manned spaceflight needs in and around LEO, and even in a financially competitive manner. At the same time, the General Accountability Office has recently pointed to the lack of a clear purpose or mission for SLS.[108]

ULA is currently developing upgrades for its main launchers, in order to reduce costs and enhance launch manifest flexibility, such as a Common Upper Stage for Delta IV and Atlas V, and a dual payload adapter. Furthermore, in view of launching manned capsules such as Boeing's CST-100 within the NASA Commercial Crew Programme, ULA is also pursuing the human rating of Atlas V. The 2015 Congressional ban on the Russian-made RD-180 engine also prompted ULA to decide to develop a next-generation vehicle (NGSL) called Vulcan, retiring the medium version of Delta IV already in 2018-2019 for commercial reasons, and ultimately replacing both families of launchers. Vulcan will be designed upon the existing subsystems and components of Atlas V and Delta IV to achieve lower risk and quicker development. In particular, key features of the new vehicle will be an American-made engine, the BE-4 manufactured by Blue Origin (with the Aerojet Rocketdyne AR1 as a second option), a step-by-step introduction of new stages, and will possibly feature a degree of reusability of its engine section starting by 2024. Vulcan is scheduled to be initially available around 2019, with performance levels equivalent to or above Atlas V. The turn of the decade would then see all three ULA launchers (Vulcan, Atlas V, and Delta IV Heavy) exploited in parallel, in order to satisfy U.S. government and national security needs, with only Vulcan remaining operational in the long-term. ULA also foresees a reduction of launch sites from five to two, one on each U.S. coast, which would reduce costs but at the same time impact schedule reliability and flexibility for commercial customers. This in turn would suggest that U.S. institutional actors could still be the prime customer targets for Vulcan and ULA.

The commercial success of SpaceX Falcon 9, with its aggressive pricing policy and persistent pursuit of reusability for the rocket first-stage, is one of the disruptive factors that has unsettled the launch industry in recent years. Following the first launch of Falcon 9 in 2010, in just 5 years SpaceX was able to capture almost 50% share of the global commercial market, also benefitting from the difficulties and launch failures encountered by the other established commercial launch service providers, such as ILS and Sea Launch. Although the company suffered its first launch failure in June 2015 it is continuing the development of improved Falcon 9 Merlin

[108] Boozer, R.D. "The downhill slide of NASA's 'rocket to nowhere' ". The Space Review. 25 August 2014. Web. http://www.thespacereview.com/article/2583/1. Accessed 2 December 2015.

engines to allow for a 30% increased lift capacity. This key development enables SpaceX to launch GTO satellites while retaining enough fuel to continue its first-stage landing attempts. The new engine was featured in Falcon 9's first launch following the June failure that took place on 22 December 2015. Notably, on the same flight, for the first time ever, the first stage of the upgraded Falcon 9 autonomously landed with success on a pad on Earth. Regarding manned spaceflight, in addition to its demonstrated capability to carry cargo to the ISS with the Dragon capsule, SpaceX is also developing a manned configuration for its capsule under the NASA Commercial Crew Program (CCDev), with a first flight foreseen by 2017.

The third major U.S. player in orbital launches is Orbital ATK, which has obtained a share of U.S. institutional launches over the past few years, particularly through the Minotaur family, Pegasus XL for small payloads, and Antares launches with the Cygnus capsule for ISS supplies within NASA's Cargo Resupply Services programme. Facing increased competition in the U.S. institutional customers segment, it is now pursuing the comeback of its Athena rocket in the responsive launch services for small payloads niche, and expanding Antares' performance. Additionally, the Antares launch failure in October 2014 led the company to accelerate its plans to replace the old Soviet-made and refurbished NK-33 main stage engines with the Russian-made RD-181. The Cygnus for ISS resupply was successfully launched again, atop an Atlas V rocket, in December 2015.

Blue Origin, the company founded by Amazon's founder Jeff Bezos, is employing an incremental approach from suborbital to orbital flight. It initially focused on sub-orbital spaceflight capabilities by developing the New Shepard spacecraft which, notably, at the end of 2015 achieved a vertical soft landing of both its capsule and rocket booster after achieving sub-orbital flight up to 100 Km. The company is further involved in the development of the BE-4 engine for ULA's Vulcan, as well as the cryogenic BE-3 engine both for the New Shepard and the second stage of Vulcan.

Outlook

In the medium-to-long term, U.S. launcher policies and development efforts will certainly put it again in a forefront position in the global landscape, as well as re-affirm the nation's autonomy in access to space on all levels and for all purposes. Furthermore, should a proposed revision of export control regulations take place, as advocated by many actors in the U.S. industrial sector, the commercial attractiveness of its launchers on the worldwide market could be further enhanced.

With SLS and Orion being developed by NASA for the purpose of manned spaceflight and cargo capabilities beyond LEO (in addition to their use for "other payloads and missions that substantially benefit from the unique capabilities of the SLS"),[109] and therefore currently not intended for the commercial market, the U.S. commercial launcher sector will chiefly comprise ULA, SpaceX and Orbital ATK. Potential new players arising particularly in the small-launcher or air-to-space market niches, and companies offering suborbital flights for space tourism purposes will complement them.

ULA's new launcher, Vulcan, will possibly focus on the large captive U.S. institutional payloads. ULA could, however, also pursue a larger presence on the worldwide commercial market thanks to the increased pricing competitiveness of its new launcher. Nevertheless, it should be considered that Vulcan, like Atlas V and Delta IV before it, will be an expression of U.S. sovereign power in granting the country assured access to space.

SpaceX, already a prime worldwide player in offering launch services, could capture a greater share of the global launch market through the imminent upgrade of its Falcon 9 rocket and completion of Falcon Heavy. Moreover, in December 2015 the company succeed in landing the first stage of its rocket, demonstrating the feasibility of vertical landing technology also for orbital flights. A reusable (and eventually low-priced) Falcon 9 rocket could be particularly appealing for more risk-prone satellite operators and customers. Furthermore, SpaceX's strategy of establishing several spaceports from which to launch – and land – its rockets anticipates increased requirements in flexibility and launch frequency to cope with a potential increased demand for launch services.

Additionally, the development of Falcon Heavy, now expected for a first flight in 2016, would give to the company a competitive advantage, being the first heavy-lift vehicle (21,200 Kg to GTO) developed in decades, and available on a market without direct competitors, at least until 2023. Should Falcon Heavy be made reusable, the additional fuel requirements to land all the three Falcon 9 cores would reduce its overall performance

[109] "H.R.2262 - U.S. Commercial Space Launch Competitiveness Act". Web. https://www.congress.gov/bill/114th-congress/house-bill/2262/text. Accessed 2 December 2015.

by around 30%,[110] consequently putting it in line with other large GTO vehicles currently available or in development but presumably with an added cost advantage.

As noted, in all probability the company will also enter the large U.S. national security satellite market following obtaining certification to launch military and intelligence payloads, possibly starting with a next-generation U.S. Air Force GPS satellite in 2018, for which ULA was unable to bid.[111]

The success of Orbital ATK's Antares both in the commercial and institutional sector will largely depend on the successful introduction of the first-stage engine. Nevertheless, the decision to adopt Russian-made RD-181 engines for Antares will require an entirely new DoD certification process, thereby putting Orbital ATK and Antares in an unfavourable position to compete for U.S. institutional launches compared to SpaceX and ULA.

3.2 Russia

Policy

The fall of the Union of Soviet Socialist Republics (USSR) caused a deep fracture, with shockwaves and ripples that a quarter of century later still shape regional geopolitics and the space sector of the region. Following the events of 1991, several key space manufacturing industries of the former Soviet Union were suddenly located in the territory of independent nations, such as Ukraine, while the Baikonur Cosmodrome, Russia's main spaceport, belonged to the newly-created Republic of Kazakhstan.

In the past two decades Russia has nevertheless been able to fully pursue and expand all its space activities either because the contribution of Ukrainian industries to the Russian space transportation activities was limited to small-to-medium sized launchers, i.e. mainly refurbished ICBMs such as Dnepr and Rockot; and through bilateral agreements such as the long-term lease of Baikonur from Kazakhstan, to the tune of around $ 115 million annually, until 2050.

In recent years Russia has nurtured a stronger impulse to achieve complete autonomy in access to space, resulting in an evolution from the post-cold war status quo. In fact, relations between Russia and Kazakhstan in space have become strained due to the periodic rise of disputes regarding Baikonur. More recently, the bitter 2014 Crimean crisis jeopardized business and cooperation links between Russian and Ukrainian companies, further underlining Russian's foreign dependence regarding the launcher sector. As stated by its President in 2008, Russia needs to ensure its *"ability to carry out all kinds of space launches from (its) own territory, from automatic satellites to manned spacecraft and interplanetary probes"*.[112] Consequently, several measures have been undertaken and ongoing initiatives have been stepped up.

The main priorities outlined in the "Space Activities of Russia in 2013-2020" programme are guaranteed Russian access to space; the development and utilization of space hardware and technologies; and fulfilment of international obligations in the space sector.[113]

The programme, which foresees two implementation phases (2013-2015, completing the existing Federal Space Programme 2015, and 2016-2020), also pursues the long-term objective of consolidating the Russian space sector by placing its programmes and subprogrammes under a co-management scheme between Roscosmos, which acts as executive managing body, and the Ministry of Defence, continuing a trend that started already in 2002. This consolidation process has proceeded at an uneven pace in the past 15 years, advancing faster when politically motivated following a string of launch failures, but also suffering from delays as a result of the 2009 economic crisis and worsened financial situation. The quick succession of reform plans, often only partially implemented, has led to a lack of stability and has increased uncertainty in the Russian space sector.

The latest of these reform plans was approved by the Russian President in January 2015 and by the Russian Duma in May 2015. A new State Corporation, Roscosmos SC, was created which ultimately consolidates under its name about 62 developers and manufacturers of space hardware and systems previously under United Rocket and Space Corp,

[110] A reusable Falcon 9 has a 30% reduced performance compared to an expendable Falcon 9, due to the amount of fuel set aside for landing manoeuvres.

[111] Gruss, Mike. "ULA Punts on GPS 3 Launch Contract Long Sought by SpaceX". Space News. 16 November 2015. Web. http://spacenews.com/ula-declines-to-bid-on-gps-3-launch-contract-long-sought-by-spacex/. Accessed 2 December 2015.

[112] "Opening Remarks at a Meeting with the Security Council on Russia's Space Exploration Policy for the Period through to 2020 and Beyond". 11 April 2008. Web. http://en.kremlin.ru/events/president/transcripts/24913. Accessed 2 December 2015.

[113] "Russian space program: a decade review (2010-2019)". Russian Space Web. Web. http://www.russianspaceweb.com/russia_2010s.html. Accessed 2 December 2015.

and another 11 entities including launch site operators and service providers.

A noteworthy factor that characterizes the status of the Russian space sector is that private companies, as understood in the Western sense, are almost totally absent. While in the early phases following the fall of the Soviet regime international joint ventures were formed with U.S. and European companies to enhance competitiveness and get easier access to the Western market, the increased experience acquired and a strengthened national economy have led to a gradual withdrawal from such international projects and joint ventures, particularly in the form of shares buy-back. Ongoing plans to restructure the space sector envisage further re-nationalization of the few remaining private companies, such as Energia, with the core of industrial entities carrying out launcher development and exploitation now organized in a way that allows full state ownership. Furthermore, all Russian launch infrastructures, including test facilities and launch complexes, are owned by the State, with some such as Baikonur (and the future Vostochny cosmodrome) under the responsibility of Roscosmos through TsENKI, and others such as Plesetsk under the control of the Aerospace Defence Forces.

Another priority measure being undertaken is to decrease technological dependence on space-related hardware components as well as raw materials, currently imported primarily from Ukraine, and to establish domestic assembly and production lines. Unlike in the 1990s, Russia today imports around 70% on average of the electronic components required for its satellites. Furthermore, as a consequence of the strained relationships with Western countries following the Ukrainian crisis, Russia is putting in place an import substitution programme, turning to other countries (e.g. China) to purchase basic electronic components.

Current Status

A quarter of century after the fall of the Soviet Union, the position of Russia in the launchers sector is still strong, with the – somewhat tarnished – ability to offer commercial launch services at low prices and full state control over the exploitation of its launcher systems. The launchers sector furthermore enjoys the support of a constant and large domestic institutional market, and the retirement of the U.S. Shuttle programme has given Russia a monopoly in human access to space.

However, Russia now has to face a number of critical issues that threaten its until-recently strong presence on the worldwide launchers landscape, chief amongst them being quality assurance and reliability issues, an increase in prices affected by domestic and non-domestic factors, as well as perceived reduced autonomy in access to space.

Starting from the autonomy issue, the more and more evident dependence on spaceports not located on Russian territory has been addressed with the development of new launch infrastructures and consolidation of existing ones. Considerable resources from Russia’s space budget have been allocated towards the upgrade of existing launch infrastructure, including the construction of a new launch site on Russian territory. The cosmodrome of Plesetsk will be further overhauled to be able to launch the next generation of Russian launchers, while the building of the new Vostochny spaceport, started in 2008, has been stepped up, with plans to make it the new main Russian launch site for all types of Russian launch vehicles by the end of the decade. Nevertheless, construction works on Vostochny spaceport are being plagued by delays and mishaps in its design,[114] ultimately leading to uncertainties about the date of its readiness.

Regarding reliability, the increase in failure rates of launcher vehicles, both reconverted and aging ICBMs such as Rockot and Dnepr, but also Proton and Soyuz including its upper stages, has started to cause alarm among commercial satellite operators and Russian institutional customers themselves. Proton, in particular, has suffered heavily from launch failures, which have happened six times since 2010, allowing competitors such as Arianespace and SpaceX to conquer an almost-50% each share of worldwide business in 2014 and 2015.[115] Furthermore, failure of the Volga upper stage of Soyuz caused the uncontrolled re-entry and subsequent destruction of an advanced remote-sensing military satellite, Kanopus-ST, in December 2015.

To overcome these critical issues and cope with evolving demand and increased reliability needs, Russia has concentrated its efforts on the modernization and consolidation of its launcher vehicles, such as the development of the new modular Angara family, formally started already in 1992, while phasing out

[114] Bodner, Matthew. “Russia's New Rocket Won't Fit in Its New Cosmodrome”. The Moscow Times. 02 October 2015. Web. http://www.themoscowtimes.com/business/article/russia-s-new-rocket-won-t-fit-in-its-new-cosmodrome/536827.html. Accessed 2 December 2015.

[115] Space News Editorial. “Welcome Back, Proton”. Space News. 08 September 2015. Web. http://spacenews.com/editorial-welcome-back-proton/ . Accessed 2 December 2015.

the Rockot and Dnepr vehicles as the refurbished ICBM stockpile diminishes. The new family would enable Russia to streamline the manufacturing process, exploit flexibility and modularity and ultimately provide the capability to launch a complete range of small-to-large payloads. The plans for the Angara family span from the small-launcher Angara 1.2 to the heavy lift Angara 7, with Angara 3 (still only at a concept stage) intended to gradually replace Soyuz, and Angara 5 (in an advanced stage of development, with 9 test flights left as at Dec 2015)[116] as a future replacement for Proton, post-2020. Both A5 and A7 also see the possibility of being human-rated.

However, the worsening economic situation of Russia, sparked by falling oil prices and economic sanctions imposed by Western countries following the Ukrainian crisis, have forced substantial budget cuts to the space programme, which ultimately led to scale down and postponement of the most far-reaching plans. Development efforts have focused so far on Angara 1.2 and Angara 5, which performed inaugural flights in 2014 and 2015 respectively, delaying the other Angara versions, 3 and 7, to later dates.

Outlook

The Russian space and launcher sector is evolving from a post-cold-war status quo. However, this is taking place as its relations with Western countries, following a period of rapprochement in the late 1990s and early 2000s, are today wavering and increasingly conflictual, due to geopolitical disputes, particularly due to the Ukrainian crisis and the Syrian civil war. Furthermore, severe economic difficulties add an element of uncertainty and instability to the evolution of the whole space sector.

Determined to achieve greater independence, Russia has recently severed the already damaged ties with the Ukrainian space sector, and is posed to gain autonomy from Kazakhstan's Baikonur launch site once its new spaceport is completed. The ongoing reform and re-nationalization of the Russian space sector, and an accelerated pace of development of the new Angara family, are trying to address critical issues such as reliability as well as increased costs and industrial inefficiencies.

The success of the industrial governance reform process, as well as the resolution of quality assurance and reliability issues, will be instrumental in determining how Russia's prospects in the commercial launcher sector develop. This notwithstanding, Russia's almost unparalleled expertise and know-how in launcher systems, accompanied by strong political support, will undoubtedly allow the country to retain a forceful role in worldwide space transportation also in the future.

3.3 China

Policy

The Chinese space programme is characterized by increasingly ambitious goals, steadfast progress through continuously increasing budgets and workforce, and the objective to be self-sufficient while attaining a prominent position in the international space pecking order. Initially focused on Earth observation and navigation systems, China's space programme now encompasses the whole spectrum of space activities. High-level objectives range from robotic exploration of Mars and the Solar System in the 2020s, to human spaceflight, with an independent space station fully operational by 2022 and manned lunar missions envisioned by 2030.

The most recent space policy guidelines were published in a 2011 White Paper,[117] following the publication of the 12th Five Year Plan that gives regular guidance for the Chinese planned economy. The paper recognizes the importance of the space sector and its activities for the nation's overall development strategy, as well as for China's economic and social development, now entering a crucial phase with deeper reforms and transformation of the country's pattern of economic development. It stresses the peaceful purposes of its programmes, maintaining independence and self-reliance while at the same time pursuing a further opening to the outside world and international cooperation.

For the period 2011-2016, the White Paper defined a wide number of tasks, such as strengthening basic capability in space science, technology and industry; continuation of major programmes in human spaceflight, Earth observation, navigation, space science; satellite telecommunications, development of space infrastructure; and promotion of the satellite application industry, amongst others. In particular, for the launchers sector it affirms that China *"will build a stronger space*

[116] Zak, Anatoly. "Angara-5 to replace Proton". Web. http://www.russianspaceweb.com/angara5.html. Accessed 11 December 2015.

[117] White Paper on China's Space Activities in 2011, Information Office of the State Council of the People's Republic of China. 29 December 2011. Web. http://www.china.org.cn/government/whitepaper/node_7145648.htm. Accessed 2 December 2015.

transportation system, keep improving its launch vehicle series, and enhance their capabilities of entering space."[118]

As a matter of fact, the Chinese space transportation sector enjoys strong and continuous institutional support both in development and exploitation, while at the same time all the space industry and corporations involved in space development are fully government-owned. The China Great Wall Industry Corporation (CGWIC) "*is the sole company authorized by the government to provide commercial satellite launch services and space technology to international clients*".[119] Furthermore, CGWIC is part of the China Aerospace Science and Technology Corporation (CASC), a large-scale conglomerate of more than 130 companies, representing the main contractors of China's space programme.[120]

In recent years, Chinese space activities have tried to progressively open up to international trade. Nevertheless, a number of important factors strongly impact China's presence in the international launchers market, chief among those being foreign policies of export control as well as a closely intertwined military and civil space programme, despite recent attempts to decouple the two.

A key issue is that China does not adhere to the Missile Technology Control Regime (MTCR), and since 1999 it has been targeted by a ban on licenses to launch U.S.-components by Chinese launchers. Indeed, current U.S. export control restrictions (prominent among which are the ITAR regulations, see Box 2) forbid any U.S. satellite parts from being exported to China. As a consequence, China is excluded from competing in the international launch services market for any major Western communication satellite, whereas Chinese launchers can still be commercialized for those few foreign satellites that are independently built, which do not include U.S. components restricted by ITAR.

As a workaround, China has developed an original strategy by offering on the international market comprehensive packages that include the launch of a Chinese-built satellite on a Chinese launcher. Different packages are offered, such as Long March 3 for GEO satellites and Long March 2 for small remote sensing satellites, but also a payload piggyback option is available. This approach targets those countries in which China has a particular strategic interest, for example oil exporters, as well as African nations and neighbouring countries, in exchange for their natural resources and raw materials. Within the framework of the "Asia-Pacific Space Cooperation Organization" (APSCO) programmes, China's *primus inter pares* position has enabled it to increase the demand for launching satellites using its Long March rockets.[121] Such a strategy fits within the broader effort of China to use space to emerge as an alternative to the United States, and claim political leadership of developing countries, in both Africa and Asia.

Current Status

China's comprehensive range of launch vehicles is successfully exploited to satisfy important domestic demand and fulfil all China's current needs, granting the country access to all orbits, to crewed and cargo launches for LEO, and to exploration missions beyond Earth orbit,

Current plans to increase the performance of the vehicles envisage a new consolidated family of Long March launchers that will also exploit modularity to maximise economies of scale in production, as well as using less toxic fuel, thus reducing environmental concerns.

Regarding launch sites, China has three fully government-owned spaceports, while a fourth is being constructed. The new Wenchang Satellite Launch Centre will provide a number of key advantages such as being the country's southernmost launching site, allowing for a substantial increase in payload mass as required by the future space exploration programmes; and its location on the South China Sea will reduce concerns about eastward launches, as their trajectory will not pass over densely populated areas.

The Chinese space sector is one of the most heavily affected by U.S. export control restrictions. The impact of such measures, and the often-difficult China-U.S. relations, has been double-fold. At first, they undoubtedly benefitted non-Chinese vehicles, preventing Long March rockets from playing a greater role in the worldwide commercial launchers market despite their good reliability and cheap prices. At the same time though, they forced the Chinese launcher sector to remain self-reliant and essentially independent from foreign actors and factors, thus largely in control of its manufacturing costs and not subjected to currency fluctuations.

[118] Ibid.
[119] Cit. "Company Profile". China Great Wall Industry Corporation. Web. http://www.cgwic.com.cn/about/index.html. Accessed 16 December 2015.
[120] For a detailed overview of Chinese space industrial governance, see: Aliberti, Marco. "When China goes to the Moon…": p. 15-23. SpringerWienNewYork. 2015.
[121] See Aliberti, Marco. "When China Goes to the Moon…". p. 244 and references therein. SpringerWienNewYork. 2015.

In addition to independence from foreign variables, other factors such as traditionally low labour costs as well as a fully subsidized industry with high production rates theoretically allowed Chinese launchers to be priced on the market significantly lower than its international competitors. While prices for the launch packages offered by China have shown a tendency to increase in recent years, it must be kept in mind that the commercialisation of the launchers remains driven by a political agenda, offering in-orbit capacity in exchange for access to resources or improved relations where there is a strategic interest. Therefore, the price factor could be put in the background (eventually through additional subsidies) when compared to the greater geopolitical and strategic benefits of this programme for China.

Outlook

With its ambitious plans for a new Long March rocket family, new and improved launch infrastructure, and an ever increasing budget and workforce dedicated to its space programme, there is no doubt that China will continue to expand the scale and scope of its space activities in the coming decade.

Against this background, China could indeed look at the opportunity to increase substantially its role in the worldwide commercial launch market during the course of the next decade, by further pursuing and expanding its comprehensive launcher strategic programme package and by offering competitive launch solutions to global satellite manufacturers.

Nevertheless, the ability to engage with the worldwide launcher market is severely constrained by geopolitical factors, first and foremost its relations with the U.S. and the latter's policies in technology and export control, and it is not obvious that this will change anytime soon.

3.4 Japan

Policy

Japan's space transportation policy, and more generally the historical evolution of its space programme, has been strongly influenced and shaped by the nation's situation following the end of the Second World War, with a prominent role played by the United States until a few decades ago.

A peculiarity of Japan's historic space programme resides in the fact that the Japanese Diet explicitly excluded such uses with a Resolution passed in 1969, ruling out space use not only for offensive purposes but also for military defensive functions, such as surveillance and communications.

During the same year, following the successful completion of its LEO vehicle programme, Japan sought to achieve full access to space beyond LEO by signing a technology transfer agreement with the U.S., thus enabling import of Thor-Delta launch vehicle technology and ultimately achieving GTO access capabilities in 1981 with the N-II vehicle. A review of this technology transfer programme in 1975 led the U.S. to recognize the emergence of Japan as a potential "*very able competitor*" in the space market, therefore subjecting further transfers in launchers technology beyond the Thor-Delta level to export control rules and regulations. Consequently, Japan started to consider the development of autonomous capabilities in accessing outer space through Japanese-only technology, initiating the development of the H-II launch vehicle in 1984.

Even with the decision to pursue the development of its own launch vehicles, another example of the historically strong dependence of Japan on the U.S. with respect to space activities is the 1990 U.S./Japan Satellite Procurement Agreement, which essentially obliged Japan to open up the procurement market for governmental satellites (excluding R&D) to competitive bidding.

In response to the changed geopolitical environment of the past two decades, both worldwide and particularly in East Asia, Japan's space policy has evolved accordingly, with a gradual abandonment of the strict "peaceful purposes" interpretation of space activities, towards a more general concept of "non-aggressiveness". This change was first recognised in the 2008 "Basic Space Law", enabling applications for military purposes and at the same time promoting commercialisation. Consequently, the security dimension of space gained increasingly greater importance in the following "Basic Plans for Space Policy" released in 2009, 2013 and 2015.[122] It is only during the last year that Japan, for the first time, has made an explicit link between its space capabilities and its armed forces, with specific reference to China's in-space activities.[123]

[122] Presentation at UNCOPUOS Legal Subcommittee. "Current status of Japan's Space Policy and development of legal frameworks". Vienna, 16 April 2015. Web. http://www.unoosa.org/pdf/pres/lsc2015/tech-03.pdf. Accessed 2 December 2015.

[123] Kallender-Umezu, Paul. "Japan Begins National Security Space Build-up". Defense News. Web. http://www.defensenews.com/story/defense/air-space/space/2015/04/12/japan-national-security-space-buildup/25412641/. Accessed 14 December 2015.

Current Status

Currently, Japan has an established capability to reach all orbits through a comprehensive fleet of vehicles. Its small launcher Epsilon can place a 700 Kg payload into LEO, H-IIA has a performance of 10,000 Kg to LEO and 6,000 Kg to GTO, and H-IIB regularly transports cargo to ISS through the HTV vehicle.

This fleet successfully satisfies the needs for Japanese institutional missions, which between 2007 and 2014 have all been launched by Japanese launchers, with the exception of a few LEO missions. Nevertheless, Japan's presence on the commercial launcher market is still very limited, despite government subsidies as well as a favourable exchange rate for the yen. Commercial Japanese satellites are in fact mostly launched by foreign vehicles, as the H-II's are too highly priced to be competitive. MHI achieved the first commercial launch contract only in late 2013, but it was not until November 2015 that an upgraded version of H-IIA secured the first dedicated commercial mission, launching a Canadian-owned Telstar satellite. As stated by MHI, its launch costs are slowly being reduced as the company assumes more and more control over the rockets' operations, with the goal being to continue to serve Japan's institutional sector and additionally accommodate two or three H-IIA commercial missions per year.[124]

In terms of future developments, the 2015 Basic Space Plan envisages continued development and exploitation of Japan's space transportation systems. In particular, the small launcher Epsilon is being upgraded (Epsilon phase 2) to further reduce launch costs, and reach a performance of 1,500 to 1,800 Kg to LEO by 2017,[125] thus expanding Japan's access to LEO and competing directly with other similar-class small launchers such as Vega.

The development of H-III, started in 2013, will continue over the next five years, ultimately providing a family of modular launchers by 2020/2021 with a performance of 2,800 to 6,500 Kg to GTO, at lower costs than the current H-II, with additional plans to further study synergies between Epsilon and H-III. To achieve anticipated cost reductions, a gradual shift of responsibility from government to industry will continue.

It is worth noting that these developments in the Japanese launcher sector mirror to a certain extent those currently being undertaken in Europe. In this sense, a double convergence between Europe and Japan can be observed: in the first instance, the new European launchers' industrial setup is getting closer to the Japanese model in which JAXA is passing responsibility for the development and exploitation of launch vehicles to Mitsubishi Heavy Industries. At the same time, the setup and configuration of future Japanese launch vehicles resemble closely the development of Ariane 6 and Vega-C, both in terms of performance and timeframe of availability on the market.[126]

Cooperation in launch services between Europe and Japan dates back to the late 1990s, started through commonality studies between Ariane 5 and H-II A/B that ultimately coalesced into a commercial launch backup agreement between Arianespace and MHI, signed in 2004. This agreement allows a European commercial satellite scheduled to be launched by Arianespace to be launched on a Japanese rocket in the case of technical problems, and vice versa.[127] Both launch providers advocate a similar backup agreement for the launch of institutional satellites but this would require a bilateral agreement[128] and might not be possible until the next generation of respective launch vehicles enters service.

Outlook

Recent developments in Japanese Space Policy must be seen in the context of Japan's increased geopolitical awareness in the global and regional context.

Proposing itself as an equal partner to the U.S., and perceiving China's space activities as a threat, Japan is looking for partnerships and alliances, with the new intent of using its space activities as a means to serve its politi-

[124] De Selding, Peter. "Japan's H-IIA Launches Telstar 12 Vantage in Commercial Debut". Space News. 24 November 2015. Web. http://spacenews.com/japans- H-IIA-launches-telstar-12-vantage-in-commercial-debut/. Accessed 2 December 2015.

[125] Kallender-Umezu, Paul. "Japan to Take Incremental Approach for New Epsilon Launcher". Space News. 11 April 2011. Web. http://spacenews.com/japan-take-incremental-approach-new-epsilon-launcher/. Accessed 11 December 2015.

[126] For an overview and comparison on the existing EU-JP space cooperation activities, see La Regina, Veronica. "Space sector. EU-Japan Business and Technology Cooperation Potential". Tokyo, 2015. Web. http://www.eu-japan.eu/sites/eu-japan.eu/files/reports/MINERVA/space_sector_EU-Japan_cooperation_presentation.pdf. Accessed 14 December 2015.

[127] Arianespace - EU-Japan Business Round Table 27-28 April 2015. Web. http://www.arianespace.com/news-on-the-move/2015/4-28-2015-EU-Japan.asp. Accessed 2 December 2015.

[128] Claudon, Jean-Louis. "Cooperation in Launch Services". Arianespace. 08 October 2014. Web. http://www.eu-japan.eu/sites/eu-japan.eu/files/10.2-3-Claudon.pdf. Accessed 2 December 2015.

cal and diplomatic goals across the Asia-Pacific region.[129] With full emancipation and independence from a decades-long U.S. influence, Japan has the potential to position itself in the next decade as a modern and even more mature space power.

Japan in fact envisages a 50% increase in satellite institutional domestic demand during the period 2015-2024 compared to the previous decade, with QZSS (Quasi-Zenith Satellite System) navigation satellites and IGS (Information Gathering Satellites) Earth Observation satellites experiencing the biggest growth, thereby greatly expanding *inter alia* national remote sensing capabilities. National institutional satellites would add up to 39, excluding HTV launches to the ISS. However, since the domestic rate of launches per year will still be limited, this could possibly push Japan to explore an increased presence on the worldwide commercial market, as already indicated by the plans of MHI for the upgraded H-IIA.

How and whether it will be successful in achieving commercial success in the long term will undoubtedly be determined by the competitiveness of the H-III launcher, and this requires that the measures put in place to reduce development costs – such as the ongoing industrial reorganization and streamlining – will be effective.

3.5 India

Policy

Since its beginnings, India's national space programme has been characterized by a strong civilian focus, rather than being driven by military interests as it has historically been the case of other space-faring nations – with the exception of Japan. The national priority in space infrastructure and applications has been chiefly Earth observation and telecommunications, given the vastness of the country and its susceptibility to natural disasters

Benefitting from early technology transfers in the 1970s, such as the European Viking engine, and later the Russian upper stage for the GSLV Mk I, India achieved access to LEO in 1980 with the PSLV launch vehicle, and to GTO with medium-sized payloads in the early 1990s with the GSLV Mk II. India has progressively developed indigenous industrial capabilities assimilating such technologies, leading to the now-autonomous development of a fully Indian-made upper stage for GSLV Mk II (also called GSLV).[130]

One of the primary objectives of the Indian space programme for the 2010-2020 decade is to complete its range of launch vehicles to avoid relying on foreign launchers for its national payloads, particularly the multi-purpose INSAT communication satellites series. In fact, the lack of a heavy-lift vehicle able to place large Indian telecommunication satellites in GEO orbit makes the completion of its launcher fleet a crucial priority.

India has also ambitions to expand its space activities to human spaceflight in the longer term. Albeit with a relatively small budget allocated so far, India has pursued the development and testing of re-entry and landing prototypes, and is aiming for a fully autonomous manned space vehicle to LEO by 2020.

Current Status

Following a positive sub-orbital test in 2014, and the first successful flight of the indigenous cryogenic stage in August 2015, the development of GSLV Mk-III, a highly prioritised 4 tonnes-class GTO launcher, is now scheduled for completion in 2017.

India's presence on the worldwide commercial launcher market has been very limited so far, mainly due to the decision to size its launcher vehicles production to satisfy just the needs of its domestic demand, and the lack of a heavy-lift vehicle for large GEO telecommunications satellites. Nevertheless, its PSLV launcher achieved noticeable success in launching small satellites, often piggybacked on domestic LEO payloads. This was the case for example for several European satellites such as DLR-TUBSAT, Agile and Proba. It is noteworthy that ISRO stated its interest in privatizing the small launcher PSLV within a four-year timeframe, handling integration and launch of the rocket to an industrial consortium of the Antrix Corporation.[131] Such privatization would enable increasing the rate of launches from 12 to 18.[132]

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[129] Japan recently started providing official development assistance (ODA) to developing countries, in order to support their procurement of satellites of space services. See Aliberti, Marco. "When China Goes to the Moon…": p. 208. SpringerWienNewYork. 2015. See also: "Signing of Japanese ODA Loan with the Socialist Republic of Vietnam". Japan International Cooperation Agency. Web. http://www.jica.go.jp/english/news/press/2011/111102.html . Accessed 2 December 2015.

[130] Indian Space Research Organization (ISRO). Launchers – Overview. Web http://isro.gov.in/launchers. Accessed 2 December 2015.

[131] Laxman, Srinivas. "Plan to largely privatize PSLV operations by 2020: ISRO chief". The Times of India. 15 February 2016. Web. http://timesofindia.indiatimes.com/india/Plan-to-largely-privatize-PSLV-operations-by-2020-Isro-chief/articleshow/50990145.cms. Accessed 22 February 2016.

[132] Ibid.

Outlook

With more than one-third of its overall space budget devoted to the development of launch vehicles, it is expected that once the GSLV Mk-III is ready for deployment in mid-2017, India will pursue the development of other elements of its space programme, such as human spaceflight, but also further develop cryogenic technology to improve GSVL Mk-III performance, as well as possibly developing a fully-reusable two-stage-to-orbit launcher.

Having developed a complete family of launchers able to satisfy domestic demand, at the beginning of the 2020s India could then look to substantially increase its share of the worldwide launchers market by offering increasingly viable launch solutions, accompanied by moderately cheap prices.

3.6 Other Nations

3.6.1 Argentina

Argentina started developing sounding rockets (Canopus and Rigel) in the 1960s, and initiated a multi-national missile programme named Condor I and II in the 1970s, which was ultimately terminated in 1993. Since then, the focus of the Argentinian National Space Programme, which is planned and executed by the national space agency, CONAE, has been put on peaceful use of space science and technology, to satisfy the country's needs mostly in terms of Earth and maritime observation.

Noting the high dependence on third parties for access to space, and increasingly recognizing the need for an autonomous capability, in the 2004-2015 Space Programme CONAE has been pursuing the development of technology in propulsion, engines, navigation, guidance and control, with the ultimate goal of developing a launch vehicle dedicated to light domestic payloads for Earth Observation.

The current status of launch vehicles, developed by CONAE and the state-owned company VENG S.A., is at a technological demonstrator level (VEx 1 tested in 2014, VEx 5 launches initially scheduled for 2015), with plans to build up technological know-how in order to reach a performance of 250 Kg to LEO with the development of the Tronador II vehicle,[133] and an improved performance of 1,000 Kg to LEO with Tronador III. The level of funding of launcher programmes, while very low during the 2003-2012 decade, increased considerably in 2013, leading to a more concrete possibility for Argentina to achieve independent access to LEO in the foreseeable future, thus meeting its domestic needs.

[133] Tronador I was flown once in 2007, as the first flight of the technology demonstrator programme.

3.6.2 Brazil

To achieve access to space, Brazil has been pursuing three different and parallel approaches: the development of an autonomous vehicle, a joint international development of a GTO launch service from Brazil, and negotiations to launch foreign vehicles from Brazilian territory, so as to exploit and maximise its favourable geographical position around the Equator.

Following the results achieved by its military sounding rocket programme in the 1970s, further development of domestic launcher vehicles was shifted to civilian entities. The 2013 policy on space activities recognizes the need for "*more launches and more launchers*", thus "*achieving the capacity to launch from Brazilian territory*" with a capacity to "*meet both domestic and foreign demand".* Brazil has long been developing its Veículo Lançador de Satélites (VLS) a programme that suffered a major setback with the 2003 accident that led to the death of 21 key personnel of the programme and halted any further launcher development. While development was taken up again in the late 2000s, the 250 Kg-to-LEO payload capacity of the fourth VLS-1 vehicle, scheduled for a test flight in 2016, is already judged to be insufficient to cope with Brazil's needs.

The "Cruzeiro do Sul" programme, initiated in 2005, aims to give Brazil independent and autonomous access to space by 2022, with the development of a family of 5 launch vehicles initially based on the VLS design, of which two are currently being developed. The first one, VLS-Alpha, is directly based on the lower part of VLS-1 and aims to reach a performance of 500 Kg to LEO in 2018. VLS-Beta is an evolution of VLS-1, possibly employing Russian technology such as liquid upper stage engines, with a projected performance of 800 Kg to LEO by 2020.

In addition and in parallel with domestic launcher development, Brazil has pursued the road of an international cooperation agreement with Ukraine. Following initial talks started between the two countries in 2002, a bi-national Ukrainian-Brazilian joint venture company, Alcântara Cyclone Space, was formed in 2006, for the development and operation of the launch complex Alcântara Launch Center in Brazil, and to launch the Ukrainian-made Cyclone 4 vehicle. Nevertheless, several factors have caused important setbacks that now jeopardize the completion of the programme. The infrastructure construction works on the Alcântara site were suspended in 2008 following environmental and social concerns regarding the impact on the surrounding population. Construction activities were then restarted but halted again in 2013; in early 2015, reportedly only 48% of the dedicated launch site for Cyclone 4 was complete. At the same time, the vehicle manufacturing process encountered several delays in Ukraine, starting with the need to obtain a Russian-Ukrainian Technology Transfer agreement, which was signed only in 2009. Furthermore, the international context also strongly affected the Alcantara-Cyclone programme, with the Crimean crisis worsening relations between Ukraine and Russia and reportedly leading to pressure from the U.S. to not use the Cyclone vehicle. With the commercial viability of Cyclone 4 now questioned due to the long delays and the changed international market, and the lack of the necessary export control agreement with the U.S., it has been reported that the Brazilian Presidency is now preparing to terminate the strategic partnership with Ukraine - with the hope also of improving relations with Russia in the context of the VLS-Beta development.

With the objective of exploiting its favourable geographical position for orbital launches, Brazil also started negotiations with Israel on the launch of the Shavit vehicle from the Alcantara launch site. This initiative was, however, impaired by the 2008 court order that halted the expansion works of the launch site on the grounds of environmental and social concerns for the local population. However, in mid-2015, the Brazilian government was reportedly conducting talks both with the U.S. and the Russian governments, with the objective of further opening the Alcantara launch site to foreign launchers.[134]

Four factors impact negatively on the current status of the Brazilian space transportation sector: a low budget, that has been so far allocated mostly to the Alcantara-Cyclone programme; a lack of investment from private firms; no guaranteed institutional satellites market; and moderate ambitions in the overall space programme.

However, the cancellation of the Cyclone 4 project could free up important funding that could be devoted to developing a domestic capability. At the same time, the very favourable position of Brazil's territory for launches and low labour costs are positive factors that could lead to a significant advantage in the commercial market, particularly should a domestic vehicle eventually be developed.

3.6.3 Iran

Iran's space programme is mostly aimed at the development of small Earth Observation satellites, and the small launch vehicle technology to put them into orbit autonomously, within a paradigm of professed peaceful uses of outer space but responding to military and security needs. A more ambitious objective is the establishment of human spaceflight capability.

Space activities are supervised by two closely connected national entities: the Iranian Space Council (ISC) under the President of the Islamic Republic, and the Iranian Space Agency (ISA), under the Ministry of Communication and Information Technology, founded in 2005. Iranian space policy and its budget are currently framed in Five Year Plans, the latest of which covers the period 2011-2015.

Historically, the Iranian launcher programme relied on foreign technology transfers. Shabab ballistic missiles, which now constitute the core of its launch vehicles, were developed in collaboration with the Democratic People's Republic of Korea, in particular the Taepodong and No-Dong ballistic missiles programmes, as well as with Chinese technology from the Long March vehicles. Currently, Iran uses the Safir-1 launch vehicle to put small payloads into LEO, with 9 test launches carried out in the period up to 2014. A better performing vehicle, Simorq, was announced in 2010 and declared to be Iran's main launcher vehicle in 2013. It has three launches scheduled in 2016, with an estimated initial performance of 60 Kg to LEO with possible increases up to 700 Kg of payload. Other launchers reportedly being developed are Qoqnoos (Phoenix) and a solid-fuel launch vehicle called Ghaem, evolved from a 2-stage ICBM, which is scheduled for development during the upcoming Five Year Plan of 2016-2020.

Given the scarcity of information available, and the overlap between space launcher and military ICBM development, the Iranian launchers programme is hard to assess –

[134] Boadle, Anthony and Winter, Brian. "Exclusive: Russia, U.S. competing for space partnership with Brazil". Reuters. 15 June 2015. Web. http://uk.reuters.com/article/us-brazil-space-idUKKBN0OV22C20150615. Accessed 15 December 2015.

other than confirmed LEO access capability for very small payloads.[135]

3.6.4 Israel

The rationale of the Israeli space programme is the operational needs of its military forces, in the context of the ongoing conflicts in the Middle-Eastern region, and to ensure non-dependence on foreign capabilities. In particular, the need to place into orbit small reconnaissance satellites (Ofeq series) led to the development of the Shavit launch vehicles, based on the Jericho 2 ICBM technology, itself originally derived from the French Dassault MD-620.

The Israeli space sector has thus been wholly characterized by military purposes since its inception in 1981, followed shortly thereafter by the foundation of the Israeli Space Agency (ISA) in 1983. In 2013, within the framework of a new space policy, the two-year budget for ISA was significantly increased (approximately from € 2 to 38 million), with the aim of creating a civil space programme and boosting the competitiveness of Israel's space industry. The initiative was reportedly successful, achieving in 2014 its goal to catch a $ 1 billion share of the worldwide space market well before the target of 5 years. It must be noted that while national space policy is defined by ISA, a civilian authority, Israel's space launch capability and development are still driven by the military.

Having reached autonomous capability to reach LEO with small satellites (approx. 400 Kg to 700 Km), and with infrequent national payloads launches (on average one every 3 to 4 years), Israel has also sought to commercialize Shavit on international markets. Since its main launch site, Palmachim Air Force base, is reserved for national institutional missions only, and prograde orbits are not allowed due to concerns regarding the trajectory of the launch vehicle over densely populated areas and critical territories, Israel has explored the possibility of launching Shavit from foreign launch spaceports, such as Cape Canaveral in the U.S. or Alcantara in Brazil. Nevertheless, those initiatives have not been pursued to their end, *inter alia* because Israel considers the Shavit launchers to be a national strategic asset.

With Shavit-2 meeting Israel's national launch requirements, and commercialization having to rely on foreign launch sites, with all the political implications that such cooperation entails, international exploitation cannot be expected to be pursued at a significant level in the coming years.

3.6.5 North Korea

The Democratic People's Republic of Korea space programme was initiated in the 1980s, with the foundation of the Korean Committee of Space Technology (KCST), a state-owned agency responsible for the development and operation of the country's space activities. Following the signature of the Outer Space Treaty and the Registration Convention in 2009, the Supreme People's Assembly adopted the Law on Space Development in 2013, creating the National Aerospace Development Administration (NADA). With very little information publically available, the country's overall space programme is still unclear, due to the fact that its launchers programme heavily overlaps with missile and ICBM development. Officially, however, the focus is on developing Earth Observation systems.

Having acquired Soviet SCUD missile technology in the 1960s, in 1998 North Korea launched its first space vehicle, Taepodong-1, heavily based on ICBM-level missile technology. This first, unsuccessful, launch was followed after a decade by two launches of the Taepodong-2 vehicle in 2009 and 2012, which both failed to place into orbit their experimental Earth Observation payloads. In 2012, North Korea ultimately succeeded in launching a small, 100 Kg payload into LEO with the Taepodong-2 (or Unha-3) vehicle. While the performance of Uhna-3 seems to be very limited, in 2012 North Korea presented plans for of a more capable Uhna-9 vehicle, possibly being developed since 2006. A few days after its controversial fourth nuclear test, in February 2016 North Korea announced the successful launch of a small satellite, Kwangmyongsong-4, using its Unha-type rocket.[136] It is, however, manifest that these activities are mainly intended to support Pyongyang's *brinkmanship* strategy vis-à-vis the international community.

Further development of the North Korean launcher programme is expected to continue at an unpredictable pace, considering that the current launcher expertise level is still strongly based on old Russian missile technology, the difficult economic conditions of the country, and the isolation and sanctions imposed by the international community,

[135] See for example: Clark, Stephen. "Iranian satellite successfully placed into orbit". Spaceflight Now. 2 February 2015. Web. http://spaceflightnow.com/2015/02/02/iranian-satellite-successfully-placed-in-orbit/. Accessed 16 April 2015.

[136] Karako, Thomas. "North Korea's February 2016 Satellite Launch". Center for Strategic and International Studies. Web. https://csis.org/publication/north-koreas-february-2016-satellite-launch-0. Accessed 22 February 2015.

with the notable exception of its cooperation with Iran.

3.6.6 South Korea

South Korea's space programme aims primarily at developing autonomous expertise in space technology, particularly domestic launch vehicles, Earth Observation and meteorology. In this context, South Korea seeks recognition as a space power both at regional and global levels, with an expansion strategy that foresees a continuous increase both in funding and manpower for the space sector.

Since 2005, South Korea's government has established and updated a National Space Plan every five years. It is currently implementing its 2nd Space Development Promotion Basic Plan, approved in 2011 and covering the 2012-2016 period. To reach the established objectives, the Korea Aerospace Research Institute (KARI), which is in charge of the civilian space programme, has established a 20-year, long-term approach, further broken down into two segments, with 2010 and 2020 milestones.

In the launchers sector, South Korea has pursued the development of the KSLV-1 (Korea Space Launch Vehicle, also known as Naro-1) small launch vehicle in cooperation with Russia, building upon know-how and domestic capabilities initially developed through the Korea's Sounding Rocket Programme (KSR).

The bilateral agreement between KARI and Khrunichev signed in 2004 provided for joint development of KSLV-1 in which Russia supplied the first stage, which has commonalities with the Angara first stage, while the second stage was based on Korean technology derived from the KSR. After two launch failures in 2009 and 2010, KSLV-1, with an initial performance of just 100 Kg to LEO, achieved success in its third launch in 2013. The successful launch of KSLV-1 allowed KARI to complete its first milestone of the plan, which included also acquiring autonomous capabilities in Earth Observation and multipurpose systems (achieved with three KOMPSAT and COMS-1 satellites), and the development of key infrastructures including launch facilities and an associated ground segment (Naro Space Center).

In accordance with the goals outlined in its "Vision 2020" plan, such as "*independent development of space launch vehicle with high reliability and high efficiency*", in 2011 South Korea started developing an upgraded, fully-Korean made LEO vehicle named KSLV-2.[137] With a payload performance of 1,500 Kg, it would allow Korea to autonomously launch its KOMPSAT-class satellites. Following a feasibility review of space development projects, triggered by the two consecutive failures of KSLV-1, South Korea decided to push to achieve domestic space access instead of buying 10 Russian KSLV-1 first stages as initially planned. Subsequently, the development of KSLV-2 experienced a major acceleration at the end of 2013, with increased funding and the appointment of a South Korean industrial prime contractor. It aims at flight tests in 2017 and full capability in 2020. The Naro Space Center infrastructure will also be upgraded accordingly by the end of the decade.

The long-term vision for access to space also foresees an evolved launch vehicle in 2030 (3,000 Kg to GTO) and a heavy-lift vehicle in 2040. Considering the continuous budget and workforce increases, the success in fulfilling previous National Vision objectives, good economic stability and a strong business drive in the country, South Korea is expected to enter the commercial launchers market at some point, although the timing of such an event and the competitiveness of its launchers remain difficult to estimate at this stage.

3.6.7 Ukraine

Until 25 years ago, the Ukrainian space sector was an integral part of the former Soviet Union's space programme. As such, it was not designed to be self-reliant but instead focused on developing and manufacturing ICBMs and launch vehicles, according to the general paradigm of decentralization and regional specialization that characterized USSR industry of the time. On the dissolution of the Soviet Union around one-third of the whole USSR space industrial base resided in Ukrainian territory, but the country notably lacked the satellite manufacturing sector, as well as launch infrastructures.

Since the late 1990s, international cooperation has been a key element for the development of the Ukrainian space sector and its overall space policy. Cooperation agreements were signed in 1998 between Ukraine and Russia, and later with Kazakhstan for the use and development of Baikonur launch pads. Examples of international joint ventures suc-

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[137] "Next Phase of Korea Space Launch Vehicle II, Implementation of Korean Model of Space Launch Vehicle II Development System". Korea Aerospace Research Institute Press Release. 12 July 2015. Web. http://www.kari.re.kr/cop/bbs/BBSMSTR_000000000031/selectBoardArticle.do?nttId=1205&pageIndex=1&mno=sitemap_02&searchCnd=&searchWrd= . Accessed 2 December 2015.

cessfully pursued by Ukraine to commercially exploit its launch technology and vehicles are ISC Kosmotras, Sea Launch, SIS, the Cyclone-Alcantara programme with Brazil, the provision of the AVUM upper stage motor for Vega and the first stage for Orbital Sciences' Antares.

Ukraine's space policy is defined by the National Space Programme, usually established for five-year periods, and developed by the National Space Agency of Ukraine (NSAU) (State Space Agency of Ukraine since 2010). A long-term national space policy plan for the period until 2032 was approved by SSAU in March 2011, this plan aiming to achieve the long-term goals through four implementation phases. The policy foresees development within the frame of international cooperation; development of launch vehicles and subsystems, in particular rocket engines; extension of Ukrainian presence in the commercial launch services market by virtue of its large array of vehicles (Zenit-2SLB, Zenit-3SLB, Zenit-3SL, Dnepr, Cyclone 4, Mayak and Air Launch).

The current status of Ukrainian space activities, and of the launcher sector in particular, is heavily affected by the 2014 Crimean crisis, and ongoing acute political tensions with Russia. The crisis led to the decision of the Ukrainian leadership to discontinue all cooperation ties in the defence sector between the two countries, and as a consequence both the Zenit and Dnepr programmes have been suspended, as well as other key activities in the delivery of space control systems and raw materials to Russia. These measures were followed by the decision of Roscosmos to exclude all Ukrainian vehicles from the Russian Federal Space Programme. The gap that now separates two countries that were successfully and closely cooperating until a few years ago is increasingly widening.

3.7 Policies and Politics of Access to Space: an Overview

This chapter has so far provided a vertical overview of the space transportation sector in established and emerging space launch powers. When comparing their policies and ongoing development efforts from an overall, transversal perspective, a number of general trends can be outlined.

3.7.1 Autonomy, Commercialisation and Privatisation of Access to Space

In all countries with autonomous access to space, the development of launch systems has been at least initially driven and funded by "governments, not companies, for fundamentally national rather than commercial reasons (i.e. assured access to space capabilities, avoiding reliance on foreign nations for space transportation needs, driving economic growth and technological progress, and national pride)".[138] Traditionally, autonomous access to space has been achieved either through indigenous development during the Cold War (U.S., Russia, Europe), or through bilateral cooperation with another country so as to reduce development time and overcome issues of non-proliferation restrictions (Japan, South Korea, India). Given that the development of launch capabilities has historically derived from ICBMs, technology transfer issues have played a crucial role when a country is a participant in the Missile Technology Control Regime (MTCR) (See Table 8).

Russia has been at the forefront of leveraging its launch technology as a means of exercising influence. To illustrate, it has transferred entire plans of its Scud missile to DPR Korea; it has provided cryogenic engine technology to India, and an unspecified liquid upper stage to Brazil; it has designed South Korea's KSLV-1 first stage; and has marketed several engine technologies to the U.S.

Conversely, the U.S. has kept a rather hesitant profile with respect to bilateral cooperation in launcher technology, though the underlying objective is the same as Russia's: advance – and defend – national interests. Apart from the transfer of Delta technology to Japan in the early 1970s, the U.S. has generally tried to prevent the dissemination of sensitive launcher technology, by *inter alia* adopting a stringent regime of export control regulations. In addition to that, it is of interest to note that the US has also exerted political pressure to prevent the development of launch capabilities in several countries. For instance, Argentina, South Africa and Brazil have been deterred in their efforts to develop autonomous launch capabilities on the basis of MTCR adherence considerations and the potential use of technology for obtaining ICBM capacity that could threaten U.S. interests.

[138] Cit. Berteau, David and Gregory Kiley (project directors). "National Security and the Commercial Space Sector. An Analysis and Evaluation of Options for Improving Commercial Access to Space". Washington: Center for Strategic and International Studies, July 2010.

Like the U.S., Europe has also been rather inactive when it comes to technology transfers. The most relevant exception is the transfer of Ariane's Viking 2 and Viking 4 engine technology to India, approved by France in the late 1970s. Once indigenized, these technologies have been used to support the development the PLSV and GSLV launchers. The utilization of launch technology as a tool of European S&T based diplomacy, however, has never been really explored to its full potential, primarily due to the rather complex intergovernmental approach so far pursued by European countries to implement their launcher strategy, as well as to the often diverging strategic views of ESA Member States and a degree of deference to the US.

Country of origin	Component / Motor	Country of destination	Launcher
USA	Thor/Delta	Japan	N1 and H1
France	Viking2 and 4	India	PLSV - GSLV
Russia	RD-180	US	Atlas V
Russia	RD-181	US	Antares
Russia	C-12	India	GSLV Mk-I
Russia	Angara technology	South Korea	KSLV-I
Russia	RD-251/2	Ukraine	Cyclone
Ukraine	RD-869	Europe	Vega
China	LM plans	Iran	Safir

Table 8: Relevant worldwide launchers' technology transfers in the past decade. (Table not exhaustive)

Moving back to the general dynamics in the field, it can be noted that once launch capabilities have been established in a country, the commercialisation of the vehicle on the international market (i.e. the provision of launch services to customers that have not contributed to its development) has been generally pursued, so as to generate economies of scale and allow the amortization of fixed operational costs over a larger number of customers and create revenue. While commercialisation efforts have not been a priority for launch vehicles that have had access to a large national government market (e.g. the U.S.), in contexts such as Europe it has been key to ensure that the flight schedule remains full and, consequently, that the capacity of the launcher system is utilised to an extent that would be impossible to achieve if launches were exclusively institutional.

When pursued, the commercialisation of launchers has been generally accompanied by a privatisation of operations. Following the example of Arianespace, the major launch powers have opted to transfer the exploitation of their launchers to private or semi-private entities, as summarised in Table 9.

Country	Launcher	Funding entity	Operating entity
United States	Atlas, Delta Falcon Antares	DoD SpaceX * Orbital Sciences Corp. *	United Launch Alliance SpaceX Orbital Sciences Corp.
Europe	Ariane Vega	ESA / CNES / ASI	Arianespace
Russia	Proton Rockot Soyuz	Roscosmos Russian Space Forces	Khrunichev/ILS TsSKB Progress/Starsem
Russia / Ukraine	Dnepr Zenit-3SL Zenit-2&3 SLB	SSAU and Roscosmos Russian Space Forces	ISC Kosmotras Sea Launch, Land Launch
Japan	HII-A & B	JAXA	Mitsubishi Heavy Industries
China	Long March	People's Liberation Army	CGWIC
INDIA	PLSV GLSV	ISRO	Antrix

* Indirect funding provided through DoD/NASA.

Table 9: The privatization of launchers' operations.[139]

[139] Source: "Government Space Markets 2013". A Euroconsult report. 2013: p.180.

The progressive shift of responsibility from the institutional sector to the private one initially involved only the commercial exploitation of the launcher itself, but in recent years it has been expanded to include also development efforts, with such companies as SpaceX, MHI, and ASL becoming increasingly active. This trend, however, can so far be observed only in the U.S., Europe and Japan.

Notwithstanding this progressive shift of responsibility and increase of private funding, both the development and commercial exploitation of launchers continue to be politically and financially backed by interested governments through a variety of means, including laws, policies and practices, including procurement practices. The complex interaction and influence exercised by both market and non-market forces in the commercial launch industry will be detailed in Chapter 4 below. What is of interest to note here is that international cooperative undertakings have taken place over the years, responding to both commercial and political drivers.

Cooperative arrangements during exploitation have shown a varying degree of intensity, ranging from mere assistance in commercialization to launch hosting. The first international joint ventures were created in the mid-1990s with the aim of exploiting launch vehicles developed in the former USSR. Their creation proved to be a good compromise between divergent interests, as they allowed Western countries to maintain some control over new competitors in the launch market, while enabling the Russian and Ukrainian partners with insufficient national budgets to secure funding and acquire hands-on commercialization know-how. The four major Joint Ventures, namely International Launch Services (ILS), Eurockot Launch Services, Sea Launch and Starsem, were set up between 1995 and 1997. In addition to these, a joint venture within the former Soviet Union, the International Space Company (ISC) Kosmotras, was created in 1997 by Russian, Ukrainian and Kazakh entities in order to ensure continuity of launch operations.

Several international cooperation initiatives also covered development/exploitation of ground infrastructure. The utilization of launch sites on foreign territory has been of particular relevance for Russia, which has signed an agreement with Kazakhstan in order to ensure a long-term lease of the Baikonur Cosmodrome and its associated facilities until 2050 at an annual fee of $ 115 million. Particularly noteworthy is also the successful exploitation of Soyuz-ST from the GSC. As already highlighted in Chapter 2.1.2, this cooperative undertaking was of interest to both Europe and Russia, as it enabled the former to complement the performance of the ESA launchers Ariane and Vega, and the latter to benefit from improved access to commercial markets and the improved performance of the Soyuz launcher when being launched much closer to Equator. At that time, it was also in the interests of both Europe and Russia to boost their relationship, and cooperation in the launcher sector was seen as a tool for pursuing this objective. In 2003, the Alcantara Cyclone Space joint venture (ACS) was created between Brazil and Ukraine with the aim of providing an equatorial launch base for Cyclone 4. While recent hurdles of a financial and political nature are now hindering the advancement of the ACS project and more broad cooperative arrangements, the resolve to obtain access to a launch base close to the equator continues to be a driver for international cooperation, as evident from the negotiations that are continuing. As noted, Brazil and Israel are negotiating an agreement for the setting up of a mobile launch infrastructure for the launch of Shavit from Alcantara. In addition, there is an increasing number of countries that do not have indigenous launch capacities but are actively looking for launch service providers willing to operate their vehicles from a launch base in their territory, as is the case of South Africa and possibly the United Arab Emirates.

Finally, another relevant area of cooperation can be seen in the area of back-up agreements. In 2003 for instance, Arianespace, Mitsubishi Heavy Industries (MHI) and Boeing Launch Services signed a mutual backup agreement for commercial satellite launches. The agreement established the Launch Services Alliance (LSA) that involved the Ariane 5 launcher, the H-IIA launcher and Sea Launch. The backup agreement does not involve manufacturing. After the bankruptcy of Sea Launch, in 2006 Arianespace and MHI signed a new agreement that "combines the satellite launch offerings for Ariane 5 and the H-IIA and both companies can jointly propose launch services with the flexibility of launching a satellite on either of the two vehicles to guarantee launch dates for commercial satellites".[140] Although no backup mission has, as yet, taken place, this agreement has been viewed by both Europe and Japan as a useful model, from both a technical and political perspective.

3.7.2 Ongoing Developments

Beside the general dynamic presented in the previous section, a number of concomitant

[140] Robinson, Jana. "Europe-Japan Strategic Partnership: The Space Dimension". ESPI Report 40. Vienna. April 2012.

trends can be observed today. All major spacefaring nations are in the process of upgrading their flagship families of launchers and launch infrastructure, primarily driven by the need to reduce costs and increase commercial competitiveness, while strengthening national autonomy and expanding existing capabilities to accommodate more ambitious goals.

Following two decades in which international joint ventures were common and successful within the global launch industry (e.g. ILS, Sea Launch, Eurockot), the current trend is for spacefaring nations to strengthen and increase national autonomy in achieving access to space, without having to rely on factors such as foreign-made rocket engines or foreign spaceports that could hamper the realization of their own space programmes due to unfavourable geopolitical developments. This trend is being observed in the U.S., Europe and Russia. Additionally, the new spaceports being constructed in Russia and China will grant them more autonomy, as well as additional redundancy to respond to a potential need to increase launch frequency.

Moreover, the trend of using launch capabilities as a geopolitical tool is growing. Instead of proposing technology transfer agreements, several countries such as China and Japan are offering or trying to offer to countries of geopolitical interest turn-key packages composed of the launch of a rocket and satellite of own manufacture.

A second major trend characterizing all current development efforts is the imperative of achieving cost reduction. This follows decades in which launcher development was mostly driven by the goal of ensuring increased performance and reliability. Cost savings are being pursued through a variety of means, including the development of new modular families of launchers that maximise common expendable elements (in all major space launch powers); systematic reorganisation of industrial governance and streamlining manufacturing processes (mainly in Europe, Japan, Russia), the fostering of disruptive technological innovation (mainly in the U.S.); and breaking up past situations of monopoly (in the U.S.).

Upgraded or brand new launch vehicles from all major nations will enter service in the next ten years (see Table 10), while current launch systems will be progressively phased out. In addition, the club of nations with autonomous access to space could expand in the future with the entrance of Brazil and Argentina. As detailed below in Chapter 4, future supply conditions will possibly lead to a situation of overcapacity and increased competition among launch service providers.

After decades of complete reliance on government funding to develop launch vehicles, a new paradigm is gradually emerging in the launch industry of several countries. As mentioned above, in upcoming years private actors are positioned to become even bigger stakeholders in the development and exploitation of launch vehicles, principally in the U.S. but, to a lesser extent, also in Europe and Japan. In contrast, in countries such as Russia and China, the development and exploitation of launch vehicles are expected to remain firmly under the control of state-owned companies.

4. Current Dynamics and Future Trends

Building upon the analyses and findings of the previous chapters, this chapter will put the spotlight on the major features and dynamics shaping the global satellite launch industry. Starting with an overview of historical data and trends in space launch activities, the chapter will provide an analysis of the global launch market, with particular emphasis on the complex interaction between market and non-market forces.[141] The third part of the chapter will be devoted to thoroughly identifying and discussing key unfolding trends and developments that will likely affect the supply and demand conditions of access to space over the next ten years.

4.1 Launch Activity Outlook

During the first 30 years of the space age, orbital launch activity remained heavily concentrated in the pioneering space powers, the U.S.S.R. and the U.S. Even though some other countries started to perform their first launches quite early (France in 1965, Japan in 1970, China in 1970, the United Kingdom in 1971, India in 1980), their level of activity, even combined, remained well behind that of the two superpowers. As late as 1989, the U.S.S.R. and the U.S. still accounted for 90% of the total number of launches performed (87 out of 96 launches).

Diversification in the number of countries conducting orbital launches began to emerge in the 1990s and has progressively consolidated over the past 10 years. As shown in Table 10, there was a total of 777 launches conducted by launch providers from Russia, the U.S., Europe, China, Japan, India, Iran, the multinational company Sea Launch, Israel, South Korea and North Korea in this period.

Year	Russia	U.S.	Europe	China	Japan	India	Iran	Multi-national	Others	Total
2006	25	18	5	6	6	1	-	5	-	**66**
2007	26	19	6	10	2	3	-	1	2	**69**
2008	26	15	6	11	1	3	1	6	-	**69**
2009	29	24	7	6	3	2	1	5	1	**78**
2010	31	15	6	15	2	3	1	-	1	**74**
2011	31	18	7	19	3	3	1	2	-	**84**
2012	24	13	10	19	2	2	3	3	2	**78**
2013	32	19	7	15	3	3	-	1	1	**81**
2014	32	23	11	16	4	4	-	1	1	**92**
2015	26	20	11	19	4	5	1	-	-	**86**
Total	**282**	**184**	**76**	**136**	**30**	**29**	**8**	**24**	**8**	**777**

Table 10: Worldwide orbital launches between 2006 and 2015.[142]

In spite of a significant drop in launch activity since the early 1990s, Russia continued to be the world leader in the number of launches in the period 2006-2015. It performed 282 launches, accounting for 36.3% of the total. The U.S. followed in second position, with a 23.7% share, while China, with its 136 launches, had the third largest share, 17.5% of the total. Europe was in fourth position, accounting for 76 launches and a 9.8% share of the total number.

Taken together, these four launch powers undertook the 87.3% of all launches performed in the period 2006-2015. The remaining 12.7% was split between Japan (30 launches), India (29), Multinational Sea

[141] All data in Chapter 4.1 have been compiled using ESPI Space Policy, Issues and Trends database, and Federal Aviation Administration Annual Reports.

[142] Others: Israel (2 launches in 2007, 1 in 2014) South Korea (1 launch in 2009, 1 in 2010, 1 in 2013); North Korea (2 launches in 2012). Out of the 777 total launches during this decade, 720 successfully placed their payload in orbit.

Launch AG (24), Iran (8), South Korea (3), North Korea (2) and Israel (2).

Table 10 also provides useful indications on the trends in launch activity over the past 10 years. It shows in particular a progressive rebound of orbital launches, with the total number increasing from 66 launches in 2006 to 86 in 2015. Launch activity has now grown to regain the level of the early 1990s – when the overall number of launches was around 90 per year – though it is still far from reaching the peak of 1967 when 139 launches were performed.

The 777 launches performed in the period 2006-2015 put into orbit a total of 1688 spacecraft. Chart 3 shows that the number of spacecraft per year has substantially increased, going from 117 in 2006 to 265 in 2015, with a peak of 296 in 2014. The exponential increase in the number of payloads launched in the last few years is due to the advent of very small satellite platforms (less than 10 Kg), which allows a larger number of spacecraft per launch. Approximately, more than half of the spacecraft launched in 2013, 2014 and 2015 were very small satellites.

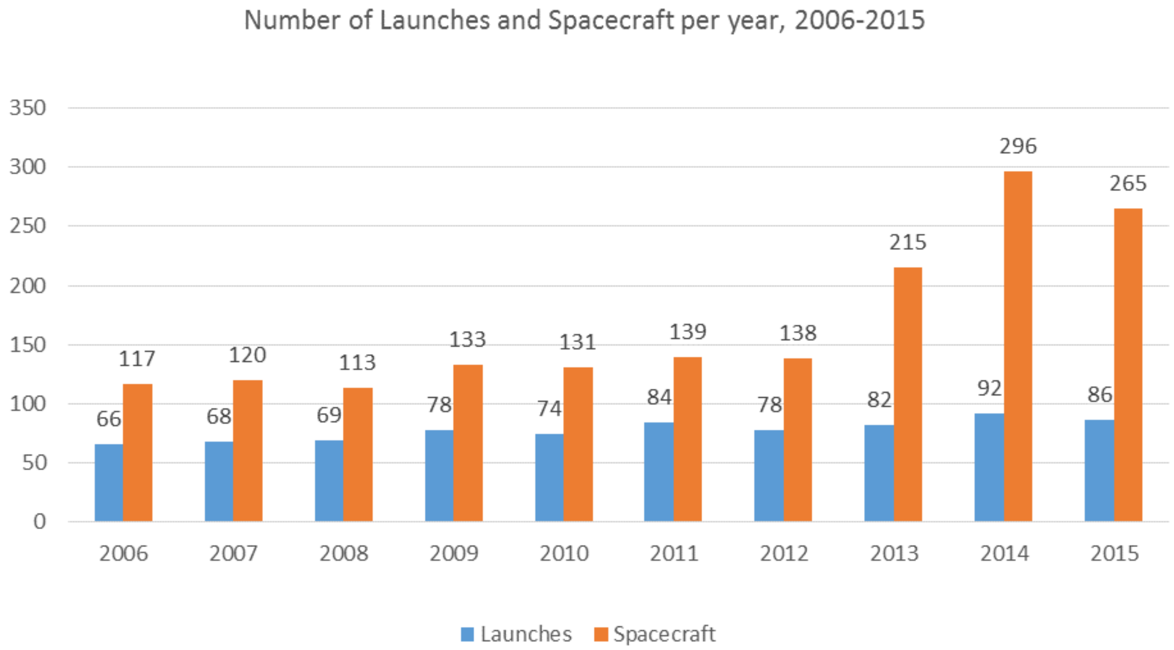


Chart 3: Number of launches vs. spacecraft, 2006 - 2015.

Commercial and Non-Commercial Launches

The vast majority of launches has been for institutional customers, whose demand continues to account for the largest part of the global launch market. Of the 777 launches conducted during the past 10 years, 552 were undertaken for institutional customers on a captive basis, while 225 were commercial launches. The Federal Aviation Administration (FAA) defines a commercial launch as "a launch that is internationally competed (including institutional ones), or privately-financed".[143]

Chart 4 shows that over the last 10 years the number of non-commercial launches per year has progressively increased from 45 in 2006 to 64 in 2015, while the number of commercial launches has fluctuated from a peak of 28 in 2008 to a trough of 18 in 2011.

On average, there have been 22 commercial launches per year against 55 non-commercial launches. The ratio of commercial to non-commercial launches thus remains highly imbalanced, commercial launches accounting for only the 29% of the global launch market.

Commercial Launches by Orbit

The biggest share of commercial launch services is the launching of GEO telecommunication satellites. Even though the total number of payloads launched into GTO is lower than the number of non-GTO payloads, in GEO the share of payloads accessible to launch providers through competition is larger than the non-accessible ones, as the demand is driven by commercial satellite operators like SES

[143] Cit. Federal Aviation Administration (FAA). "Commercial Space Transportation: 2014 Year In Review." Washington D.C. February 2015

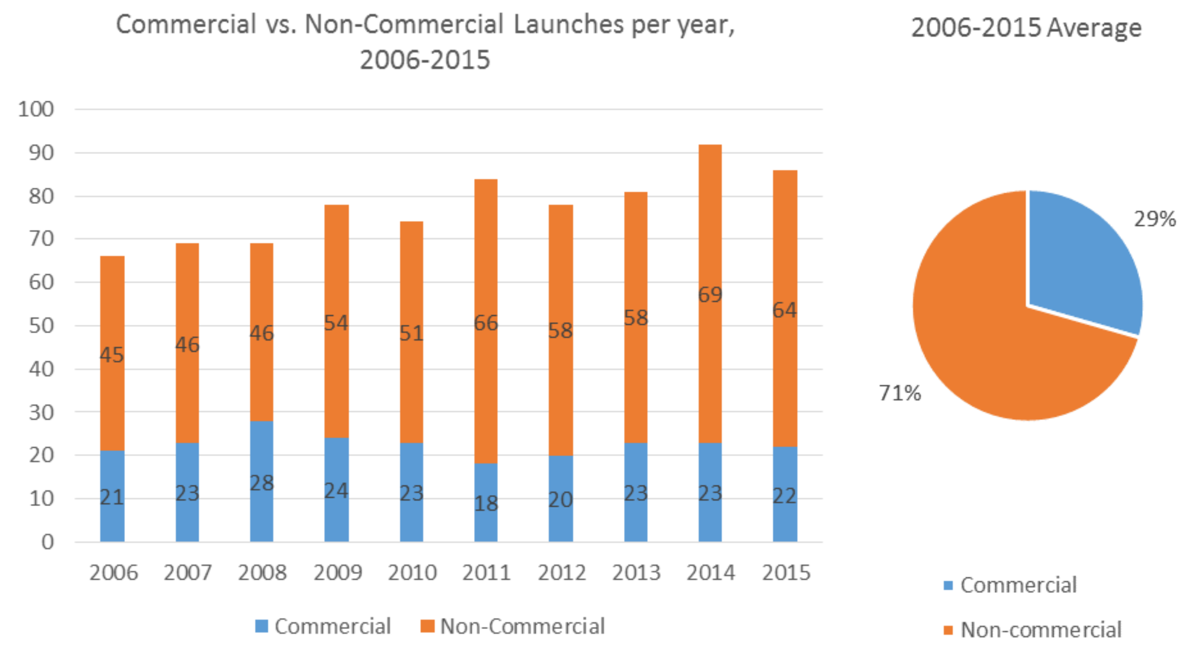


Chart 4: Commercial versus non-commercial launches, 2006 - 2015.

(10% of the total demand for GTO payloads over the past 10 years), Intelsat (8%), and Eutelsat (6%).

Conversely, the non-GTO launch market has been mainly driven by an institutional demand largely captive to domestic launch services. Over the last 10 years, the strongest demand has come from the government of Russia (32% of total demand), the U.S. (25%) and China (19%). Launches open to competition in this segment are generally driven by the demand of countries with no launch capacity.

Chart 5 shows a breakdown of commercial launches by orbit type for the last 10 years.

Out of a total of 225 commercial launches, there were 148 launches to GTO and 77 launches to non-GTO orbits. There was a brief jump in the number of commercial GTO launches in 2008 and 2009, but this trend has not continued over the past six years, as the number of commercial GEO launches decreased back to 15 in 2010 and to 10 in 2014. The number of non-GTO launches has fluctuated, between a low of 3 in 2005 and a high of 12 in 2014.

Commercial Launches by Country

When looking at the commercial launches performed by specific countries over the past 10 years (Chart 6), Russia has a substantial lead, with 93 launches, accounting for the 41.3% of the total number. Europe was in second position, with 53 launches and a 23.6% share. With 46 commercial launches, the U.S. had the third largest share, accounting for 20.4% of the total. The Multinational Sea Launch enterprise followed in fourth position with 27 launches and a 10.2% share. China, India and Japan split the remaining 4.5% share of commercial launches.

Commercial Launch Revenues

Revenue from the 225 commercial launches over the last ten years amounted to an estimated $ 18.4 billion. With a total of $ 9.34 billion, Europe earned the highest amount of commercial launch revenue during this period, corresponding to 45% of total revenue. With $ 5.56 billion earned by its 93 commercial launches, Russia had the second largest amount, accounting for 27% of the total. The U.S. was in third position, with total revenue of $ 3.28 billion (16%), followed closely by Sea Launch, which earned $ 1.87 billion (9%). China's four commercial launches generated revenue of $ 300 million (2%), while India earned $ 92 million from its two commercial launches in 2007 and 2014. Finally, Japan performed its first commercial launch in 2015, generating revenue of $ 113 million (See Chart 7).

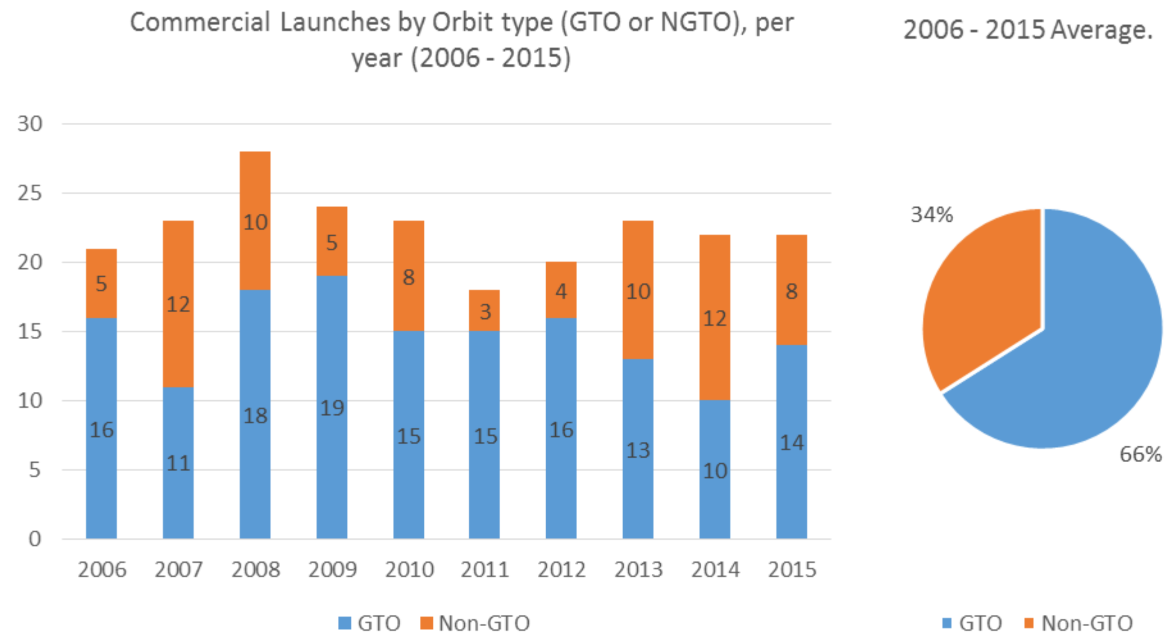


Chart 5: Commercial launches by orbit type, 2006 - 2015.

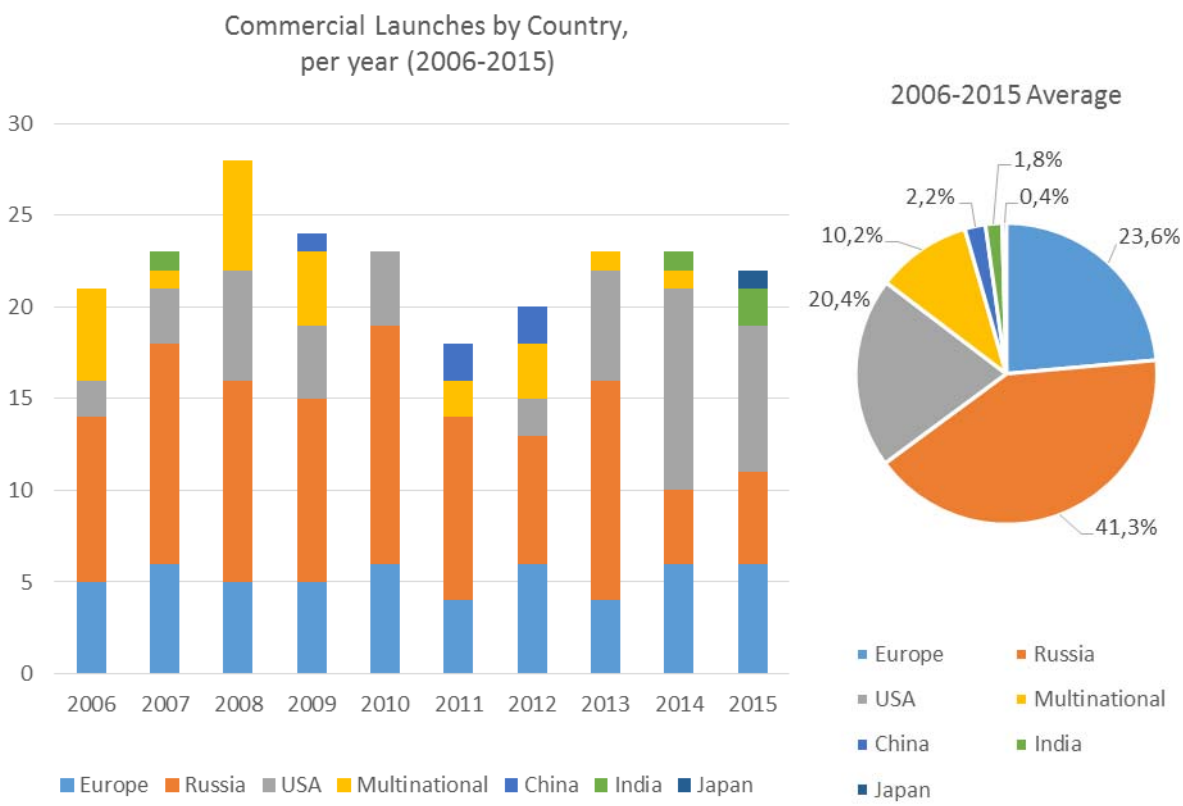
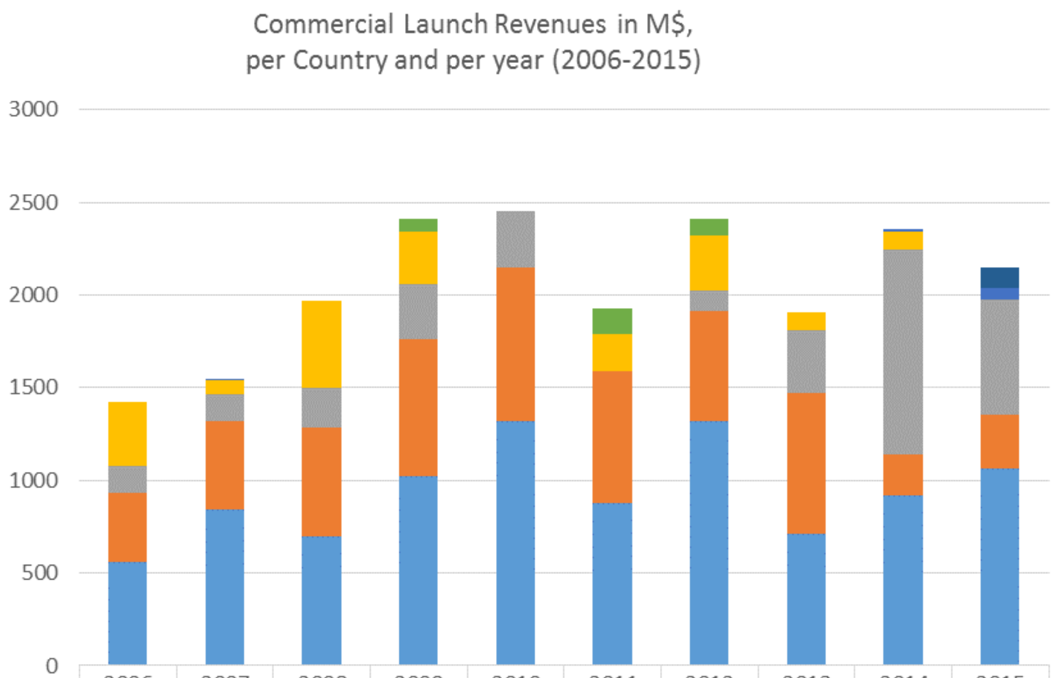


Chart 6: Commercial launches by country, 2006 - 2015, and historical average market shares.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Japan	0	0	0	0	0	0	0	0	0	113
China	0	0	0	70	0	140	90	0	0	0
India	0	11	0	0	0	0	0	0	15	66
Multinational	350	70	475	280	0	200	300	100	95	0
USA	140	150	215	298	307	0	108	340	1107	617
Russia	374	477	581	742	826	707	595	759	218	289
Europe	560	840	700	1020	1320	880	1320	710	920	1066

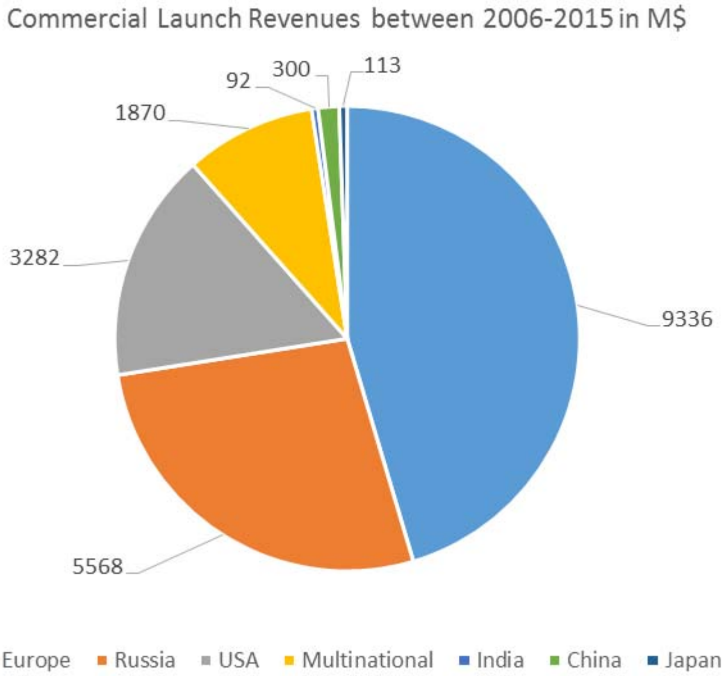


Chart 7: Commercial launch revenues in M$, 2006 - 2015.

4.2 The Structure and Dynamics of the Space Launch Market

4.2.1 Geo-economics of Launchers

In light of the limited number of players launching commercial payloads and of the small number of commercial launches performed each year, providing an assessment of the commercial market for launch services through an analysis of demand and supply conditions could appear a relatively straightforward exercise. In fact, such an assessment is highly problematic, as the typical economic measurements of comparing the price paid for a commodity with the quantity bought would – in the case of launch vehicles – be encumbered by a number of factors.

To begin with, there are practical complexities in the construction of a meaningful set of economic data, because: a) there is no standard destination in space for all payloads and no clear separation between the different market segments (LEO, MEO, GEO, etc.); b) different launch vehicles have different capabilities in terms of mass, orbit and fairing configurations; c) even for the same basic vehicle, each launch is unique, since each payload and customer generally requires customised services; d) a given launch may include multiple payloads (dual manifesting), with the secondary payload deeply discounted in price; e) commercial satellite operators may negotiate so-called Multiple Launch Agreements (MLA) with providers, as *inter alia* done by Intelsat, SES, and Inmarsat;[144] f) launch prices vary in what is actually included in the launch service.[145]

What further clouds the market picture is that the price of a launch is only one of the many considerations guiding the selection of a launch provider, and not always the most important one. An equally important factor is the reliability of a launcher, given that the key rationale behind the selection of the launch provider is to ensure the success of the mission and that the selection of a "vehicle with high reliability translates into reduced insurance rates for companies who choose them".[146] Representing a substantial part of the total cost of launching, the insurance rate is indeed a major concern for commercial satellite operators. Availability and minimum delays in the time from shipment to launch are likewise key factors. The specific performance of a vehicle, its flexibility in orbit injection strategy, in handling delays and in successfully integrating the payload with the vehicle (see Annex 4), as well as technology-security safeguards, are also essential. Finally, the environmental footprint – on both Earth and space – is progressively becoming a relevant consideration. The criteria and priorities for selecting a launch service, as defined by commercial satellite operator EUTELSAT, are presented in Chart 8.

What needs to be highlighted is that even by introducing a number of approximations and translating all these factors into costs and prices, market conditions for launch services prove to be atypical at best when looking at the overall demand and supply dynamics.

Unlike typical customer-oriented services, which respond predictably to price changes, the overall demand for launch services has been rather irresponsive to the conditions on the supply side. As aptly underlined in a study on the commercial space sector by the Center for Strategic and International Studies, a "brief review of launch trends compared with launch prices suggests rather strongly that factors other than price dominate the launch demand equation. Launch prices were fairly constant from 1993 to about 2000, but launches fluctuated from a peak of 35 in 1996 to a valley of 16 in 2001, as prices were falling. Prices fell through 2003 as the number of launches fell, and launches increased in 2007, as prices increased".[147] Thus, the impact of price on the overall demand has not been relevant. In economic terms, the demand curve for launch services has been inelastic so far, meaning that improvements on the supply side have not been able to stimulate additional demand, which on the contrary, remains most closely related to overall growth in commercial space applications, (particularly telecommunications) that is, the capabilities provided by satellites. This paradigm may, however, change if lower cost satellites become more prominent or if launch prices decrease in a more radical manner.

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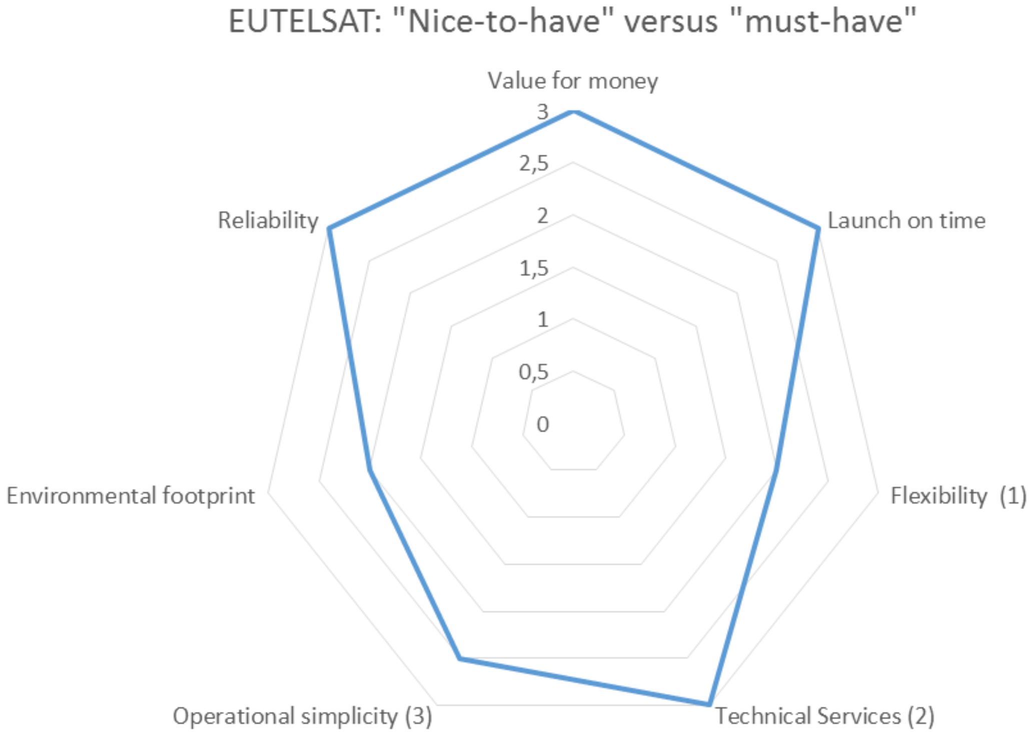
[144] Euroconsult. "Satellites To Be Built & Launched By 2022". 2013: p. 111

[145] Herzfeld, Henry R, Ray A. Williamson, Nicolas Peter. "Launch Vehicles: an Economic Perspective". Space Policy Institute. Washington D.C. September 2005: p.9

[146] Cit. Federal Aviation Administration. "Selecting a Launch Vehicle: What Factors Do Commercial Satellite Customers Consider?" Second Quarter 2001. Quarterly Report Topic. Web. https://www.faa.gov/about/office_org/headquarters_offices/ast/media/q22001.pdf. Accessed 10 September 2015.

[147] See Berteau, David and Gregory Kiley (project directors). "National Security and the Commercial Space Sector. An Analysis and Evaluation of Options for Improving Commercial Access to Space". Washington: Center for Strategic and International Studies, July 2010, http://csis.org/publication/national-security-andcommercial-space-sector.



1) Flexibility means ability to offer orbit-raising strategies minimizing duration and/or propellant consumption
2) Technical services with respect to compatibility with spacecraft: fairing volume, shock, vibration, RF …
3) Operational simplicity refers to duration of mission integration analysis and launch campaign

Chart 8: Criteria and priorities for selecting a launch service according to commercial satellite provider EUTELSAT.[148]

> It could be argued that the inelasticity of launch demand mainly stems from the fact that supply improvements have always been rather marginal. Although since the early 1970s it has been assumed that access to space will become much less expensive over the time, launch prices have historically remained within the same order of magnitude. This is primarily due to the unchanged underlying technology of chemical propellants, the long R&D investment cycle and the relatively small quantity of launchers produced, which has prevented the creation of true economies of scale etc. Thus, a drastic reduction in terms of launch prices, as a result of technological innovation and more profound production efficiencies (see Chapter 4.3), could induce demand to become more elastic.

When looking at the factors associated with supply capacity, these even more clearly reveal that launchers cannot be treated as "just another commodity". Indeed, due to the predominant influence of non-market forces, the market conditions for launch services remain far from truly commercial.

As a strategic enabler for the conduct of any military, civil and commercial space endeavour, as well as constituting a key element for promoting technological and industrial capabilities and fostering national pride, access to space has always been within the remit of national policy and decision-making. Government needs and missions have driven launch capability developments irrespective of the market conditions to achieve what are essentially non-economic goals and objectives. In order to ensure the availability and sustainability of autonomous access to space, governments provide foundational support to their launchers, thus retaining a high degree of freedom of action at international level. This is shown *inter alia* by the lack of a multi-

148 Source: Mussalian, Raphaël. "Launch Service Requirements: From the point of view of satellite communication operators". Presentation at "International Conference on the European Space Launchers", Paris, 3-4 November 2015.

lateral trading regime and the fact that Member States of the WTO have neither listed space transport services among their obligations under the Agreement on Government Procurement, nor have made specific commitments within the General Agreement of Trade in Services (GATS) framework.

Not only development, but also subsequent exploitation has been sustained by the public sector. In this regard, it is of interest to note that no single launch service provider has been so far able to sustain itself only on the basis of the market for launch services. Public support during exploitation on the commercial market has typically materialised in two forms: the first is the guarantee of a stable and predictable launch business base that is ensured through the captivity of institutional payloads to domestic launch systems;[149] the second is the direct injection of public funding that compensates the limited demand by covering a part of the exploitation costs. Governments typically consider these costs as "sunk", or unrecoverable. As a consequence the actual cost of a launcher in terms of development and operations is not necessarily reflected in the offering price, as would happen if launchers were "just another commodity". However, even if commercial customers do not ultimately pay the expenses that would arise in a purely market-driven system, this *modus operandi* is not disadvantageous for governments that sustain production and exploitation costs. Indeed, commercial customers ultimately ensure that the flight schedule remains full and, consequently, that the capacity of the launcher system is utilised to an extent that would not be possible to achieve if launches were exclusively institutional. In short, thanks to commercial demand, launcher systems can be produced and operated in numbers large enough to make prices more convenient for institutional customers.

The predominant role of government in the launch industry thus has the effect of hiding investment and supporting costs, and clarifies why launch price setting is structurally different between the government that developed the launch system and other users of the vehicles that did not fund its development.

Among the variety of tools national governments deploy to sustain the competitiveness of their launch vehicles, the utilisation of policy directives and regulations that are *de facto* intended to limit foreign competition (see for instance the adoption of quantitative limits or quotas for foreign launches) as well as the role of the Export Credit Agencies (ECAs) should be recalled. ECAs are governmental or quasi-governmental agencies that *inter alia* facilitate the commercialization of launch services either through the provision of direct loans, as in the case of the U.S. Export-Import Bank, or by providing governments with guarantees for loans, as for the French-based Coface, the Russian EXIAR, and the Chinese Sinosure. Thus the more interested governments back ECAs, the more a given launcher increases its possibility of gaining a share of the commercial market.

All in all, the extent of public support is so wide and engrained in the structure of the launch business that even for internationally competed launch contracts, the commercial space launch market cannot be aptly labelled as a "free and fair" trade environment. In addition to that, another important piece of evidence of the dominance of non-market forces is offered by such security-related issues as non-proliferations concerns and government protection of space technology through export control regulations.

These measures have had – and continue to have – a deep impact on the global launch market, because they can strongly affect the ability of launch vehicles to compete internationally by *de facto* restricting their potential customers. While not directly intended to put a limit on global competition, export controls regulations ultimately have the effect of excluding some competitors and rewarding others. It is of interest to note that although the majority of spacefaring nations have adopted export control measures for sensitive items, U.S. export license schemes – and in particular ITAR – remain those that have the greatest impact globally. Since most commercial satellites make use of U.S.-manufactured components, these measures are an effective tool for controlling the participation of non-U.S. commercial launch service providers in the commercial launch market and thus for ultimately freezing potential competitors out of it. To illustrate, the successful commercialisation of the Chinese LM rockets on the global market continues to be primarily hindered by U.S. refusals to release export licenses for their payloads.

In light of all these considerations, it becomes evident that the market – or more properly the markets – for launch services cannot be properly assessed through the application of a purely economic approach. The playing field is shaped as much by geopolitical as market forces and its dynamics thus respond to what can be defined as a geo-economic paradigm – to use the terminology of Edward Luttwak – i.e. they are the

[149] This type of support enables amortizing fixed costs over more launches and enhances the competitiveness of a given launcher, because it creates economies of scale that reduce the price of a launcher.

result of the interaction between economic and political forces.[150] While market forces impact the strategies of launch services providers, politics heavily shapes the structure of the market and the commercial competitiveness of the players.

The complex interaction between economic and geopolitical drivers becomes more apparent when examined in the context of the overall evolution of the launch market. This analysis will also help to better frame current and future trends in this highly strategic sector.

4.2.2 The Evolutions of the Launch Service Market

Historical Overview

Opportunities to provide launch services on a commercial basis began to emerge in the early 1980s, with the increase of commercial uses of communication satellites and as a result of two landmark developments worldwide: the creation of Arianespace and the U.S. decision to commercialize access to space through the use of the Space Shuttle. The first commercial launch service contract was signed by Arianespace in 1981 with the U.S. company GTE Spacenet as the client,[151] while the Space Shuttle launched its first commercial payload in November 1982.

The U.S. had made the decision in the late 1970s to migrate all commercial and governmental payloads to the Space Shuttle, so that the proposed fleet of seven vehicles could be used to their fullest extent and significant cost reductions could be made by taking advantage of economies of scale.[152] In 1984, the U.S. Congress also passed the Commercial Space Launch Act as a means of encouraging private companies to develop commercial ELVs. All in all, however, the policy pursued by the U.S. was contradictory. On the one hand, the U.S. government was offering to turn over ownership and operation of existing expendable launch vehicles (Delta and Atlas) to the private sector for commercial use; at the same time, it was pursuing an aggressive policy of marketing the space shuttle as a commercial launcher.[153] In the end, the private sector could not compete with the government-subsidised Shuttle launch prices and the production lines for the two ELVS began to close down. After the explosion of the Space Shuttle Challenger in 1986, and the realization that the U.S. could not rely on a single launch system, a presidential directive in August 1986 banned commercial payloads from the Shuttle (except for Shuttle-unique payloads) in favour of a "mixed-fleet" approach. This policy change offered a renewed opportunity for U.S. industry to seek commercial customers in competition with Arianespace. In the short term, however, the resulting changes in the U.S. commercial launch strategy provided an opening for Europe, and Ariane launchers took advantage of this opportunity. From the mid-1980s, the number of European commercial launches grew significantly and Europe gained the majority share of the commercial market, also thanks to the introduction of the more powerful Ariane 4 in 1998.[154]

The U.S. first tried to counteract the dominant position of Arianespace through a Section 301 petition initiated in 1985 pursuant to the Trade Act of 1974.[155] The petition, which was initially filed by the company Transpace Carrier Inc. (TCI), claimed that Ariane was unfairly subsidised by European governments and accused Arianespace of predatory pricing and of illegally dumping its launch services on the U.S. market. The Reagan administration was requested to retaliate by imposing sanctions and prohibiting Arianespace from commercialising its launchers on the U.S. market. However, the commercial and political assault put forward by the Office of U.S. Trade Representative ultimately failed, as Europeans were able to demonstrate that their practices and policies were undertaken also by the U.S. in the provision of launch services through its Shuttle Programme. Accordingly the petition was eventually withdrawn.[156]

The U.S. thus turned its efforts towards the establishment of mutually agreed trading rules with Europe. In 1990, President Bush

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[150] Luttwak uses the word geo-economics to describe the mixture of the logic of conflict with the methods of commerce that characterises the new world politics in the aftermath of the Cold War. Cit. Luttwak, Edward. "From Geopolitical to Geo-economics, Logic of Conflict, Grammar of Commerce". The National Interest, No 20. 1990: p. 17-24.

[151] Arianespace. Web. http://www.arianespace.com/about-us/milestones.asp. Last accessed 10 September 2015.

[152] Herzfeld, Henry R, Ray A. Williamson, Nicolas Peter. "Launch Vehicles: an Economic Perspective". Space Policy Institute. Washington D.C. September 2005: p.9

[153] Cit. Logsdon, John. "Commercial Launch Industry". Encyclopaedia Britannica online. http://www.britannica.com/EBchecked/topic/332323/launch-vehicle/272750/Commercial-launch-industry>. Accessed 12 September 2015.

[154] Futron. "The Declining U.S. Role in the Commercial Launch Industry". Futron Report. June 2005. p.2.

[155] See Kriege, John. "The History of the European Launchers: an Overview". In Proceedings of an International Symposium on "The History of the European Space Agency". 11-13 November 1998, London. ESA SP-346. 1999: p. 69-78.

[156] Ibid: p. 77.

announced his National Space Policy, setting the stage for "The Rules of the Road" trade negotiations.[157] Also these talks, however, failed to achieve a mutual understanding on fair trading practices between the U.S. and European representatives, especially because the many military-related issues – that the U.S. was not disposed to deal with – eventually stalled the discussions.

At this point however, two new players had tried to step into the commercial launch market: China, and the former Soviet Union. The entry of these non-market economies encountered great resistance from both the U.S. and Europe. For one thing, the new competition was seen as particularly menacing because of the low prices it offered. In addition, the vast arsenal of launch vehicles maintained in particular by Russia by far exceeded commercial demand during the early 1990s. Finally, considerations on missile proliferation continued to raise strong concerns despite the end of the Cold War. In order to cope with the perceived threat and to avoid potentially disruptive market practices, bilateral trade agreements were negotiated by the U.S. with China, Russia and Ukraine and signed in 1989, 1993 and 1996.[158] Through these agreements, the U.S. intended to protect its launch industry against the new competitors by imposing quantitative limits (or quotas), regulating pricing and redirecting the defence-oriented launch sectors of China and Russia towards commercial-oriented launch production. As noted by Reed, the three bilateral agreements more broadly served as both trade agreements and as political bargaining chips for achieving foreign policy objectives; in particular for the purpose of encouraging market reforms in non-market economies and reducing the incentives for countries to engage in illicit dual use technology exports".[159]

While Europe was not an active player in the negotiation of these bilateral trade agreements, it ultimately benefited from such U.S. initiatives. Indeed, with such a framework in place, the Ariane launchers and the new generation of U.S. ELVs developed after the Challenger accident (Atlas 2 and Delta 2) continued to dominate the commercial market of the early 1990s. Even though Ariane 4 had several years head-start, by the mid-1990s European and American vehicles had reached rough parity in terms of market share: in 1995 there were 8 commercial launches by the U.S. compared to seven European launches.[160]

In order to circumvent part of the restrictions enclosed in the bilateral agreements and increase their presence on the commercial marketplace, Russian and Ukrainian entities opted for the creation of the abovementioned joint ventures. ILS, Eurockot Launch Services, Sea Launch and Starsem were all set up between 1995 and 1997.

In addition to the commercialization of ex-Soviet launchers (Proton, Soyuz and Zenit), the mid-1990s also saw the development of a new generation of U.S. vehicles through the Evolved Expendable Launch Vehicle (EELV) programme of the DoD: Boeing's Delta 4 and Lockheed Martin's Atlas 5. Thus, in the latter half of the 1990s the launch service market witnessed an expansion of supply, although it remained characterized by stable launch prices and little price dispersion among different providers. This can be in part explained by the attitude of the U.S.: on the one hand the U.S. wanted the Atlas V and Delta IV to be commercialized, on the other it did not allow a commercial price structure. In part, such a situation can be explained by the fact that by that time demand was relatively robust and, what is more, projections were showing an even stronger commercial market, largely driven by the launch of Non-Geostationary Orbit (NGSO) telecommunication constellations like Iridium, Teldesic and Globalstar. In 1998 the FFA forecast an average of 31 NGSO commercial launches per year from 1998-2010, with an additional average of 25 commercial GSO launches during the same period.[161]

The optimism about the growing demand from commercial satellites led the Clinton administration to announce that, at the expiration of the three trade agreements on launchers, the U.S. would replace "negotiated trade" in commercial launch services with a "trade environment characterized by free and open interaction of market economies".[162] Accordingly, in December 2000 launch quotas were removed. Unfortunately, the emergence of a market-oriented trading environment remained somehow elusive, primarily due to the profoundly changed market conditions of the early 2000s.

[157] Reed, James L., "The Commercial Space Launch Market and Bilateral Trade Agreements in Space Launch Services". American University International Law Review, Volume 13, Issue 1. 1999. p 170.
[158] For a detailed analysis of the three agreements see Reed, James L., "The Commercial Space Launch Market and Bilateral Trade Agreements in Space Launch Services". American University International Law Review, Volume 13, Issue 1. 1999.
[159] Cit. Ibid. p. 182.

[160] Futron. "The Declining U.S. Role in the Commercial Launch Industry". Futron Report. June 2005. p.2.
[161] See FAA Commercial Forecasts 1998.
[162] Reed, James L., "The Commercial Space Launch Market and Bilateral Trade Agreements in Space Launch Services". American University International Law Review, Volume 13, Issue 1. 1999.

Contrary to the earlier market forecasts, in the early 2000s the commercial launch market experienced a sharp downturn: not only did the operators of the proposed NGSO constellations enter bankruptcy or cease operations; the overall demand for satellite communication started to level off dramatically as a result of the telecom stock market crash that occurred in 2001 and a cyclical downturn in new GEO commercial satellites. Ironically, this contraction in demand ran in parallel to the substantial growth in supply capacity resulting from the arrival of converted ICBMs and the maturation of Sea Launch. With the large number of ex-Soviet launchers no longer subjected to quantitative limits and able to profit from low production costs, competition intensified, leading launch providers to a price war. Due to this situation of overcapacity, the market became a "buyer's market", with satellite operators in a position to benefit from bargain launch prices, with a price of as little as $ 50 million for a commercial GSO.[163] Against this background, European and American launch vehicles found it increasing difficult to capture shares of the market on economically viable conditions and inevitably called for strong political backing and additional financial support.

In 2003 ESA Member States launched the European Guaranteed Access to Space (EGAS) programme, through which they covered the fixed operational costs of the new Ariane 5 ECA launcher and provided around 250 million euros a year to Arianespace.[164] In the U.S. both Boeing and Lockheed Martin received additional financial support from the Air Force to maintain their EELVs production lines, and in 2005 announced plans to merge their launch operations into a Joint Venture, the ULA, in order to provide cost savings to the government. Yet, for the two EELVs it remained impossible to commit to the price war initiated by Sea Launch and Proton and they exited *de facto* from the market to concentrate on the captive institutional missions of the DoD and NASA.

In the second part of the 2000s, commercial satellite demand progressively recovered, while competitive pressure decreased following the withdrawal of the newly established ULA from the market. Consequently, commercial launch services became almost exclusively a domain for European and Russian launchers. With the Sea Launch bankruptcy in 2009, the launch market reverted to the duopoly that had characterised the late 1900s, with Arianespace and ILS dictating launch market prices. Dispersion in launch prices decreased and prices returned to the previous ranges (from $ 75 to $ 100 million per satellite to GEO).[165] Notwithstanding the return to flight of Sea Launch's Zenit rocket in September 2011, the commercial market domination of the Ariane-Proton duopoly continued to consolidate in the period up to 2013. By that time, however, the underlying dynamic of the launch service industry had already set the stage for the emergence of a completely new landscape for commercial launch activities.

Recent Evolutions

Over the past few years the commercial launch market has experienced a number of major changes. The most visible and structural change is the abrupt advent of SpaceX, which in the span of a couple of years has established itself as a fierce competitor on the commercial launch market. Thanks to its large backlog of U.S. institutional payloads and the significant support received from the U.S. government through the COTS programme (see Chapter 3.1) the company has been able to pursue an aggressive penetration pricing strategy in the commercial market.[166] With a published price of $ 61.2 million per commercial launch to GTO, Falcon 9 rockets provide the cheapest launch solution in the commercial market, consequently threatening the position of established launch providers. Since the launch of its first GTO commercial satellite (SES-8) in December 2013, SpaceX has built a significant commercial backlog for Falcon 9 (36 as at June 2015), winning many "customers that formerly would have been all but certain clients of Europe's Arianespace launch consortium"[167] or of ILS.

In parallel to the successful comeback of the U.S. on the commercial market, a series of failures of the Proton and Zenit rockets in 2012 and 2013 has led potential customers to avoid signing new launch service contracts with ILS and Sea Launch. In 2014, for the first time, no commercial launches were booked on the Proton-M and Zenit launch services, an occurrence that clearly demon-

[163] Euroconsult. "Satellites To Be Built & Launched By 2022". 2013.
[164] Al-Ekabi, Cenan. "European Access to Space: Factors of Autonomy". In: Al-Ekabi, Cenan (ed.). European Autonomy in Space. Springer, 2015: pp. 137-155.p.145. / See ESA Bulletin 2003.
[165] Euroconsult. "Satellites To Be Built & Launched By 2022". 2013.
[166] It should be highlighted that prices paid by the U.S. government are substantially higher than those charged to commercial operators and have been estimated by NASA to correspond to up to three times that of commercial prices.
[167] Cit. De Selding, Peter B. "Satellite Operators Press ESA for Reduction in Ariane Launch Costs" Space News. 14 April 2014.

strates the strong volatility of the launch market.

Among its most immediate effects, the commercial success of Falcon 9 – combined with the string of failures of Proton and Zenit – has created a situation where commercial satellite launch contracts in 2014 and 2015 were exclusively signed by Arianespace and SpaceX. While in the heavy GTO segment Ariane still holds almost a monopoly, competition has already become stiffer in in the market for smaller GTO payloads (below 5,000 Kg), with Falcon 9 strongly competing against all GTO launch providers. Also in the LEO segment, whose commercial offer has been in the past entirely dominated by converted Russian ICBMs (Dnepr and Rockot), the market penetration of SpaceX has proved successful.

This expansion of supply has been warmly welcomed by satellite operators – which look for increasing diversity in launch offerings – and has inevitably generated market pressures on SpaceX's competitors to lower their own prices. Quite notably, in mid-2014 Eutelsat announced that the company would use the lower prices it can get from SpaceX against Arianespace in negotiations for launch contracts.

It is in response to this increasing price competition that some major initiatives were kicked-off in 2014, including the creation of the ASL joint venture (see Chapter 2.2), as well as ULA's plans to strategically restructure its launch business – reducing its launch offer to one vehicle, Vulcan – while implementing an incremental development programme to build a partially reusable and much lower cost launch system over the next decade. In October 2014, ULA also announced a major restructuring of the work processes and workforce in order to decrease launch costs by half. Needless to say, one of the reasons given for this restructuring and the new cost reduction goals was competition from SpaceX.

All in all, the commercial launch market, albeit far from being a sector of free competition, seems to have become ever more responsive to price pressures, with increased competition leading to an intensification of cost reduction efforts, and possibly to new approaches and disruptive innovation in the domain of access to space (see Table 11).

Trend	Relevant Examples
Innovative approaches in development and production	• Production lines of SpaceX's Falcon 9 • Ariane 6's integrated project teams with industrial partner for co-engineering
Flexibility through vehicle modularity	• P120 motor shared between Ariane 6 and Vega-C • China's New Long March Family (LM-5, LM-7)
Launcher commoditisation	• Tailored solutions for commercial customers offered by Arianespace and SpaceX • Reduction of turn-around times • New injections orbits • Multiple launch sites targeting specific customers, enabling increases in launch rates (e.g. SpaceX)
Extension of payload capacity (very small and very heavy launchers)	• Development of SpaceX's Falcon Heavy • Development of LM-9 and LM-11
Environmental considerations	• Increasing focus on eco-friendly fuels by China and Europe • Formal disposal of spent launcher stages by all providers

Table 11: The evolving space launch service offer.[168]

4.3 Unfolding Trends in Demand and Supply

The worldwide landscape of space launch systems could experience fundamental changes in the next decade, owing to several new trends in both the supply and demand for space transportation services.

Potentially disruptive technologies are currently in the process of being developed and tested for space launchers, such as first-stage recovery and reuse, non-vertical launching as well as 3D printing manufacturing processes. These game-changer concepts have the potential to bring a new era of cheaper launch costs, thereby facilitating a more democratic access to space, in which a

[168] Source: Author´s re-elaboration of Linares, Lucia. “Worldwide Competition in Launch Services”. Presentation at “International Conference on the European Launchers”, Paris, 3-4 November 2015.

much larger number of space users could directly benefit from space activities.

In the telecommunication satellite market, which constitutes the lion's share of GTO market revenues, 2015 witnessed the introduction of the first all-electric propelled platform, a solution that could lead commercial operators to create lighter or more capable satellites. Furthermore, an almost exponential rise in the launch and utilization of small satellites weighing less than a few hundred kilograms has opened the door for unprecedented plans to place constellations composed of thousands of satellites into LEO, dedicated to Earth observation or to provide global internet broadband and telecommunications.

Other technological advancements are paving the way for a number of advanced space activities, which could become everyday business by 2025. Those new activities could take place in or near Earth orbit, such as in-orbit satellite servicing and active debris removal, but also in the longer term, such activities as mineral resources exploitation and space tug missions.

It is not within the scope of this report to address the practicality of these ventures and concepts. However, the following paragraphs will highlight some developments that have the potential to strongly affect demand and offer for space launch services in the medium-term. This is to put in place ideas on the evolved landscape in which the new European launchers will enter into service, ultimately contributing to the reflection that will be provided in Chapter 5.

4.3.1 All-Electric Satellites

The use of electric propulsion technology for satellite manoeuvres has been available on the market for two decades, and has been extensively used in space science missions. Only recently though, has electric propulsion gained prominence as one of the trend-setting technological advancements for commercial telecommunication satellites propulsion. In these missions, electric propulsion has been used so far only for north-south station keeping and/or for partial orbit raising in a hybrid system together with chemical propulsion. In 2015, for the first time a new class of all-electric systems, the 702SP platform manufactured by Boeing, was successfully launched on a SpaceX Falcon 9 rocket.[169] Electric propulsion enables these platforms to move from the point of insertion to final position without the need for other propulsion sources.

The immediate advantage of using technology such as the main satellite thruster is that it greatly reduces fuel loads, resulting in a substantial lower satellite mass than traditional all-chemical or hybrid systems. As a consequence, the lifespan of a full EP platform can be considerably longer, in the order of 50-70%,[170] leading to a higher return on investment (RoI). A drawback of this approach is the longer time required for orbit raising, particularly from GTO to GEO, which is in the order of several months longer than all-chemical satellites (delayed RoI). Hence, it is for commercial satellite operators to decide and evaluate the financial and schedule differences between the two platforms.

While the economic benefit of fully electric propelled satellites is still to be determined, the adoption of such propulsion systems is an increasing trend: for delivery in the period 2016-2022 around 10% of satellite orders were for full-EP, adding to the first four Boeing 702SPs in 2015. However, industry estimates predict that at least 50% of the commercial geostationary satellite market will make use of a kind of electric propulsion in the medium-term,[171] and that by 2022, a quarter of all satellites will be all-electric.[172]

Considering their recent adoption, the impact of all-electric satellites on the launchers market is still unclear. The significantly lower mass of such satellites could lead to two different scenarios for satellite operators to consider: either using the mass savings to keep constant payload capacity and thereby exploiting more dual/multiple-launch configurations, which allows for potential savings of 20-50% on launch costs for the satellite owner; or pursuing greater payload capacity, maintaining the satellite mass constant and in this way increasing the mission's overall revenue.

It is worth noting that the first scenario (i.e. reduced satellite mass and dual launch), by virtue of cheaper launch costs would open up new business opportunities, which were deemed at first economically unfeasible due

[169] Svitak, Amy. "Dawn of the All-Electric Satellite". Aviation Week. 16 March 2015. Web. http://aviationweek.com/space/dawn-all-electric-satellite. Accessed 2 December 2015.

[170] Frost & Sullivan. "Space Mega Trends – Key Trends and Implications to 2030 and Beyond". August 2014: p. 10. Web. https://www.frost.com/reg/file-get.do?id=4483847&file=1. Accessed 2 December 2015.

[171] Airbus Defence & Space. "Space Systems. Mission and system requirements for Electric Propulsion". 25 November 2014. Web. http://espace-ftp.cborg.info/epic_2014/d1_s2_1_EPIC_AirbusDS.pdf. Accessed 2 December 2015.

[172] Safran Group. "Satellite propulsion and equipment". Web. http://www.safran-group.com/space/satellite-propulsion-and-equipment. Accessed 2 December 2015

to high launch prices. At the same time, electric propulsion is also considered a key enabler for new, innovative multi-mission transportation platforms, for example tugging applications to transfer payloads between LEO and GEO, as well as on-orbit servicing[173] or multi-debris removal missions.

4.3.2 Satellite (Mega) Constellations

The return of large satellite constellations, particularly small satellite clusters (on average satellites weighing less than 500 kg), is one of the most noticeable trends in the commercial satellite market.

Historically, the satellite industry was headed towards the development of telecommunication satellite constellations as early as the late 1990s, in order to provide global telephone and data services. Some companies, such as Globalstar, Iridium and ORBCOMM, achieved the full deployment of their constellations, while many others only reached earlier stages of development of their systems. Following increased competition from terrestrial-based GSM telecommunication networks, and the bursting of the telecom/dotcom bubble at the turn of the century, such grand plans were abruptly halted, forcing the major constellation operators into Chapter 11 bankruptcy and reorganization.[174]

In recent times, possibly owing to the technological developments (such as miniaturization of electronic components and electric propulsion) that have spurred an almost exponential rise in the use of small satellite platforms, satellite constellations - or more precisely, mega constellations - are back in the plans of both newcomers and established commercial satellite companies. [175]

In addition to technological progress, a key development favouring this development is in fact today's launchers market and the variety of launch options, which promise reduced costs for small satellites: there is an emerging fleet of small launchers, increased launch possibilities for piggybacking primary payloads, as well as innovative approaches such as ISS-launched cubesats from the NanoRacks system.[176]

Plans for such very large constellations were noticed by the public when, at the end of 2014, the International Telecommunication Union (ITU) registered several early filings for massive, unprecedented constellations of satellites, numbering from hundreds to thousands.[177] Some examples are SpaceX/Google plans for a 4,000-satellite constellation in Low Earth orbit, OneWeb's 650 broadband satellite network, Planet Labs 250 small satellites dedicated to Earth observation, and proposals from less known actors with constellations of up to several hundred satellites each. As a matter of relativity, it is worth noting that in 2015 the total number of operational satellites in orbit amounted to around 1300.[178]

The primary purpose of some of these constellations is to provide low-latency internet broadband to every corner of the planet - not reachable by terrestrial broadband anytime soon - but other applications are also being pursued, ranging from high-resolution Earth Observation – pioneered by Skybox Imaging and Planet Labs – to meteorology.

While it is beyond the scope of this study to delve deeply into the details, practicability and commercial viability of such ventures (to name a few, competition with established GEO telecommunication systems and related new technological improvements, such as High-Throughput and software-defined satellites), it is important to reflect on the impact that such mega constellations could have on the launcher sector.

In mid-2015, the largest ever commercial launch contract was signed between OneWeb and Arianespace: a € 1.3 billion deal to launch 650 to 720 of Oneweb's LEO satellites aboard the Soyuz vehicle. The contract envisages a tight launch rhythm (one launch every five weeks), in order to place such a large amount of satellites in orbit within a two-year timeframe between 2017 and 2019, at a pace of around 36 satellites per launch. To cope with such an increased frequency of launches and considering its current launch manifest, which is largely dominated by

[173] Frost & Sullivan: "Space Mega Trends – Key Trends and Implications to 2030 and Beyond". August 2014: p. 12.
[174] Foust, Jeff. "The return of the satellite constellations". The Space Review. 23 March 2015. Web. www.thespacereview.com/article/2716/. Accessed 2 December 2015.
[175] It should be, however, noted that none of the planned mega-constellations (including Globalstar and Iridium) have never produced comprehensive business plans that allow to make a thorough assessment of their economic viability.
[176] Foust, Jeff. "The ups and downs of smallsat constellations". The Space Review. 22 June 2015. Web. www.thespacereview.com/article/2776/1. Accessed 2 December 2015.
[177] De Selding, Peter. "Signs of a Satellite Internet Gold Rush in Burst of ITU Filings." Space News. 23 January 2015. Web. http://spacenews.com/signs-of-satellite-internet-gold-rush/ Accessed 2 December 2015.
[178] Union of Concerned Scientists. Satellite Database. Web. http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database.html. Accessed 2 December 2015.

European government demand for Soyuz-ST, Arianespace affirmed that it will explore the possibility of launching Soyuz from the Baikonur Cosmodrome via the Russian joint-venture Starsem, as well as from the Plesetsk launch site (which has a Soyuz launch pad), if need be.[179]

SpaceX plans for a mega constellation of 4,000 broadband satellites would not have a commercial end per-se, but would fit with Elon Musk's vision of a human settlement on Mars. Hence, the constellation is seen as a means to generate enough revenue to finance such an endeavour.[180] The details of the SpaceX constellation are still unclear, even more so as some top executives downplayed the project in October 2015,[181] but it is reasonable to assume that the satellites will rely on the company's own rockets to be placed into orbit, particularly by exploiting reusability of the first stage – should economic feasibility be proven.

The possible additional demand for launchers due to the potential deployment of large constellations is too early to assess at this stage, apart from the remarkable Arianespace-OneWeb contract. Pending further development and concrete materialization of such initiatives, the sheer number of satellites envisioned to provide global broadband coverage would undoubtedly lead to a hard-to-meet demand for LEO/MEO launch services. This increased demand will then be added to the ongoing deployment and upgrade of other non-GEO constellations such as Galileo, Iridium NEXT, Skybox Imaging, O3b and Globalstar 2G.

More generally, through low manufacturing costs and not mandating dedicated launch vehicles, small satellite clusters are beginning to set the trend for improved space capabilities, also enabling penetration into densely populated orbital space. The benefits of such clusters with respect to large satellites are – at least in theory – the reduced financial risk, improved capabilities and multi-mission possibilities.[182]

4.3.3 Rocket Reusability

Launcher technology has evolved continuously since the pioneering work undertaken in the early 50s, allowing for improved performance but without achieving any major or game-changing breakthrough. Roughly speaking, the way we access space today is the same as 30 years ago, with parameters such as cost and reliability in the same order of magnitude.

A general shift towards more environmental-friendly fuel is a current trend, but it is the much-discussed concept of reusability that in principle has the potential to profoundly change the way access to space is achieved in the near future.

Since the 1960s, there have been regular calls for a reusable launch vehicle (RLV), chiefly due to its potential to provide low cost, reliable and frequent access to space. Most projects were in the form of single-stage reusable rockets that could launch and land vertically (SSTO VTVL), or single-stage reusable rocket planes that could launch and land horizontally (SSTO HTHL). Various designs and plans were proposed in the following decades, alongside the continuous technological advancements in engine technology and material science. Nevertheless, with the notable exception of the partially-reusable Space Shuttle (and the similar, but only once flown Soviet Buran), a comprehensive reusable system has never been developed either because it was deemed technologically unachievable, or economically unfeasible – as ultimately was the case for the Space Shuttle programme.

Until 2014, all major industries and launch service providers were still shrugging their shoulders and dismissing reusability for launchers as a "been there, tried that" scenario that would lead nowhere. While low-level research was still being pursued,[183] feasibility studies of the past decade considered several features, such as a very high launch rate to break-even on cost, a weight penalty for additional fuel, and ground instal-

[179] De Selding, Peter. "Launch Options were Key to Arianespace's OneWeb Win". Space News. 26 June 2015. Web. http://spacenews.com/launch-options-were-key-to-arianespaces-oneweb-win/. Accessed 2 December 2015.

[180] De Selding, Peter. "SpaceX to Build 4,000 Broadband Satellites in Seattle". Space News. 19 January 2015. Web. http://spacenews.com/spacex-opening-seattle-plant-to-build-4000-broadband-satellites/. Accessed 2 December 2015.

[181] De Selding, Peter. "SpaceX President Downplays Commitment To Building Broadband Constellation". Space News. 27 October 2015. Web. http://spacenews.com/spacex-president-downplays-commitment-to-building-broadband-constellation/. Accessed 2 December 2015.

[182] Frost & Sullivan: Space Mega Trends – Key Trends and Implications to 2030 and Beyond. August 2014: p. 6.

[183] E.g. see: L. Innocenti, C. Dujarric and G. Ramusat. "An Overview of the FLPP and the Technology Developments in RLV Stage Structures for Elevated Temperature Applications". ESA – D/LAU-SF. 2003. Web. http://adsabs.harvard.edu/full/2003ESASP.521...57I. Accessed 2 December 2015.

lation safety provisions as reasons to consider rocket reusability impractical.[184]

Nevertheless, the economic imperative to achieve cheaper access to space still convinced some that reusability could be one of the main pathways to lower the price per kilo required to place a payload into orbit.

With its promise to decrease launch costs by one order of magnitude by 2020, and the concrete attempts it made to try to land the first stage of Falcon 9 on a floating barge in 2014 and 2015, SpaceX undertakings generated a shockwave through the launch industry, ultimately putting reusability firmly back in the spotlight. It has now become a recurring theme, with almost every major launch service provider and manufacturer considering or developing plans to recover parts of their upcoming new launch systems, whilst adopting different approaches.

The SpaceX path for reusability envisions a vertical landing for the first stage of its Falcon 9 rocket. Technology demonstrator tests at low altitude with the Grasshopper vehicle were first started in 2011, and after failed attempts in 2014 and early 2015, on 22 December 2015 SpaceX finally achieved success in landing the first stage of the upgraded Falcon 9 on a ground launch pad. The same approach was followed by Blue Origin. In November 2015 it flew its New Shepard vehicle to the edge of space (100 Km above sea level), and successfully landed both sections of the vehicle, capsule and booster rocket, vertically.[185] What is more, the same vehicle was re-launched in a subsequent test in January 2016, with a successful second landing.

Other major launcher manufactures have decided to follow a different path: both Airbus and ULA approaches aim not at recovering the full rocket first stage with a vertical landing, but to focus only on the engine section, which contains most of the value of the vehicle. In both cases, this approach aims to ensure that the launcher is ready to fly again with the same level of quality and reliability, reducing as much as possible the time, processes and costs of refurbishment.[186] Airbus unveiled its concept, called Adeline, at the beginning of 2015, although its research and development reportedly had been undertaken since 2010. It envisions an autonomous horizontal landing system for the first-stage engine that would enable the main engines and avionics of the launcher (representing around 70% to 80% of the total value of the launch vehicle) to be recovered and refurbished.[187] Following a qualification flight scheduled for 2025, Adeline could be implemented in the new Ariane 6, with the possibility of being adapted to any launcher.

In April 2015, along with the presentation of its new Next Generation Launch System, Vulcan, ULA also presented an ambitious project for mid-air recovery of the engine section[188], named "SMART". Similarly to Adeline, this would allow ULA to reuse the most expensive portion of the first stage – the booster main engines.[189] As with Airbus, it is not expected to become an effective part of the Vulcan launch system before 2024.

Other major national actors that provide access to space are also considering reusability for their new generations of launchers. In India, ISRO is considering a series of technology demonstrator missions for a Two Stage to Orbit fully re-usable vehicle,[190] and this concept is reportedly also being studied for Chinese as well as Russian new launchers, albeit with much less detailed plans. In addition, several smaller companies, mostly U.S. based, are also pursuing partially reusable vehicles, particularly focusing on air-to-space systems for small payloads (see paragraph 4.2.5).

While in principle promising, the prospective cost reductions from using reusable vertical launch systems rather than expendable rock-

[184] Svitak, Amy. "NASA, CNES warn SpaceX of Challenges in Flying Reusable Falcon 9 Rocket". Aviation Week. 05 May 2014. Web. http://aviationweek.com/blog/nasa-cnes-warn-spacex-challenges-flying-reusable-falcon-9-rocket. Accessed 2 December 2015.

[185] Foust, Jeff. "Blue Origin Flies – and Lands – New Shepard Suborbital Spacecraft". Space News. 24 November 2015. Web. http://spacenews.com/blue-origin-successfully-flies-new-shepard-suborbital-vehicle/. Accessed 2 December 2015.

[186] For a possible reusability economic scheme, see for example: Astorg, Jean-Marc. "Technical (R) Evolutions in Launchers". Presentation at ESPI Autumn Conference. 21-22 September 2015. Web. http://www.espi.or.at/images/stories/dokumente/Presentations_2015/Autumn_Conference/Jean-Marc_Astorg.pdf. Accessed 07 December 2015.

[187] "Airbus Defence and Space's solution to reuse space Launchers". Web. http://airbusdefenceandspace.com/reuse-launchers/. Accessed 2 December 2015.

[188] Ray, Justin. "ULA chief explains reusability and innovation of new rocket". Spaceflight Now. 14 April 2015. Web. http://spaceflightnow.com/2015/04/14/ula-chief-explains-reusability-and-innovation-of-new-rocket/. Accessed 2 December 2015.

[189] "United Launch Alliance Unveils America's New Rocket – Vulcan". ULA. 13 April 2015. Web. http://www.ulalaunch.com/ula-unveils-americas-new-rocket-vulcan.aspx. Accessed 2 December 2015.

[190] Indian Space Research Organization - Reusable Launch Vehicle - Technology Demonstration Program (RLV-TD). Web. http://www.isro.gov.in/technology-development-programmes/reusable-launch-vehicle-technology-demonstration-program-rlv-td. Accessed 2 December 2015.

ets are strongly dependent on a number of factors that are still hard to assess. Detractors of this approach point to the fact that the very basic principle of reusing a single rocket could lead to reduced economies of scale until now realized from the production of rocket stages and motors in great numbers for expendable systems. This is even more important when considering that a Falcon 9 rocket contains 9 Merlin 1D engines (and its larger version, Falcon Heavy, will use 27 Merlin engines), whereas an Ariane 5/6 has only one, the Vulcain 2 (a configuration similar to ULA's NGLV, powered by the BE-3 engine). Such crucial differences point to different approaches and attitudes to first-stage reusability from different manufacturers. Additionally, the increased fuel required for re-entry manoeuvres substantially diminishes rocket performance, i.e. the mass available for the payload, with some estimates numbering it at up to 30%.[191] Finally, the cost and time required to inspect and refurbish a rocket stage are still largely unknown. In fact, it is clear that while for ELVs the production costs account for the largest share and can be determined to a great extent in advance, for RLVs this share would be operations costs, which are uncharted territory as of today. Even more unknown is the reliability of such a refurbished vehicle – the factor that ultimately will determine its appeal to typically risk-averse large commercial satellite operators.

With SpaceX and Blue Origin acting as a pioneers, should reusability become an everyday reality following both companies successful landing at the end of 2015, they will also become the first companies to have to concretely address the concerns around this new technology – as well as reaping the potential benefits, both in orbital and suborbital flights. Nevertheless, it is unlikely that reusability will have a large impact on the overall launch sector in the short term – except for possibly spurring an accelerated pace of similar developments by competitors – until the technology as well as the business case are proven solid.

4.3.4 Additive Manufacturing

Additive manufacturing technology, popularly known as 3D printing, is positioning itself to become a revolutionary technology also for launchers, potentially as paradigm shifting as re-usability, but less in the public eye.

[191] Grondin, Yves-A. "Musk lays out plans for reusability of the Falcon 9 Rocket". NASA Spaceflight. 03 October 2013. Web. http://www.nasaspaceflight.com/2013/10/musk-plans-reusability-falcon-9-rocket/. Accessed 2 December 2015.

This innovative manufacturing process, already hailed as the third industrial revolution, constitutes a paradigm change at the very bottom of the manufacturing chain: it involves creating a solid object from a series of layers, each one printed on top of the last, typically by melting powder or wire materials and starting from a computer-designed model.[192] Among its advantages, there is the possibility to create very complex geometries impossible to make in traditional ways, leading to potentially enormous mass and cost savings with respect to traditional manufacturing, as well as huge savings in material wastage.[193]

3D printing is a less discussed technological breakthrough in the space and launchers sector, so far limited only to a few key components such as small satellite structures and satellite propulsion parts as well as for some parts of launcher systems (e.g. the SuperDraco thruster used by SpaceX's Dragon capsule). NASA has already hot-tested a rocket engine that was 75% composed of 3D printed parts.[194] In the coming years, as the technology progresses, it could be the key to drastically reducing the cost of access to space, even more so than reusability.

With substantially increased performance due to the large mass saving and other performance gains in the order of two digits,[195] once this technology reaches maturity, possibly by 2025,[196] its widespread employment in launcher manufacturing could lead to mass production of still expendable, yet much cheaper launch vehicles.

4.3.5 Non-vertical Launch and Small Satellites

Vertically launched rockets have so far been the most viable option for launching into space. Nevertheless, alternative approaches

[192] ESA - 3D Printing For Space: The Additive Revolution. 16 October 2013. Web. http://www.esa.int/Our_Activities/Human_Spaceflight/Research/3D_printing_for_space_the_additive_revolution. Accessed 2 December 2015.

[193] Mass savings could be of the order of 50% with respect to traditionally manufactured components. See for example: Wolfgang Veit. "Additive Manufacturing (AM) for Space (and Earth) Applications" presentation at the Preparatory Meeting for the High Level Forum "Space as a Driver for Socioeconomic Sustainable Development". Vienna, Austria. 19 November 2015.

[194] See: "Piece by Piece: NASA Team Moves Closer to Building a 3-D Printed Rocket Engine". NASA Press Release. 17 December 2015. Web. https://www.nasa.gov/centers/marshall/news/news/releases/2015/piece-by-piece-nasa-team-moves-closer-to-building-a-3-d-printed-rocket-engine.html. Accessed 21 December 2015.

[195] Ibid.

[196] Frost & Sullivan: Space Mega Trends – Key Trends and Implications to 2030 and Beyond. August 2014: p. 8.

have been pursued in the past, in some instances with some success. One example is assisted air-to-launch systems, in which a rocket carrying the payload is first brought to a very high altitude by a conventional airplane, then detached to reach the escape velocity necessary to inject the payload into orbit by rocket propulsion.

Such systems have the capacity to inject into orbit only a limited payload, typically less than 500 Kg. Therefore, during the age of large, chemical-propelled massive satellites, non-vertical launch solutions, while still looked at with interest, could cover only a small niche of the global space launch landscape. Until 2015 in fact, the most successful non-vertical launcher was Orbital Sciences' Pegasus, an airplane-assisted, air-to-space rocket with a capacity of up to 450 Kg into LEO and 42 launches between 1990 and 2013.[197]

A recent increase in the use of small satellites, particularly in the nano/micro mass range,[198] has the potential to become a game-changer for small and air-to-space launchers, with an increasing number of commercial operators, as well as institutional actors, now exploring opportunities in this segment. In fact, a total of 510 small sats are to be launched in the next five years,[199] a 66% increase compared to the average over the last decade. While in 2015 the small satellite market segment generated but a fraction of the global revenue, some estimates put its worth around $ 7.4 billion by 2020.[200]

Currently, the majority of small satellites and in particular cubesats are using opportunistic rides alongside main payloads on large rockets, exploiting excess capacity when it is possible. This leaves their exploitation often "at the mercy" of the decisions of the main payload owner, in terms of launch schedule and orbital parameters, yet increasingly, "conventional" rockets are offering piggyback possibilities even for free.

While today's small satellite revolution is undoubtedly exciting for developers and potential users, it is also a cause for concern from the space debris mitigation and regulatory perspectives. While small satellites of all kinds should indeed meet the appropriate debris policy regulations (as well as technical measures to ensure their timely de-orbit), it is also true that their exploitation could greatly benefit from the development of dedicated small launchers, offering orbital injection capabilities tailored for these kinds of missions.

A number of companies around the world are in fact starting to meet that challenge. Some examples of small, non-vertical launch systems currently being developed are DARPA's ALASA (although its development was stopped in December 2015), XCOR Aerospace's Lynx Mark III, Orbital Sciences' Pegasus II (and resurrected Athena vehicles), Swiss Space Systems' SOAR, Virgin Galactic's Launcher One, Stratolaunch Systems, and Reaction Engines Limited's Skylon.[201]

In the U.S. in particular, the development of such small launcher systems has been stimulated, for more than a decade, by the DoD's quest for "responsive launch" capabilities, which would allow it to launch satellites or payloads into orbit on relatively short notice. Since traditional rockets have a lag of two or more years between contract and launch, the DoD has put efforts into dramatically shortening that timetable, driven by what military officials say is a need to quickly plug gaps in space capabilities or deploy new ones in response to emerging military requirements.

The Skylon spaceplane from UK-located Reaction Engines, based on a previous project from the 1980s known as HOTOL, has the potential to become the first "true" single stage to orbit, fully reusable spaceplane. While still at an early design phase, it claims a significant payload capacity, up to 15,000 Kg to a 300 Km equatorial orbit, or 11,000 Kg to the ISS (almost 45% more than the capacity of the ATV).[202] The company has secured significant funding from the British government as well as ESA and BAE Systems, which nevertheless constitutes only a fraction of the projected billions required in overall programme costs. In 2015, its hybrid air breathing rocket engine called SABRE, around which the Skylon spaceplane is built, passed a U.S. Air Force feasibility test, dem-

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197 See: Orbital ATK. Pegasus Air Launch System Factsheet. Web. http://www.orbitalatk.com/flight-systems/space-launch-vehicles/pegasus/docs/FS002_02_OA_3862%20Pegasus.pdf; and: Pegasus Mission History. Web. http://www.orbitalatk.com/flight-systems/space-launch-vehicles/pegasus/docs/Pegasus%20Mission%20History.pdf. Accessed 2 December 2015.

198 Buchen, Elizabeth. "2014 Nano/Microsatellite Market Assessment" and "2015 Small Satellite Market Observations". SpaceWorks Enterprises, Inc.

199 Messier, Doug. "Euroconsult sees large market for smallsats". Parabolic Arc. 02 March 2015. Web. http://www.parabolicarc.com/2015/03/02/euroconsult-sees-large-market-smallsats/. Accessed 2 December 2015.

200 Ibid.

201 For a complete list, see: Messier, Doug. "Updated list of smallsat launch vehicles". Parabolic Arc. 04 October 2015. Web. http://www.parabolicarc.com/2015/10/04/updated-list-smallsat-launch-vehicles/. Accessed 2 December 2015.

202 Reaction Engines – Space Access: Skylon. Web: http://www.reactionengines.co.uk/space_skylon.html. Accessed 2 December 2015.

onstrating the potential of such technology.[203,204]

The future availability of reactive, non-vertical launch solutions for small payloads could generate competition with vertical vehicles currently available or in development, such as Vega, Minotaur, Epsilon and PSLV (taking into account that Rockot and Dnepr will be phased out in the near future). It must be noted though that solid rockets maintain a strong record of reliability. Moreover, they are able to cover a higher mass range in terms of performance, albeit at a greater cost.

How vertical and non-vertical launch systems will compete to inject small satellites into orbit will largely depend on the viability and price of such non-vertical launch solutions, as well as on how the small satellites market itself will develop. It is currently expanding in a context of relative lack of regulations: in all probability small satellites will be increasingly subject to stricter guidelines in the future, in particular in terms of space traffic regulation and debris mitigation. On the other hand, ultimately a more regulated environment could be favourable for the small satellite segment by providing planning stability and security of use.

4.4 The Future Landscape

Even though the space transportation sector is a highly dynamic environment, a number of trends and their possible impact on the future landscape can be discerned.

One of the most visible trends is the strengthening national autonomy and the reduction of interdependence among the players. This tendency has been intensified since the 2014 Crimea crisis, which marked the end of the historical cooperative undertakings that Russia and Ukraine put in place in the mid-1990s. While disengaging from multinational joint ventures, and repatriating their shares to Russian entities, Russia also started to accelerate the construction of a new launch site on its territory to replace its dependence on Baikonur and put a stop to the future use of vehicles not entirely manufactured domestically (see Chapter 3.2).

Also on the U.S. side, increased development efforts have been initiated to eliminate dependence on Russian engines to launch national security payloads (see Chapter 3.1) and on Russian rockets for human spaceflight. Similarly, Europe is developing the Ariane 6 partly in order to overcome its reliance on the Russian-made Soyuz. More broadly, most spacefaring nations, including the U.S., Europe, and Russia, are now developing production capabilities for critical components that are not yet domestically available. Finally, a growing number of emerging space nations is seeking to limit dependency on third parties by acquiring (Argentina and Brazil) or further upgrading (Israel, South Korea, Iran) their own launch capabilities to LEO (see Chapter 3.6).

While access to space still firmly remains in the hands of national governments, the role of private actors (and private investment) is ostensibly increasing. In the U.S., SpaceX is currently developing its vehicles with consistent private investment, while benefitting from the NASA contracts awarded to the company. Pushed by this game-changing approach, ULA also recently begun development of the new Vulcan launch vehicle with private funds. In the case of Europe's Ariane 6 launcher, € 400 million of development capital has been requested as "industry's share". While this amount is still a tiny fraction of the € 4+ billion required to develop the new Ariane 6, the overall level of responsibility entrusted to industry is unprecedented (see Chapter 2). Finally, in Japan the government is also taking steps to stimulate private capital to enter the launch industry and to provide a legal framework for private companies' spaceflight initiatives.[205]

An even more striking trend is the rapid change in the main competitors on the commercial market. In the span of a few years, the longstanding Ariane-Proton duopoly has come to an end. New competitors have entered the commercial market, as demonstrated by the entry of SpaceX and its almost-50% market share of GTO revenues in 2015 (with Arianespace acquiring a similar share), and by the efforts currently being undertaken by launch service providers that previously were mostly inactive.

In Japan, MHI has announced its intention to compete on the commercial market with the support of export financing mechanisms and by offering packages (satellite construction and launch) to emerging nations.[206] In the

[203] Davies, P., Hempsell, M. and Varvill, R. "Progress on Skylon and SABRE'', IAC-15-D2.1.8, and references therein.

[204] A comparison analysis of the launch costs per Kg between a reusable Falcon 9, Falcon Heavy and Skylon can be found at: https://theconversation.com/spaceplanes-vs-reusable-rockets-which-will-win-51938. Accessed 15 December 2015.

[205] See "Private-sector rocket launch legislation eyed". Yomiuri Shinbun. 3 June 2015.

[206] Euroconsult. "Satellites To Be Built & Launched By 2022": p. 106

U.S., ULA has started to proactively revitalise its efforts to capture commercial payloads, motivated at least in part by the astonishing success of SpaceX.

China has started to offer a portfolio of alternative launch solutions for its platforms (restricted on the international market by U.S. export controls regulations) and also India is currently seeking commercial launch opportunities for its GSLV to offset vehicle development and operations costs. Even if ITAR restrictions continue to limit the impact of Chinese launch vehicles and domestic demand limits the availability of GSLV, it should not be overlooked that these launch vehicles are still benefiting from low production costs, enabling them to possibly step forward with prices lower than those currently being offered.

Moreover, in all the major spacefaring nations significant development programmes are currently underway (See Table 12, Table 13, Chart 9 and Annex 2). In the 2020s, the new GTO-capable vehicles will be Ariane 62/64, Vulcan, Falcon 9/Heavy, H-III, Long March 5/7, GSLV Mk-III, and Angara A5, alongside previous generation vehicles until their respective phase-outs. Non-GTO vehicles will be represented by Vega-C, Epsilon-I, Long March 6/7, Minotaur-C, Antares, Falcon 9, PSLV, Soyuz 2.1v and Angara 1.2.

The next decade will thus be characterized by a larger offer of launch vehicles in the commercial market. As major development efforts progress towards operational readiness, offering increased flexibility and promising cost reductions, competitive pressures are expected to further stiffen and to challenge the position of established actors.

Already now, however, access to space seems to be becoming even more responsive to cost and price pressures. While in the past decades increasing performance and reliability were the key goals behind the development of new launch vehicles, cost reductions are now becoming ever more a driver. From a technology point of view, the largest development programmes currently underway in many spacefaring nations all aim at reducing costs and increasing flexibility, continuing the trend of modular families of launchers with maximisation of common expendable elements. Rationalisation and streamlining industrial organisation has also become a common feature among all space launch providers.

Price targets of the upcoming launch vehicles remain in the same order of magnitude as today's prices, but increased competition can be expected to lead to a further intensification of cost reduction efforts, and to the eventual materialisation of disruptive innovation for access to space. A potential game-changer could result from demonstration of the commercial viability of reusability, achieved for the first time by SpaceX and Blue Origin, and further envisaged by ASL and ULA.

It should be highlighted, however, that this growing competition is taking place in a market in which it is assumed that overall demand in the GTO segment will remain stable over the medium term, bar a substantial decrease in launch prices.[207] Additional supply could thus potentially lead to a situation of overcapacity similar to that of the early 2000s, consequently leading to the emergence of a buyer's market, in which price would be the strongest differentiator between providers.

Should a substantial decrease in launch prices occur as a result of some major breakthrough (e.g. routine rocket reusability, widespread adoption of additive manufacturing, etc.), the way will be paved for a large increase in demand for launch services and the current structure of the commercial launch market will be substantially disrupted.

In the LEO segment, the number of national actors with initial capability is poised to increase. Since the LEO segment is constituted in principle by a large majority of institutional launches, the growing number of launcher solutions would at first be aimed at satisfying domestic demand in an autonomous fashion. Additional supply options in this market segment will reduce the share of payloads accessible to launch providers, through competition.

At the same time, however, the rising number of commercial ventures interested in deploying their small satellites fleets in low orbits, including large broadband constellations, will generate increased demand for flexible, affordable and possibly tailored launch solutions. This demand could be met both by traditional small and medium launchers, but also possibly by non-vertical launchers, with the two systems then competing to reduce the cost-per-Kg to orbit in this segment.

[207] See FAA 2015 Forecasts.

Launcher	Performance to GTO (Kg)	Launch Price (M$)	Commercial Capacity /yr.	Single / Dual
Europe [208]				
Ariane 62	4,500 - 5000	75	12	Single
Ariane 64	9,500 – 10,500	125	12	Dual
U.S.				
Vulcan step 1-2	4,500 – 13,000	100 - 200	2	Single
Falcon 9	4,000 – 5,000	60	10+	Single & stacks
Falcon Heavy	6,400 – 20,000	85 - 135	10+	Single & stacks
Russia				
Angara A5	5,000 – 12,000	100	5	Single & stacks
Proton [209]	6,300	80 - 100	n.a.	
China				
Long March 5	6,000 – 14,000	TBD	1-2 [210]	
Japan				
H-III	2,000 – 6,000	60 - 100	2	Single
India				
GSLV Mk-III	4,000 – 5,000	50 - 75	1	Single

Table 12: The future competitive landscape for Ariane 6 (at 2015 economic conditions).[211]

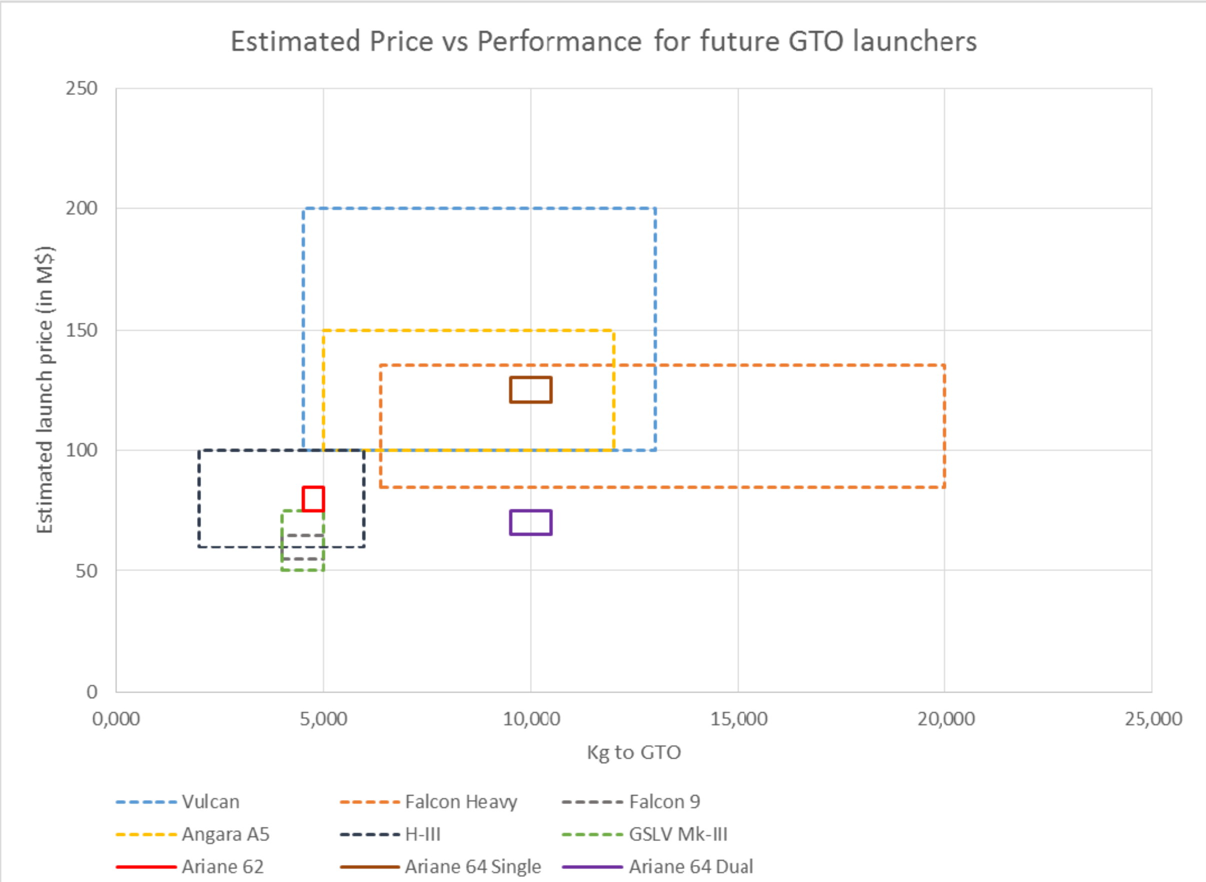

Chart 9: Estimated price vs. performance for future commercial GTO launchers.

[208] For comparison purposes, the estimated prices for Ariane 62 and 64 in the chart are converted in M$.
[209] Until phase-out. Price is heavily susceptible to rouble fluctuations.
[210] Subject to ITAR restrictions.
[211] Launch price estimations and other key parameters for GTO vehicles under development, potentially intended for the commercial market. Source: authors' elaboration of data from presentations and interventions at the "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

	Vehicle Name	First Flight	Timeline									
			2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
EUR	Ariane 62	2020										
	Ariane 64	2020										
	Vega-C	2018										
USA	SLS Block I	2018										
	SLS Block II	> 2021										
	Falcon Heavy	2016										
	Vulcan Step 1	2019										
	Vulcan Step 2	2023										
	Athena III	TBD										
RUS	Angara A3	> 2020										
	Angara A5	> 2016										
	Angara A7	> 2028										
CHN	Long March 5	2016										
	Long March 7	2016										
	Long March 9	> 2023										
JAP	H-III	> 2020										
	Epsilon ph.2	> 2017										
IND	GSLV Mk-III	> 2016										
KOR	KSLV-II	2020										
BRA	VLS Alfa/Beta	2020										
ARG	Tronador III	TBD										

Table 13: New launchers and indicative timeline for the scheduled first flight.[212]

[212] GTO-capable vehicles (including SLS not intended for the commercial market) are in blue. NGTO vehicles are in orange. Source: ESA and authors' elaboration.

5. What Prospects for European Launchers?

Building upon the analyses and findings of the previous chapters, an overall assessment of the current European strategy on access to space and the medium-term prospects for European launchers will be provided in the first part of Chapter 5. This will in turn be used as a basis to present and discuss policy options to best cope with the potential areas of concern identified in the assessment.

5.1 Europe's Strategy on Access to Space: an Assessment

The reference analyses laid out in Chapters 3 and 4 above provide the basis for an overall assessment of the strategy set up by the ESA Ministerial Council and, more broadly, of future prospects for Europe's access to space. Key points are highlighted hereafter.

- The new European strategy on access to space as defined by the 2014 ESA Ministerial is a politically well-balanced compromise that follows a period of intense disagreement between ESA Member States, most notably Germany and France. However, the decision to proceed with the development of Ariane 6 was taken as late as 18 years after the qualification flight of Ariane 5, and the rocket itself it will enter into service 24 years later. This is in stark contrast to decisions historically taken by the ESA C/M on the development of the Ariane launcher family, when the development of each subsequent generation was decided well before the qualification flight of each previous Ariane rocket (see Chapter 2, Table 4).
- The Resolution lays down a multi-pronged strategy aimed at maintaining robust launch competencies while increasing flexibility and reducing costs through a number of levers, including the utilisation of heritage hardware, the streamlining of industrial organisation, the maximisation of common expendable elements and the creation of synergies between different market segments, and the guarantee of five institutional launches per year. All the identified levers are essentially designed to decrease launch costs and to generate economies of scale so as to ensure competitive pricing for Ariane 6 and Vega-C without the need for public support payments during exploitation.
- The success of this new launcher strategy will rely *de facto* on the guarantee of an institutional launch business base, which might be difficult to ensure, however. ESA has been the only institution to provide a clear commitment to using European future launchers (see Chapter 2), whereas ESA Member States have not so far committed. As for the EC, it may provide some comfort in terms of procurement policy, but probably not a guarantee on the use of Vega-C and Ariane 6.
- The projected way forward remains to a large extent conservative rather than trend setting, at least for the new heavy-lift vehicle. The Resolution sanctions a *revolution* in terms of processes (efficiency-driven industrial reorganization and governance), but a mere *evolution* in terms of product – as the development of the new launchers, Ariane 6 in particular, is not technology-driven but cost-driven and subsequently will primarily rely on consolidated technologies.
- While flexible enough to respond to a wide range of needs, Ariane 6 has a strong commercial focus, and it is highly tailored to satisfying demand from commercial satellites operators. This commercial focus might make it more difficult to serve the main purpose of the Agency's missions. Furthermore, Ariane 6 is not designed to be human-rated. Consequently, Europe will not be able to conduct autonomous human spaceflight missions in the foreseeable future.
- In terms of production costs, Ariane 6 will be 40% less demanding than the current generation.[213] However, the development phase will still require a substantial financial investment focused on

[213] Interview of Arianespace CEO Stephane Israel. Bayart, Bertille, and Guillermard, Veronique. "Arianespace a su réagir à la concurrence". Le Figaro. 12 December 2015.

making use of heritage and consolidated technology. The new launcher will realize cost savings principally by virtue of modularity, common design synergies as well as industrial reorganization and streamlining. The core objective is to eliminate the need for public support payments during exploitation while maintaining a competitive pricing policy. Apart from this, however, European stakeholders have not clarified what the overarching goals of Ariane 6 and Vega-C are in terms of market share (e.g. Is Ariane 6 looking for a market duopoly with Space X, or is it looking for dominance?). Still, the risks to be borne by Member States due to market fluctuations are minimised, at least in principle. Industry, as prime designer – and exploiter – will carry those risks.

- There are limited margins of profit for Ariane 6. As noted, the expected launch cost of Ariane 64 is € 90/100 million while the launch price is € 115 million. This surplus will however be largely devoted to covering the mismatch between the expected launch costs (€ 78 million) and launch price (€ 70 million) of Ariane 62 (See Chapter 2.2.2). Crucially, this reduced margin allows little room for manoeuvre in case of a price war. Higher margins can be expected for Vega-C, provided that the difference between production costs (in the order of € 25 million) and launch price (ranging from € 35 to 45 million) can be maintained.
- The European benchmark on the future GTO market should not be only SpaceX's Falcon 9 or Falcon Heavy. The main GTO launchers of the 2020s other than Ariane 6 will consist of Vulcan, Falcon 9/Heavy, H-III, Long March 5/7, GSLV Mk-III and Angara A5. Considering respective phase-outs, the number of GTO-capable vehicles will be about the same as today. However, compared to today's situation in which the commercial GTO market is almost equally split between Arianespace and SpaceX, the future will probably see an increased degree of competition as more players will be interested in capturing a share of the commercial market (that, remarkably, is not expected to undergo a stronger cycle in the mid-2020s).[214] This could easily lead to a situation of overcapacity with respect to launch demand. However, the requirement to satisfy the respective institutional and domestic markets first, as well as currency fluctuations and export restriction considerations, indicate that the main competitors for Ariane 6 will be Falcon 9/Heavy and Vulcan, and probably by GSLV Mk-III, H-III and Angara A5 (see Chapter 4.4, Table 11 and Chart 9).
- The new launcher strategy appears to project the current policy reality over a 15-year period in the belief that the current strong market situation and beneficial financial scenario (with near-zero interest rates and favourable exchange rates) will last.[215] Potential oversupply or changed market conditions could lead to more aggressive competition on the commercial market by national actors - including a new price war similar to what the sector experienced in the early 2000's, with governments subsiding their launchers even more than today. Should this scenario materialise, it might be difficult for Ariane 6 to maintain its competitiveness, unless some form of financial backing from ESA Member States is reintroduced. In the meantime, the extent of support to the exploitation of Ariane 5 for the period 2016-2023 also remains unsettled.
- Furthermore, the new launcher strategy may not have been able to completely calibrate the strength of certain key factors such as the determination and focus of emerging powers and the eventual success of new entrepreneurial efforts in establishing and commercialising game-changing launch technologies and approaches. Indeed, the introduction of disruptive innovation technologies currently pursued by several launch providers, most notably first-stage reusability as well as non-vertical launch systems, could dramatically affect the new European launchers' future prospects and the anticipated competitive edge by the time it enters into service or soon thereafter.
- The roadmap for Vega, which just recently entered its commercial exploitation phase following the successful end of the VERTA programme, appears to be robust. However, the underlying objective of fully 'Europeanising' the new European launchers will not be achieved until the Ukrainian-made engine present

[214] See Euroconsult "Satellites To Be Built & Launched By 2022. World Market Survey". Euroconsult. 2013.

[215] Indicative of this, is the speech of Arianespace CEO Stephane Israel at the French Assemblée Nationale on 12 May 2015, in which he affirmed the possibility that Arianespace could outcompete SpaceX. e.c. Web. http://www2.assemblee-nationale.fr/14/commissions-permanentes/commission-des-affaires-economiques/secretariat/a-la-une/audition-de-stephane-israel-president-directeur-general-d-arianespace . Accessed 17 December 2015.

in the Vega fourth stage is replaced. This will happen possibly only in Vega-E (see Chapter 2.2.2). In addition, while the forecast evolution of the lightweight Vega into what will *de facto* be a medium-lift launcher (the performance envisioned for Vega-E would be up to 3,000 Kg to GTO) will meet the demand for launches of smaller payloads into GTO, it leaves open the question of how to best meet the ever-growing demand for small/micro satellites. Unless both Vega-C and Vega-E are made simultaneously available, there could be considerable difficulties in terms of the pairing of satellites and the scheduling of launches.

- Regarding the NGTO environment, it will probably continue to be dominated by captive institutional demand, but the growing number of commercial applications (and the related constellations) points to a possible increase of commercially competed contracts for small launchers. Still, there will be high competition to deliver payloads to LEO/MEO orbits between Vega-C, Epsilon, Long March 6/7, Antares, Athena III, Falcon 9, PSLV, Soyuz 2.1v and Angara 1.2.
- One of the main drivers behind the development of Ariane 62 and Vega-C is to replace Soyuz-ST. A major reason for this decision was that Soyuz does not sustain European industrial activities. Therefore, the decision down-prioritises the fact that the presence of the Russian-made Soyuz-ST at the Guyana Space Centre represented much more than mere technical and economic cooperation; that the presence was a significant geopolitical signal. The eventual phase-out leaves open the issue of finding an analogous valuable mechanism for European-Russian cooperation in space.[216]
- When comparing Europe's current strategy on access to space with policies and recent developments in the other major spacefaring nations (see Chapter 3), the following observations can be made:
    - Europe is following the worldwide trend of strengthening sovereign autonomy in access to space, by realizing an all-European family of rockets and thereby overcoming the current dependence of European institutional launches on the availability and prices of the Russian-made Soyuz. The era of international joint ventures seems to have reached an end at this stage.
    - Several countries are putting a strong emphasis on upgrading their launch infrastructure, also through the construction of new spaceports, while Europe will continue to rely on the Kourou site. While located in one of the most advantageous locations in the world, the Guyana Space Center will remain the only spaceport for Ariane and Vega in the foreseeable future, with inherent risks.
    - In addition to Russia, countries such as China and Japan are increasingly interested in using their launchers as a geopolitical tool to support their foreign policy objectives. In this respect, new trends are emerging. While in the past it was the launcher technology itself that was leveraged by means of technology transfers, today's efforts are taking the shape of offering to target countries a complete service package (which includes launch, satellite, and technical support to the domestic ground infrastructure). This new policy reality might have potentially disruptive effects in the launch market. Currently Europe seems to have no comprehensive plans for how to respond to this new approach.
    - There is a double convergence between Europe and Japan's launcher developments in terms of governance schemes and launcher performance. Commonalities in performance and timeframe can provide a basis for cooperation and the continuation of the current backup agreement for commercial services, including possibly extending this agreement to institutional launches as well. At the same time, the respective launchers are positioned to compete against each other in future markets.
- It could be argued that the U.S. and Europe are heading in opposite directions with regard to the structure of their institutional launch markets. In the U.S., the launch sector has been characterized by an ULA monopoly since 2006, with Atlas and Delta as the only viable options for launching national security payloads. The DoD is seeking to foster competitiveness,

[216] As *inter alia* urged by ESA Director General Johann-Dietrich Wörner, a new European-Russian space cooperation endeavour at a high political level should be found. See the ESA Director General's intervention at Q&A panel during the "International Conference on the European Space Launchers", Paris 3-4 November 2015.

so as to ultimately reduce the spiralling launch costs for its satellites and provide the necessary procurement redundancy for assuring access to space. This endeavour was met by success with the rise of SpaceX as a second launch service provider having completed the Air Force certification for the launch of national security payloads.[217]

In Europe an opposite process could be in the making. First, the end of the European-Russian Eurockot joint venture is all but certain, as the reconverted ICBM Rockot is progressively phased out.[218] In the coming years, no European company other than ASL will be able to provide launchers and launch services. Second, as the industrial governance reform of the European space transportation sector proceeds, CNES's share of Arianespace is set to be acquired by Airbus Safran Launchers, thus ending the presence of the institutional stakeholder in the launch service provider. This situation has already started to create serious concerns for both commercial satellite operators and satellite manufacturers like Thales Alenia Space (TAS). As emphasised by TAS Senior Vice President Christophe Wilhelm in a presentation at the "International Conference on the European Space Launchers" on 3 November 2015 in Paris, "an integration of Arianespace in ASL is, first of all, a significant market verticalisation move where one of its shareholders (Airbus Defence and Space) is also a major satellite manufacturer. [Ensuring] Arianespace's future growth potential and market competitiveness requires that major antitrust safeguards [will] be put in place to maintain the customer trust from all satellite manufacturers".[219] In addition, should a European preference clause be enforced for the procurement of launch services for institutional customers, a monopoly situation would *de facto* materialise with regard to the provision of launch services in Europe.

5.2 Europe's Way Forward: Some Reflections

Based on the areas of concern identified in the assessment above, the following sections provide a set of reflections on how to overcome the challenges identified. The considerations set out hereafter are not specific recommendations but rather open points of reflection for possible implementation in order to ensure the future competitiveness of Europe's launchers and optimise their strategic value. Considerations of political feasibility, affordability and effectiveness will be laid out at the end of the chapter, while concrete policy recommendations will then be provided in Chapter 6.

The following propositions have been grouped in five different – yet strongly interlinked – areas: future commercial launch market; disruptive technological innovation; use of launchers as geopolitical tools; human spaceflight; Europe's spaceports.

5.2.1 Enhancing the Commercial Competitiveness of European Launchers

As already noted, the supply and demand conditions of the launch market in the next decade cannot be forecast accurately. However, the anticipated stability in demand coupled with overcapacity in supply could easily lead to a price war similar to that experienced in the early 2000s, consequently forcing launch service providers to adopt more aggressive stances and arguably pushing governments to subsidise their launchers even more than now. Since one of the main drivers – not to say the most central one – behind the development of Ariane 6 and Vega-C is to eliminate the need for public support during exploitation, it is clear that a series of measures will be necessary if Europe wants to avoid such an eventuality. Five potential policy measures are outlined hereafter.

1. Ensuring – and ideally expanding – a solid launch business base for European launchers is certainly the most relevant measure for generating economies of scale and thus ensuring competitive prices for Ariane 6 and Vega-C.[220] This objective could be achieved by either enforcing a European preference clause for all European institutional missions or by introducing innovative – and so far unexplored – solutions such as the provision of launch packages to developing coun-

[217] SpaceX will probably launch its first U.S. Air Force satellite in 2018.

[218] Eurockot has on its backlog three Copernicus Sentinel launches for the EC, scheduled for launch in 2016.

[219] Cit. Wilhelm, Christophe. "European Space Launchers. Launch Services: Expectations from a Satellite Manufacturer". Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

[220] "For the first time, the meeting of Ministers for Space Policy also raised the issue of setting up a mechanism for jointly addressing requirements and terms and conditions for the supply of launchers for institutional space missions. Access to space is an essential element for space activity. Finding ways to guarantee this access under the best possible conditions is a major challenge for Europe." EU-ESA informal Space Council, 30 November 2015. Web. http://www.eu2015lu.eu/en/actualites/communiques/2015/11/30-ue-ase/index.html. Accessed 16 December 2015.

tries by leveraging Official Development Assistance (ODAs) (see below).

Europe is noticeably the only space actor in the institutional field that simultaneously finances the development of an autonomous fleet of launchers, and yet often purchases launch vehicles from foreign providers.[221] Thus, the enforcement of a "buy European" clause for all European institutional satellites could ultimately provide European future launchers with the institutional support they need to maintain their competitive edge in the global market without direct financial subsides.

However, it has to be stressed that a comprehensive and legally binding agreement might prove hard to reach. For one thing, the legal process would be extremely complex, as ASL would have to reach an agreement with each satellite operator, including the various national governments and the European Commission.[222]And this could potentially clash with some national legislation requiring commercial competition in the procurement of services.

In addition, there are visible political hurdles. Whereas in the current setup European satellite operators, either commercial or institutional, have the possibility to choose their launch option from the worldwide offerings (export control restrictions notwithstanding), under a "buy European" regime this possibility would cease, with the inherent risk of discouraging rigorous cost reduction efforts by industry, as happened during the period of ULA monopoly in the U.S. market. This risk would however be offset if the agreed fixed pricing can be maintained. Finally, it should be noted that even by introducing a European preference clause the expansion of the launch business base would not necessarily be sufficiently strong, in light of the limited demand for institutional missions in Europe.

Given that the often-raised suggestion to expand national launch demand in Europe can only materialise through radically changed demand, ideally the expansion of the launch business base for European vehicles should be achieved through the adoption of alternative measures. Among these, the practice of providing ODA to developing countries to support the procurement of European service packages (satellite, launch service and ground support) could arguably be an effective – though highly controversial – mechanism. Considerations of the political feasibility that relate to the implementation of this measure are provided later in the chapter. What needs to be highlighted is that endorsing such an option would allow Europe to tackle the need to increase its strategic presence with developing countries, particularly those interested in establishing their own space infrastructure.

2. Another possible measure to support European launchers in the global market is to reinforce the role of Export Credit Agencies (ECAs) in a more effective manner. While the importance of ECAs is often overlooked, in fact they play a crucial, strategic role for the satellite and space launch industry. Quite ironically, their importance becomes clearer when they fail to operate properly. Thus, when the activity of the U.S. Export-Import Bank was not re-authorised by U.S. Congressional budget appropriations, there were very negative repercussions on the competitiveness of U.S. aerospace industries. This in turn gave a considerable advantage to European operators, with the year 2015 being a record year in terms of contracts signed (for satellite export). In response to these undesired effects and the growing pressure of the U.S. Aerospace Industries Association, the U.S. Senate eventually attached an amendment to the Transportation Bill of 30 July 2015 reauthorizing the Ex-Im Bank.

   Whereas in Europe the French-based Coface already plays an important role in supporting European satellite exports and the commercialization of Ariane launch services, its effect is somewhat limited by its national character. European stakeholders could thus contemplate the creation of a pan-European ECA in which the resources of all actors involved are pooled to support the overall European space industry more strongly. As an alternative, the European Investment Bank (EIB) could be mandated to support the activities of European satellite manufacturers and Arianespace. In both cases, the European External Action Service (EEAS) could play an enabling role, so as to link the provision of European space-related services to the foreign policy ob-

[221] For instance the Italian COSMO Sky-Med constellation and German SAR-Lupe, launched by U.S. and Russian rockets respectively.

[222] On some of the legal issues related to the guarantee of a European institutional market for Ariane 6, see de Selding, Peter. "Profile: Antonio Fabrizi". Space News. 27 January 2015. Web. http://spacenews.com/profile-antonio-fabrizi-director-adviser-to-the-director-general-european-space-agency/. Accessed 2 December 2015.

jectives of the European Union (see below).

3. In order to enhance the commercial competitiveness of Ariane 6 and Vega-C, the launchers themselves could undergo some further technical development. As noted in Chapter 4.4, the demand for increased payload capacity is expanding at both ends of the mass spectrum: development plans in many nations envision the return of very-heavy-lift launchers, as well as a growing number of small launchers (mostly led by private company efforts). On the larger side of the mass spectrum, ESA and ASL could explore the possibility of reinforcing the performance and flexibility of Ariane 6 with an upgraded Ariane 66 (equipped with 6 boosters, for a capacity of 13,000 Kg to GTO, as currently being studied by CNES) in order to effectively respond to the projected market conditions of the next decade. On the smaller side of the mass spectrum, the development of a cheaper, micro-launcher system (a mini-Vega, so to speak) could offer great potential in terms of capturing the ever-growing micro/nano satellite launch market (see Chapter 4.3.5) – ideally making use of the small spaceports and launch bases already present in several ESA Member States (see Chapter 5.2.5).

4. Another possible way to support the competitiveness of European launchers in the future commercial launch market is – at least theoretically – to achieve international consensus on trade rules. Since one of the main drivers of the new European launchers is to eliminate the need for public support during exploitation, European stakeholders could arguably become interested in encouraging a transition of the commercial space launch market from an era of discriminatory government support structures toward a "free and fair trade" environment. Such a concept of "free and fair trade" should not necessarily be intended as trade free from substantial government support structures in the development of launch vehicles, but it could be thought of as achieving mutually agreed upon trading rules (such as the absence of distorting grants or subsidies, inducements to international customers, offering of additional services, or providing unregulated government funding).[223] Europe could also be interested in the establishment of a more stringent regime for commercial launches with regard to compliance with environmental requirements, where it has a rather strong competitive position.

   It has to be stressed that this way forward has a low level of political feasibility, given the need for the convergence of interests of many different and heterogeneous nations.[224]

5. Finally, the long-term competitiveness of European launchers could be greatly supported by the introduction of game-changing technologies, as detailed in the following section.

5.2.2 Promoting Disruptive Technological Innovation in Europe

As previously noted, the long-term competitiveness of European launchers will not come as a matter of course. Irrespective of the potentially successful commercialisation of Ariane 6, the increasing dynamism of the international launch industry and the hardening of international competition pose challenges that Europe must necessarily continue to confront. Such challenges dictate a steady and constant investment in launch capabilities that go beyond Ariane 6 / Vega-C. In particular, they dictate a strong commitment to the pursuit of disruptive innovation and to leapfrogging by way of new technologies.

When it comes to disruptive innovation, however, Europe is often regarded as a 'follower' rather than a 'trend setter', especially when compared to the "fast moving, risk-loving and pioneering" Silicon Valley entrepreneurs. While this general view does not do justice to the actual reality,[225] it is perhaps true that the often-praised, if not idolised, "Silicon Valley" mind-set is a typical American phenomenon.

However, as innovation economist Mariana Mazzucato has poignantly pointed out, the mythmaking about Silicon Valley's wildcat entrepreneurs often forgets that many of the seeds were planted by public sector agen-

[223] On general considerations on the benefits stemming from a "free and fair" trade environment in the launch market see Reed, James L., "The Commercial Space Launch Market and Bilateral Trade Agreements in Space Launch Services". American University International Law Review, Volume 13, Issue 1. 1999. p 170.

[224] The difficulty of establishing a regime for commercial launch services mainly stems from the fact such a regime would require cooperation mechanisms rather than simple coordination. Constructing international regimes to solve cooperation problems is inherently more complex, as they arise when individual and collective incentives cannot be aligned without adequate adjudication and enforcement mechanisms.

[225] For one thing, WIPO Patents statistics prove that Europe is a leading innovation centre.

cies.[226] Indeed, what is often heralded as a product of Silicon Valley creativity is in fact government-funded and backed research. For example many of the technologies that make the iPhone so smart (the Internet, the GPS, the Siri voice-recognition services and the multi-touch screen) were in fact the offspring of R&D efforts pursued by the government, and more precisely by DARPA.[227] In a similar fashion, DARPA has played – and continues to play – a crucial role in backing the competitiveness of SpaceX's launchers (see Chapter 3.1).

There is no DARPA-equivalent in Europe, and only a rather marginal involvement of the military. R&D efforts in the launcher sector have been essentially driven and supported by ESA and a few national agencies, while the most important pan-European instrument for pursuing technological innovation in general is the EU Framework Programmes for Research and Technological Development.

In this respect, it could be argued that pursuing disruptive technological innovation is a domain where not only ESA but also the EU should consider taking action. Two main reasons supporting complementary efforts can be pinpointed. First, the EC is generally better positioned to initiate programmes that pursue disruptive innovation. As opposed to sustaining innovation, the outcome of disruptive innovation is not guaranteed and thus it entails stronger risk and uncertainty in terms of pay-offs. In this sense this type of innovation requires strong political commitment and support – something that can more easily be provided by the EC, which in principle has a more risk-tolerant mandate Second, the EU as an actor has an interrelated number of interests and tools to support disruptive innovation in terms of industrial policy, promotion of European industrial competitiveness and research and innovation schemes.

Possible EU efforts towards ensuring the competitiveness and sustainability of European launch capabilities over the long term should thus be seen as complementary – not alternative – to those of ESA. The EU could allocate an amount of seed funding within the current Horizon 2020 Framework programme. Indeed, several proposals on the topics of "independent access to space" and "bottom-up technologies at low TRL" for industrial competitiveness were approved in the last few years.[228] Interestingly, at the "8th Annual Conference on European Space Policy", even EC DG GROW Director Philippe Brunet highlighted the possibility of the EC becoming more actively involved in activities related to future launcher development.[229]

Additional funding could thus, for instance, be allocated to pursue technological reusability of the first stage of an Ariane rocket, thus complementing the too modest research efforts currently undertaken by ESA and industry. Besides the fact that such efforts are not easy to implement within the EU Framework Programmes, it should be emphasised that supporting the development of potentially disruptive technologies in the launcher sector does not necessarily mean that Europe should follow the same path as SpaceX. Whether or not reusability proves cost-effective, choosing this path would continue to make Europe a follower rather than a trendsetter. Europe must find its own path. And there are already several examples of potentially disruptive space transportation technology in which Europe could take the lead and gain an economically profitable competitive advantage.

One of the most prominent examples is Reaction Engines' Skylon space-plane. As mentioned in Chapter 4.3.5, thanks to its SABRE engine, this project has a large potential to break the rules of the game and put Europe at the vanguard of access to space in the coming decades, though to achieve this it needs even stronger financial and political support. Additive manufacturing is another recent technological advancement that could constitute a game-changer for a plethora of manufacturing activities, including the satellite and launcher industry. Ultimately cheaper, more flexible and environmentally sound than traditional manufacturing, 3D printing is expected to cause a global industrial revolution and become the backbone of future industrial manufacturing for decades to come (see Chapter 4.3.4). While European industries already have a lead in this new sector ‾ and ESA's push forward in this sense

[226] Mazzucato, Mariana. "The Innovative State". Foreign Affairs. January/February 2015: 61-68.

[227] In the U.S the research and development effort for military technology is an important part of U.S. innovative activities and of the government's technological policy as a whole.

[228] See: Horizon 2020 Call H2020-COMPET 2015 of 4 November 2014 for research into breakthrough technologies to provide access to space and for research into Key Enabling Technologies with relevance for the fields of energy production, energy storage, material and structures, additive layer manufacturing techniques, etc.

[229] See the intervention of Philippe Brunet during the panel "Upheavals in sight in the launchers' market" at the "8th Annual Conference on European Space Policy". Brussels. 12-13 January 2016. See also: de Selding, Peter. "Brunet: EC Should Have Hand in Designing Europe's Next-gen Rocket". SpaceNews. 12 January 2016. Web. http://spacenews.com/brunet-european-commission-should-have-hand-in-designing-next-gen-rocket/. Accessed 25 January 2016.

is commendable[230] – stronger financial and political commitment by the EU would not only enable Europe to maintain its edge, but also allow European industries to widely exploit 3D printing for launcher manufacturing and therefore reap the benefits (primarily cost savings) for new generations of launchers. Alternatively, a EU-sponsored effort to test potentially disruptive technologies could be directed to exploring ground-breaking space transportation concepts, including non-rocket space launch concepts (e.g. mass drivers).

Irrespective of the specific concepts to be explored, what needs to be more broadly highlighted is that Europe should avoid playing S&T catch-up, but choose its own path to technological innovation, in space and elsewhere.

5.2.3 Boosting the Strategic Value of Launchers

Other than the driver of commercial competition, there also appears to be a strong geopolitical rationale behind the possible proactive involvement of the European Union in the launcher sector. As already emphasised in previous chapters, not only is it a strategic necessity for launchers to be secured for the conduct of any space undertaking, but they are also instruments at the service of a variety of policy objectives, including foreign policy. The way Russia, China and more recently Japan have been leveraging their launch vehicles on the international stage is a very clear example of this.

If looked at from a purely geopolitical perspective, Europe's launcher geopolitical strategy appears un-optimised at present: not only are European launchers not embraced as potential diplomatic tools; more importantly, their strategic significance is overlooked. It suffices to recall that current launcher-related activities, including the management of the launch infrastructure in French Guiana, are programmes subscribed to by ESA Member-States on an optional basis: arguably, something not truly reflecting a strategic good!

Moreover, Europe's policy on access is characterised by structural constraints of a political nature, which ultimately reflect the inherently national character of European politics (in space and elsewhere) and ESA's lack of an explicit political mandate. The constraints – which are well exemplified by the past dispute between France and Germany on post-Ariane 5 developments – constantly risk endangering an effective decision-making process for Europe's policy on access to space.[231] Not only that, but to a very large extent these structural constraints have also precluded the possibility of leveraging European launchers as potential diplomatic tools.

It can be argued that the proactive involvement of a *super partes* institution, such as the EU, may be necessary to better capitalise on the geopolitical dimension of access to space, independently from the specific interests of individual states.

Like many other countries, the EU has progressively developed a proactive S&T diplomacy to promote its goals, which has now emerged as one of its most important axes of cooperation with third countries and has gradually been extended to cover space affairs as well. As aptly argued by Nicolas Peter, the increasing inter-linkages of the EU's S&T and foreign policy are particularly important in space activities, as space has always been a domain of *high S&T politics*.[232] Launchers could thus be leveraged more in a geopolitical sense, so as to: a) strengthen Europe's political profile and b) provide stronger support to the EU's foreign policy objectives.

Given that launchers are one of the most tangible icons of a nation's space activities, the creation of a stronger EU brand in the field can be seen as of considerable importance to affirming Europe's role as a strong political actor in space and to substantially increasing European *actorness* and *presence* on the international scene. In addition, launchers could be instrumentalised as a tool for international alliance building with existing or emerging space powers and for S&T based diplomacy. As noted, one possible option is the provision of a 'complete launch package', (including launch, satellite and ground segment support) to developing countries interested in establishing their own space infrastructure. In a similar manner to what Japan has been doing (see Chapter 3.4), this strategy could even utilize ODA to build-up institutional demand for European launchers outside Europe. While certainly controversial from the perspective of interna-

[230] ESA - 3D Printing For Space: The Additive Revolution. 16 October 2013. Web. http://www.esa.int/Our_Activities/Human_Spaceflight/Research/3D_printing_for_space_the_additive_revolution. Accessed 2 December 2015.

[231] A broader reflection on this issue cannot ignore the broader misalliance between national and pan-European interests, not only in the launcher domain, but in the very concept of the European project itself. The necessity for a "Grand Strategy" for pan-European geopolitical endeavours is becoming increasingly evident as Europe faces a growing number of internal and external crises with discordant national voices. Leadership and enhanced cooperation are ultimately needed to put Europe on a firmer footing.

[232] Peter, Nicolas. "The EU's emergent space diplomacy". Space Policy 23. 2007: pp.97-107

tional development, such a move could prove very effective geopolitically, although it would re-introduce conditionality at a time when such concepts are out of favour. Another possible option for Europe is to leverage "discarded" launcher technology as a tool for alliance building with emerging space powers with ambitions for own launch capacity. While certainly worthy of consideration, this possibility appears less pursuable under current conditions where technology transfer agreements - which were instrumental in kick-starting the space transportation programme of many space nations – are today in sharp decline. This notwithstanding, it should be recalled that countries that are determined to achieve own launch capability will be successful in the shorter or longer run, and hence the question for Europe is whether it wants to be seen as a friend in these endeavours. Providing "last generation" technology might be the best way to build alliances while not undercutting the technological excellence of current generation launchers.

Irrespective of the specific way launchers can be instrumentalised, it is quite evident that these are important objectives that not only individual European countries and ESA, but more properly, the EU, have the legitimacy to address. The crafting of such arrangements goes well beyond the mere scope of technological and industrial cooperation. There are political payoffs at stake; payoffs from which the EU (specifically the EEAS) might harvest benefits, and it is thus safe to argue that through more active involvement in the sector the EU could better ensure the consistency of such initiatives with its overall foreign policy action. In such a scheme, the role played by ESA could become that of a "broker beyond the border" in service of a pan-European grand strategy defined by the EEAS.

Yet other potential pathways could also be considered.

As already mentioned in Chapter 3.7 and 4.4, one of the most important trends in the U.S., European and Japanese launch sectors is that industry is being entrusted with more and more responsibility in developing and exploiting a strategic asset like launchers. With the progressive shift in responsibility from the state to the private sector, the question that arises is whether in the future private companies will be able to support national foreign policy objectives through the utilisation of their launch vehicles. The recent manoeuvres of SpaceX vis-à-vis the Brazilian space programme seem to be clearly going in this direction.[233]

In this respect, interesting parallels could be drawn with the role of private companies in the energy sector: like launchers, the availability of natural resources such as oil and natural gas is a strategic necessity to be secured for national security. And like the commercialisation of launchers, energy extraction and distribution activities are predominantly commercial undertakings performed by private companies, yet at the same time they continue to be instrumentalised as geopolitical tools in support of the foreign policies of the major powerhouses.[234] These few observations already suggest that also in the launcher sector the ever-increasing role played by private companies like SpaceX, MHI and ASL could in the future lead to a progressive commoditization of access to space; a commoditization that would, however, be likely to be complemented by the enactment of strategic actions in support of the foreign policy goals of their respective governments.[235]

In the short term, the possibility for ASL to be assigned with functions of political support to the foreign policy objectives of the EU seems unrealistic, essentially due to the still fragile European diplomacy and lack of a one-voice system in Europe, but the potential is there and should not be overlooked.

5.2.4 Pursuing Autonomy and/or Cooperation in Human Spaceflight?

In the assessment, attention was drawn to the fact that Ariane 6 has a strong commercial focus, and it is in a certain sense almost exclusively tailored to satisfying the needs of commercial satellites operators. In light of the large revenues generated from the launch of commercial satellites the decision appears rather straightforward, but at the same time the question is how to serve the other important interests of ESA. Human space exploration is certainly one of these. Whereas Ariane

[233] Boadle, Anthony and Winter, Brian. "Exclusive: Russia, U.S. competing for space partnership with Brazil". Reuters. 15 June 2015. Web. http://uk.reuters.com/article/us-brazil-space-idUKKBN0OV22C20150615. Accessed 15 December 2015.

[234] Also see the concept of "Energy security", as the intersection of national security and the availability of natural resources for energy consumption. See for example: https://ec.europa.eu/energy/en/topics/energy-strategy/energy-security-strategy. Accessed 07 December 2015.

[235] This may not be the case for those countries in which access to space is still firmly under the control of state-owned companies, such as China and Russia – which again is a situation akin to the status of their energy sectors.

5 was originally conceived to be human-rated by design (although never exploited in this sense), Ariane 6 does not envisage such a possibility at this stage.

This choice will have important, long-term consequences for Europe. As ESA will not be able to conduct autonomous manned missions for the foreseeable future, the consequence is that ESA will continue to promote human spaceflight through a paradigm of "cooperation and interdependence". This approach is evident for instance in the agreement with NASA to develop and supply the Orion Multi-Purpose Crew Vehicle (MPCV) with the ATV derived Service Module, which will provide the spacecraft with propulsion, power and thermal control.

Whereas it is clear that for Europe any future space exploration scenario can only be achieved through international cooperation,[236] many – including ESA Director General Johann-Dietrich Wörner [237] – have suggested that international cooperation should not lead Europe to give up on home development, and that it should ideally develop full spectrum capabilities to be on equal footing in future cooperation endeavours with other space powers. Without a complete portfolio of capabilities, Europe's ability to shape the priorities and timing of future endeavours, its ability to attract partners, and its overall position in the "space hierarchy" will be diminished. In addition, not possessing critical technologies required for independent human spaceflight, Europe could run the risk of being kept out of the "critical path" and ultimately lose its voice on programme implementation, also in terms of decision-making.[238]

Therefore, to avoid such risks and exercise its 'space power' to the fullest extent possible, Europe should "demonstrate clear leadership across a wide range of space sectors, including space exploration, by having ambitious plans and objectives of great appeal to its stakeholders, as well as to potential international partners".[239] The role that Europe will play in global space exploration will ultimately depend on its actual capability in the field.[240]

However, feasibility considerations must also be properly taken into account. Any decision for Europe to develop an independent human spaceflight capability would require not only a huge financial effort – which spans from rocket and capsule development to launch site upgrades and maintenance – but also a very high degree of political will and support. This political dimension – which is arguably missing in the science-based and technology-focused approach of ESA to exploration activities – is an indispensable element for developing key capabilities in human spaceflight and becoming substantially involved in new major undertakings. It is no coincidence that such ambitious European programmes as Hermes and Aurora did not ultimately pan out. Nor is it a coincidence that, in spite of the considerable efforts of ESA over the years, a comprehensive and long-term vision for space exploration and human spaceflight in the post-ISS period is still lacking. In short, the development of autonomous capabilities will need financial backing and a sound political commitment at the highest level, which could then empower ESA to pursue and craft ground-breaking endeavours in human spaceflight. And, besides national governments, a supra-national actor such as the European Union could support pan-European efforts in this domain.

In this respect, a previous ESPI report has explored the possibility of embedding such goals within the framework of a new flagship programme by the European Commission.[241] The report showed that more pro-active EU involvement in this field could bring to human spaceflight activities the political dimension that is currently lacking in Europe, in addition to more solid financial investments for the implementation of a major undertaking in this domain. Concretely, an EU space exploration flagship programme could be devoted to the development of new complementary capabilities that have not been mastered through national and ESA programmes, and thus the technologies required for the development of a human-rated launch vehicle.

[236] This is evident from the policy orientations of all European stakeholders that have emerged since the first ESA-EU Conference on Human Space Exploration that was held in Prague in October 2009, and regularly reiterated in a number of documents, including the EC working document "A role for Europe within a Global Space Exploration Endeavour" released in August 2013

[237] Oral intervention of ESA Director General Johann-Dietrich Wörner during a Q&A panel at the "FFG Forum" in Vienna, 16 September 2015.

[238] On these points see Peter, Nicolas. Space Exploration 2025: Global Perspectives and Options for Europe. ESPI Report 14. Vienna. August 2008. See also Aliberti, Marco. "When China Goes to the Moon… ". SpringerWienNewYork. 2015.

[239] Cit. Ibid: p. 6.

[240] See for example: De Winne, Frank. "European Autonomy in Space: Human Space Flight". In Al-Ekabi, Cenan. European Autonomy in Space, Chapter 10. SpringerWien-NewYork.2015.

[241] See Aliberti, Marco, and Arne Lahcen. "The Future of European Flagship Programmes in Space". ESPI Report 53. Vienna. November 2015: pp. 40-46.

5.2.5 Securing Europe's Gateways to Space

In contrast to all other major spacefaring nations, which enjoy the availability of more than one spaceport on their continental territory, Europe continues to have *all its eggs in one basket*, as the Guyana Space Centre (GSC) is the only European spaceport available for launching Ariane and Vega rockets. In the case of the sudden unavailability of the Kourou launch pads, due to natural, accidental or geopolitical reasons, European launching autonomy would disappear. In addition, according to the plans of CNES for the GSC upgrades, the theoretical maximum launch capacity of Ariane 6 from Kourou will be 17 launches per year,[242] (i.e. one launch every three weeks).

In order to tackle the inherent risks posed by these factors, a number of options could be considered. Whereas the ideal solution for building a second, Ariane 6-capable spaceport within the continental territory of Europe or in another strategic location (e.g. within the Italian-owned Luigi Broglio Space Centre, near Malindi, Kenya)[243], would clearly present vast financial, political and security-related constraints, European stakeholders should continue to keep ready an array of measures to ensure redundancy of launch options and to address the potential need for increased frequency of launches. The Europe-Japan backup agreement (the so-called Launch Service Alliance) is certainly one of these mechanisms (see Chapter 3.4), but should perhaps be extended to include government launches.[244, 245] Similarly, Arianespace's arrangement with Starsem – which foresees the possibility of using the Baikonur/Plesetsk Cosmodrome for the launch of Soyuz-ST in case of necessity – has been of utmost importance for Arianespace, as evidenced by the successful conclusion of the Arianespace-OneWeb contract in summer 2015. In the light of the future phase out and replacement of Soyuz-ST with Ariane 62 and Vega-C, European stakeholders should consider the possibility of concluding a new agreement to ensure the availability of Soyuz from Baikonur/Plesetsk also in the next decade.

Some considerations should be also directed to the future management of the Guiana spaceport. As already noted, the GSC is not a truly European infrastructure, being financed through an ESA programme subscribed to on an optional basis by a limited number of European countries. Even acknowledging that the funding of the GSC will likely be secured after the expiration of the current financial scheme, it is also clear that the management of a strategic asset – indispensable for autonomy in space – should ideally be sustained through a Europe-wide effort. In the wake of the financial crisis, the necessity for increased "Europeanization" of the Guiana spaceport was already raised at the 2008 Ministerial Council, and reiterated in the resolution on the GSC for the period 2012-2017, adopted at the 2012 ESA Ministerial Council.

A dedicated debate among all European stakeholders on the future setting of the GSC should be seriously considered. Beside this, European stakeholders could also explore the potential of setting up additional European spaceports for small launchers to capture the increasing demand for small satellites, and even space tourism in the future. Andoya Space Center in Norway, Esrange Space Center and Kiruna in Sweden are in fact very well suited to accommodating a range of polar orbit missions and further infrastructure could be developed through a Europe-wide effort. In addition to that, the UK's efforts to build a spaceport viable for commercial flights are worth noting,[246] with two potential locations shortlisted as at the end of 2015.

5.2.6 Propositions Overview

When evaluating the possible implementation of the various policy measures proposed in the previous sections, some key indicators need to be taken into account. Three evaluative criteria prove to be particularly important: political feasibility, financial affordability, and effectiveness, which were measured on a five-level scale (very low, low, medium, high, and very high). The overall assessment of the propositions discussed in paragraphs 5.2.1 to 5.2.5 can be visualised in Table 14.

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[242] See Astorg, Jean-Marc. "The Ariane 6 System: On Board-Ground interfaces and launch facility. Presentation at "International Conference on the European Space Launchers". Paris, 3-4 November 2015.

[243] The spaceport, developed in the 1960s in cooperation with NASA, was used to launch Italian and commercial satellites on-board the American Scout rocket until 1988. While the base is still operational to track ESA, NASA and Italian satellites, the main offshore launch platform (San Marco) is no longer in use. For further information, see. Agenzia Spaziale Italiana. "Luigi Broglio Space Center". Web http://www.asi.it/en/agency/bases/broglio . Accessed 10 October 2015.

[244] Claudon, Jean-Louis. Presentation: "Cooperation in Launch Services". Arianespace. 08 October 2014: p.7. Web. http://www.eu-japan.eu/sites/eu-japan.eu/files/10.2-3-Claudon.pdf. Accessed 2 December 2015.

[245] On this point see Robinson, Jana. EU-Japan Strategic Partnership: The Space Dimension". ESPI Report 40. April 2012: p. 31.

[246] UK Space Agency, Department for Business, Innovation & Skills, Ministry of Defence, Foreign & Commonwealth Office. "Shaping the future of the UK space sector", 30 April 2014. Web. https://www.gov.uk/government/news/shaping-the-future-of-the-uk-space-sector. Accessed 02 December 2015.

Proposal	Political feasibility	Financial affordability	Effectiveness
Enactment of a European preference clause	Low	High	Very high
Expand the launch base through ODA	Medium	Medium	High
Establishment of a Pan-European ECA (e.g. EIB)	Medium	Medium	High
Development of an "Ariane 66" configuration	High	Medium	High
Development of a "mini-Vega"	Low	Medium	High
Achieving mutually agreed upon trading rules	Very low	Medium	Low
Seeding fund for disruptive innovation	High	Medium	High
Use of 3D printing for launchers manufacturing	High	Medium	High
Provision of ODA for launch services	Low	Medium	High
EEAS involvement in technology transfer	Very low	Medium	High
ASL support to European foreign policy	Low	High	High
Development of a human rated launcher	Very Low	Very low	High
New spaceport/launch pad for Ariane and Vega	Low	Very low	Medium
Launch backup agreements	Medium	High	Medium
Utilization of launch sites in Europe for small launchers	High	Low	High

Table 14: Overview of potential policy measures.

6. Conclusions and Recommendations

By any measure, access to space has been a true success story for Europe. Despite uncertain beginnings, pan-European cooperation efforts have guaranteed the availability of an independent, reliable and efficient means for launching into space for over more than three decades. The Ariane family of launchers has become a symbol of European autonomy and achievement in space, and more broadly a "tangible sign of what Europe can do when it is genuinely united when it resolves to pursue European goals and there is the shared wisdom to see what should be avoided".[247]

Thanks to an impressive launch performance, the Ariane 5 rocket, the most recent and major evolution of the Ariane launcher family, has emerged as a global point of reference for commercial launches and a cornerstone of European institutional launches, while the exploitation of lightweight Vega is proving very fruitful.

Whereas European launchers have many achievements to look back on, the great dynamism of both the supply and demand conditions of the international launch industry has been posing challenges that Europe has had to confront. In order to ensure the long-term availability and commercial sustainability of its gateways to space, the ESA Ministerial Council of 2 December 2014 approved the development of a new modular family of launchers and sanctioned radical changes in the structure of the European launch sector.

Such decisions will probably go down in history as a turning point for Europe, comparable to the very first decision to proceed with the development of Ariane itself. Indeed, there are interesting parallels between the two historical junctures. Just like the years before the 2014 Ministerial Council, the Ministerial Conference of July 1973 was preceded by a period of intense disagreement between the two leading European nations, France and Germany. And just like Ariane 6, the first Ariane was born – to use the words of John Kriege – "at a time of great uncertainty and ambiguity […]. The overriding fear in the minds of many was that Europe was investing in an obsolete technological concept, which could never be commercially competitive with NASA's technologically innovative reusable Space Shuttle".[248]

Greatly supported by well-defined goals, by a strong dose of Gaullism and also by "une part de chance", the first Ariane turned out to be stunningly successful.

As for Europe's future path, the implementation of additional policy actions may prove necessary to ensure that the decisions endorsed at the 2014 Ministerial Council will steer Europe's access to space in a direction as bright as it has been in the past. This path will meet its first key milestone in June 2016, when ESA, ASL, and its subcontractors will review the preliminary design of Ariane 6. This will be followed by another ESA Ministerial Council, which will be convened in Lucerne, Switzerland, in late 2016.

A variety of possible policy measures has been already explored in the previous chapter. While not all these propositions can be easily implemented, primarily due to considerations of political feasibility, affordability and effectiveness (see Chapter 5.2.6), there are concrete steps that can be taken to ensure the long-term availability and competitiveness of autonomous access to space for Europe. Relevant recommendations and possible concrete policy options are the following:

1. It is recommended that the debate on Ariane 6 and Vega-C follow-ups should be pursued in the very near future. Ideally, decisions on a possible Ariane 66 configuration and on Vega-E should be taken as early as the ESA Ministerial Council of 2016, and those on Ariane 7 well before the Ariane 6 qualification flight in 2020 – which also needs to be confirmed. It is also recommended that these decisions become part of a unified "European Roadmap for Access to Space" that will pave the way for a smoother decision-making process in the future, and ultimately make Europe a more pro-active and trend-setting actor vis-à-vis the rapidly evolving worldwide landscape of access to space.

[247] Cit. Charles Hanin, President of the 1973 European Space Conference.

[248] Kriege, J. "The History of the European Launchers: an Overview". In Proceedings of an International Symposium on "The History of the European Space Agency". 11-13 November 1998, London. ESA SP-346. 1999: 69-78.

2. A dedicated European-wide R&D seed funding or programme (also at start-up level) for targeting disruptive technological innovation – particularly, but not only – in the domain of launchers, should be established. Funding could be provided by more risk-tolerant actors such as the European Commission – and due to the absence of geo-return constraints, in a steadier manner than today.

3. In light of the future phase-out of Soyuz from GSC, an alternative and symbolic instrument for European-Russian space cooperation should be identified. Since it is unlikely that future cooperative undertakings will directly involve access to space – also considering the general trend of strengthening national autonomy and privatisation or re-nationalisation of the industry – the historical capacity of Europe to act as a bridge- and coalition-builder should be more firmly enshrined into the broader framework of a "European Vision for Space", in which other options are explored. Among these, the idea of a Moon Village, recently promoted by the ESA Director General, could indeed provide an even more symbolic and effective framework for cooperation in the post-ISS period, resulting in a bold international endeavour endorsed at the very highest political level.

4. The creation of a "pan-European ECA" should be considered. In this respect, the European Investment Bank could be entrusted with dedicated functions of support for the export of European satellites and launch services, with the ultimate goal of providing a larger launch business base both for current and future European launch systems.

5. ESA and its Member States should assess the possibility of better leveraging existing small spaceports / launch pads such as Andoya and Kiruna or the upcoming launch facility in the UK, by incorporating the possibility of accommodating new light-weight launch vehicles. These infrastructures are well suited for polar orbit missions and would thus enable the capture of the ever-growing demand for small/micro satellites. Such decisions would ideally be accompanied by the introduction of an even smaller configuration of the Vega rocket or even by opening these spaceports to international launch service providers.

6. The possibility of building a second launch site for Europe's upcoming launchers should be considered to ensure redundancy and cope with the potential need for increased launch frequency. At the same time, in view of the converging dynamics and similarities between European and Japanese launcher programmes, extending the Europe-Japan launch backup agreement to cover institutional missions would provide a greater margin for assuring Europe's access to space in case of the unavailability of Kourou. When compared to the highly demanding – in both political and financial terms – establishment of a second launch site for Ariane 6, such a move would entail rather marginal efforts, while at the same time providing politically relevant benefits to be harvested. Equally importantly, European stakeholders should consider the possibility of concluding a new agreement to ensure the availability of Soyuz from Baikonur/Plesetsk in the next decade.

7. The development of full spectrum capabilities in access to space, and in particular the development of a human-rated launch vehicle and re-entry system, should not be put on the backburner, but more actively discussed among all European constituencies within a broader vision for space exploration in the post-ISS period, by *inter alia* considering the potential benefits offered by the involvement of both European institutions and private companies in future space exploration and human spaceflight activities.

8. Finally, the potential benefits offered by more active involvement of other EU institutions, particularly the EEAS, should be considered with regard to a more efficient exploitation of launcher-related technology or services for S&T-based diplomacy. Among the possible options, the provision to developing countries of "launch package agreements" through ODA could be a highly effective geopolitical move for also providing indirect support to the European space industry. The benefits of assisting the building of geopolitical alliances through the transfer of 'previous generation' technology to countries intent on developing own launch capabilities should also be kept in mind, particularly at this time of generational changeover in launchers in Europe.

Annex

A.1 Worldwide Expendable Orbital Launch Vehicles as at 2015

U.S.

ULA – Atlas V and Delta IV

The United Launch Alliance (ULA) consortium, a joint venture of Lockheed Martin and Boeing formed in 2006 to provide spacecraft launch services to the U.S. government, currently provides the Delta IV and Atlas V family of launchers. Both are heavy-lift vehicles with the capability of reaching GTO. The Atlas V is considered the workhorse of the U.S. launchers, with 127 successful launches for the overall Atlas programme, and a reliability of 100%. Originally a product of the U.S. Air Force's Evolved Expendable Launch Vehicle Program (EELV), it is now manufactured and operated by ULA, which also commercializes it in the U.S., while in the worldwide commercial market it is sold by Lockheed Martin Commercial Launch Services (LMCLS). It consists of a Common Core Booster (CCB) powered by a Russian RD-180 engine, a Centaur upper stage, and can also use up to five solid-rocket strap-on boosters attached to its first stage. The CCB engine is manufactured by RD Amross, a joint venture between Pratt & Whitney Rocketdyne and NPO Energomash, a company largely owned by the federal government of Russia, while the upper stage engine is manufactured by Aerojet Rocketdyne. Its various versions can deliver up to 18,500 Kg into LEO and 8,900 Kg into GTO. While in principle available on the commercial market, due to high prices and a launch manifest dominated by government missions, it has attracted little commercial business.

Delta IV is the second family of rockets derived from the EELV and now manufactured and operated by ULA, which also markets it in the U.S., while Boeing Launch Services commercializes it worldwide. Delta IV is available in five variants, constituted by a Common Booster Core (CBC) and various cryogenic upper stages with engines manufactured by Aerojet Rocketdyne. It first debuted in 2002, and can deliver a payload of up to 22,560 Kg into LEO and 14,400 Kg into GTO, in its Delta IV Heavy version.

SpaceX – Falcon 9

With a first successful launch achieved quite recently, in 2008, with the Falcon 1 and in 2010 with the Falcon 9, Space Exploration Technologies Corporation (SpaceX), a private company founded by billionaire Elon Musk, has quickly imposed itself as a major player in the commercial launchers market. Its Falcon 9 v1.1 medium-to-heavy lift rocket has achieved 18 successful launches and one failure as at October 2015, and has a launch manifest of more than 30 future launches in the next few years.[249] The dual-stage vehicle is powered by SpaceX-manufactured engines, the Merlin 1D, and can launch the Dragon cargo module to resupply the International Space Station, a large payload to LEO (up to 13,150 Kg) or a medium-sized payload to GTO (up to 4,850 Kg). Its launch pads are located at Cape Canaveral Air Force Station (CCAFS) and Vandenberg Air Force Base (VAFB).

Orbital ATK – Antares, Minotaur-C, Pegasus XL

The Antares vehicle is the first two-stage cryogenically fuelled rocket commercialized by Orbital ATK, a company previously focused on solid-fuelled rockets such as Pegasus, Taurus and Minotaur. The Ukrainian company Yuzhnoye, with two engines derived from the Russian NK-33 originally developed for the Soviet Union's heavy-lift N-1 rocket in the 1960s produces its first stage. The second stage is produced either by Alliant TechSystems or by Orbital according to customer needs. Antares is launched from the Mid-Atlantic Regional Spaceport (MARS) located on Wallops Island (Virginia), provides access to LEO (up to 5,700 Kg), and can also carry the Cygnus cargo module to the ISS.

The Minotaur family is derived from converted U.S. ICBMs. Its latest version, Minotaur C, is a small, four-stage solid-propelled launcher derived from the Taurus launcher family, designed as a quick reaction launch

[249] SpaceX - Launch Manifest. Web. http://www.spacex.com/missions. Accessed 02 December 2015.

vehicle mostly intended for small national security payloads. It is aimed at placing small payloads up to 1,160 Kg to LEO or 1,600 Kg to SSO. Following several failures in 2009 and 2011, it has now been upgraded, with a first launch scheduled for 2016.

Conceived by Orbital as a low-cost system to launch small satellites to LEO, the air-launched Pegasus XL can place in orbit light-weight payloads up to 450 Kg. In service since 1994, it has seen reduced launch rates in the past few years (only three since 2008) as piggyback options with other launchers have flourished.

Russia

Rockot

Developed from refurbished intercontinental ballistic missiles (ICBM) components by Khrunichev and marketed by Eurockot, a joint company between Khrunichev and Astrium, the Rockot is a three-stage launch vehicle predominantly used for sending scientific, Earth observation and climate monitoring satellites into LEO orbit - it is scheduled to launch EU Copernicus satellites Sentinel 3A, 2B and 5P in 2016. It can deliver up to 2,150 Kg in LEO from the Plesetsk launch centre.

Dnepr

The Dnepr is another launch vehicle derived directly from a surplus of Soviet ICMBs, the R-36 (known outside the USSR as SA-88), and refurbished by the Ukrainian company PA Yuzhmash. The launch service provider is a joint project between Russia, Ukraine and Kazakhstan, ISC Kosmotras. It is suitable for launching medium-sized payloads (up to 3,700 Kg) or clusters of small and micro satellites into LEO from the Baikonur Kosmodrome or the Russian Dombarovsky missile base.

Proton-M

International Launch Services (ILS), a U.S.-Russia joint venture, provides and commercializes the Proton-M, the latest iteration of an historical Russian launch family. Manufactured by Khrunichev and launched from the Baikonur Kosmodrome, Proton-M is a four-stage vehicle mainly suited for government and satellite operators aiming at the geostationary orbit, with a GTO capacity of 6,920 Kg.

Soyuz FG and 2.1 a/b/v

Thanks to its three different launch sites - Baikonur, Plesetsk and the Guiana Space Centre (GSC) - the Soyuz 2 achieves great versatility in placing medium-sized payloads into any orbit, as well as being currently the only launcher system certified to carry astronauts to the ISS. The Russian companies TsSKB-Progress and NPO Lavotchkin manufacture its first two stages, and the third stage is built by NPO Lavotchkin. The vehicle comes in two versions, an older Soyuz FG used for human spaceflight programmes, and the currently commercialized Soyuz 2. The launch service providers for Soyuz 2 are Arianespace for the GSC launch centre, and its sister company Starsem for launches from Baikonur.

China

Long March 2

Built by the Shanghai Academy of Spaceflight Technology (SAST) and marketed by the China Great Wall Industry Corporation (CGWIC), the Long March 2 launch vehicle is provided in two versions, 2C and 2D. Long March 2C is predominantly used to place payloads in SSO orbit, and is launched from Jiuquan Satellite Launch Center (JSLC). Long March 2D is launched from JSLC, Taiyuan Satellite Launch Center (TSLC) and Xichang Satellite Launch Center (XSLC). Long March 2 series launch vehicles have a capacity of around 3,850 Kg to LEO or 1,300-1,900 Kg to SSO.

Long March 3

The three-stage Long March 3 family, marketed by the CGWIC and manufactured by the China Academy of Launch Vehicles (CALT), constitutes China’s commercially available vehicles to place payloads into GTO. It is available in several variants (3A, 3B, 3BE, 3C) with various boosters and fairings, combining a GTO capacity varying from 2,600 to 5,500 Kg. It is launched at XSLC.

Long March 4

The Long March 4C, also known as the Chang Zheng 4C, CZ-4C and LM-4C, previously designated Long March 4B-II, is a 3-staged rocket with a performance of 4,200 Kg to LEO or 2,800 Kg to SSO. It is launched from the Jiuquan and Taiyuan Satellite Launch Centers. It is manufactured by SAST and commercialised by CGWIC.

Long March 6

Long March 6 (also known as Chang Zheng-6) is a recent vehicle developed by China Aerospace Science and Technology Corporation and the China Academy of Launch Vehicle Technology. It features two solid stages and a restartable third stage to allow precision orbital injections. Its performance is 1,500 Kg to LEO, or 1,080 Kg to a 700 Km SSO, and achieved a first launch from the Taiyuan launch site in late 2015. It is expected that the launcher will be made commercially available.

Long March 11

The Long March 11 is a solid-fuel rocket designed to meet the need to rapidly launch satellites, and developed by CALT. It was first launched on 25 September 2015, carrying a payload of microsatellites to SSO. There is, however, a dearth of information regarding the specifics of this new launch vehicle.

Japan

H-IIA/B

Mitsubishi Heavy Industries (MHI) designed and built the two-stage liquid H-IIA and H-IIB launchers, which are Japan's main launch vehicles. Coming in two versions for the former, and one for the latter, H-IIA is mainly used to launch payloads to LEO, GTO and Earth escape orbit. The larger H-IIB currently launches the H-II Transfer Vehicle (HTV) to the ISS, but recently has been made available on the commercial satellite market. The launch site is located in Tanegashima.

Epsilon

Developed for the small-satellites market, the solid-propelled Epsilon rocket was intended to provide a low-cost, easy and efficient launch service. Its three-stage configuration can carry up to 700 Kg to LEO, but it can also place payloads into SSO by using a liquid post-boost stage. It is launched from the Uchinoura Space Center.

India

PSLV CA, G and XL

The Polar Satellite Launch Vehicle (PSLV) is India's main launch vehicle for Sun-Synchronous Polar Orbit (SSPO) as well as LEO. It consist of a four-stage system produced in several variants, specialized in launching medium-to-small payloads (mini- and micro-class satellites) also in a multi-satellite configurations, with a capacity of up to 1,750 Kg to SSPO and 3,250 Kg to LEO. Notably, the PSLV also successfully launched the first Indian Moon mission, the Chandrayaan-1.

GSLV Mk-II (also known as GSLV)

With a payload target of 2,500 Kg to GTO and 5,000 Kg to LEO, the Geosynchronous Satellite Launch Vehicle (GSLV) is the main medium-lift, three-stage launcher developed by India, using proven components from the PSLV programme. In addition to the delivery of communication satellites to the geostationary orbit, the GSLV programme was primarily developed to launch the multi-purpose INSAT (Indian National Satellite System) class of satellites, to satisfy the country's needs in terms of telecommunication, broadcasting, meteorology and Search and Rescue operations.[250]

[250] Indian Space Research Organization (ISRO) - Geosynchronous Satellite Launch Vehicle. Web. http://isro.gov.in/launchers/gslv. Accessed 2 December 2015.

Summary of Current Expendable Orbital Launch Vehicles. [251]

Launch Vehicle	Launch Service Provider	Performance range (Kg) LEO	SSO	GTO	GEO	Launch Site
Europe						
Ariane 5 ECA	Arianespace			10,500		Guyana Space Centre
Soyuz-ST	Arianespace		4,400	3,200		Guyana Space Centre
Vega	Arianespace	1,500				Guyana Space Centre
USA						
Atlas V series	ULA/LMCLS	9,800 – 18,800	7,700 – 15,000	4,700 – 8,900	Up to 3,900	CCAFS, VAFB
Delta II	ULA	2,800 – 6,000		1000 – 2,100		CCAFS, VAFB
Delta IV Medium	ULA	9,400 – 14,000	7,700 – 11,600	4,400 – 7,300	1,200 – 3,100	CCAFS, VAFB
Delta IV Heavy	ULA	28,800	23,600	14,200	6,800	CCAFS, VAFB
Falcon 9 v.1.1	SpaceX	13,100		4,900-5,300		CCAFS, VAFB, KSC, Brownsville
Antares	Orbital ATK	3,850 – 5,650	2,900 – 4,450			WFF, CCAFS, VAFB, KLC
Minotaur	Orbital ATK	1,000 – 3,360	700 – 1,830			WFF, CCAFS, VAFB, KLC
Russia						
Proton M / Block DM	Khrunichev	19,800		4,400	1,900	Baikonur
Angara 1.2	Khrunichev	3,800				Plesetsk, Vostochny
Soyuz 2-1.a/b	TsSKB Progress	7,000 – 8,300				Baikonur, Plesetsk Vostochny
Soyuz 2-1.v	TsSKB Progress	2,800	2,600			Plesetsk, Vostochny
Soyuz FG	TsSKB Progress	7,130				Baikonur
China						
Long March 2 series	CGWIC	3,850	2,100			Jiuquan, Taiyuan, Xichang
Long March 3 series	CGWIC	6,000 – 11,500	5,100 – 7,100	2,600 – 5,500		Xichang
Long March 4	CGWIC	4,600	3,100	1,420		Xichang
Long March 6 series	CGWIC	1,500	1,000			Wenchang, Taiyuan, Jiuquan, Xichang
Japan						
H-IIA series	MHI	10,000	4,400	2,900 – 6,000		Tanegashima

[251] Data as at December 2015, including vehicles not commercially active. Source: ESA.

H-IIB	MHI	16,500				Tanegashima
Epsilon	JAXA	700 – 1,200	> 500			Uchinoura
India						
PSLV	Antrix/ISRO	2,100 – 3,700	1,050 – 1,750	1,100 – 1,500		Satish Dhawan Space Centre
GSLV Mk-II	Antrix/ISRO	>6,000	>2,300	2,500		Satish Dhawan Space Centre
Ukraine						
Zenit-3F	SIS/Yuzhnoye	13,900		4,000	1,900	Baikonur
Zenit-3FU	SIS/Yuzhnoye	4,500		4,100	2,100	Baikonur
Multinational						
Zenit-3SL	Sea Launch/ Ener-gia	7,300		6,200		Odyssey Platform
Zenit-3SLBU	SIS/Yuzhhnoye			4,900	1,900	Baikonur
Rockot	Eurockot	2,100	1,600			Plesetsk
Dnepr-1	ISC Kosmotras	3,700	2,300			Yasny, Baikonur
Proton M	ILS	23,000				Baikonur
Proton M / Breeze M	ILS			6,900	3,300	Baikonur

A.2 Launch Vehicles under Development

U.S.

ULA – Vulcan

The New Generation Launch System (NGLS) being developed by ULA stems from the decision to stop the use of Russian-made RD-180 engines for national security missions, which constitute the majority of Atlas V payloads. It foresees a process based on several steps, initially based on reliable Atlas V and Delta technology. Vulcan should be flown starting in 2019, with a target performance of 18,000 Kg to LEO and 8,900 Kg to GTO. A further step scheduled for 2023 envisages a new upper stage called the Advanced Cryogenic Evolved Stage (ACES), allowing for greater mission flexibility. Its target performance, although still susceptible to further changes, is 37,000 Kg to LEO and 18,000 Kg to GTO. Finally, the last step in 2024 foresees the introduction of Sensible, Modular, Autonomous Return Technology (SMART) technology, allowing the recovery of the propulsion system of the first stage.

SpaceX – Falcon Heavy

Already purposed as "the most powerful operational rocket in the world by a factor of two", Falcon Heavy's first flight is scheduled for 2016. Its first stage will be composed of proven technology, such as central Falcon 9 v1.1 engine cores, and two side cores from the upgraded Falcon 9, for a grand total of 27 Merlin 1D engines. Its intended performance is 53,000 Kg to LEO, or 21,200 Kg to GTO, and it is already designed to meet all the current requirements for human rating, and to benefit from first-stage reusability technology. It will be launched from the Vandenberg Air Force Base.[252]

NASA – SLS

The SLS (Space Launch System) is NASA's planned very heavy-lift rocket intended to replace the cancelled Ares-5 concept, targeting beyond-LEO exploration and high energy, deep-space missions, chiefly sending humans to Mars. It will make use of several proven elements from the Space Shuttle programme, such as the Solid Rocket Boosters (SRB), to reduce the upfront development time and costs, and will be NASA's fist human-rated vehicle since the Shuttle itself. Its 2-phase development approach ("Block 1" and "Block 2" configurations) envisions reaching a 70,000 Kg LEO capacity for 2018, and a 130,000 Kg performance for 2021. The manned version of SLS will feature the Orion Multi-purpose Crew Vehicle. Its first launch will take place at Kennedy Space Center in Florida.

[252] SpaceX – Falcon Heavy. Web. http://www.spacex.com/falcon-heavy. Accessed 02 December 2015.

Russia

Angara 1.2

The smallest Angara under development is the Angara A1.2, which consists of one URM-1 core and a modified Block I second stage. It can deliver 3,800 Kg of payload to a 200 Km x 60° orbit. A modified Angara 1.2, called Angara 1.2PP, made Angara's inaugural sub-orbital flight on July 9, 2014. The flight carried a mass dummy weighing 1,430 Kg. Angara A1.2PP consists of a URM-1 core stage and a partially fuelled 3.6-metre diameter URM-2, allowing each of the major components of Angara A5 to be flight tested before that version's first orbital launch, conducted on December 23, 2014. Angara will primarily be launched from the Plesetsk Cosmodrome, and in future from Vostochny.

Angara 5

The second Angara being developed is the Angara A5, which is intended to replace Proton as the major Russian heavy-lift launch vehicle after 2020. It consists of one URM-1 (Universal Rocket Module) core and four URM-1 boosters, a 3.6m URM-2 second stage, and an upper stage, either the Briz-M or the KVTK. Angara A5 has an overall payload capacity of 24,500 Kg to a 200 Km x 60° orbit, and can deliver 5,400 Kg to GTO with Briz-M, or 7,500 Kg to the same orbit with KVTK. It is currently in an advanced test phase, with 9 test flights left as at end 2015. It will be also proposed in a manned version, called Angara A5P, with a capability of 18,000 Kg to LEO.

Angara 7

The A7 concept envisages six strap-on URMs each one with one RD-191 engine, and a larger core stage for increased fuel capacity. Its intended capacity is 40,500 Kg to LEO, 12,500 Kg to GTO and 7,600 Kg to direct GEO orbit.

China

Long March 5

China's next-generation heavy-lift launch system, the Long March 5 family, is currently under development by the China Academy of Launch Vehicle Technology (CALT). Six versions of LM-5 are envisaged, aiming at a maximum payload capacity of 25,000 Kg to LEO and 14,000 Kg to GTO and potentially commercially available. The designated launch site is the new Wenchang Satellite Launch Center.

Long March 7

The Long March 7 is devised as a modular family of medium-lift rockets intended to replace the current LM-2, LM-3 and LM-4 families. Therefore, its intended performance varies from 3,000 to 10,000 Kg to LEO, and 1,500 to 6,000 Kg to GTO depending on the rocket configuration. It will make use of the Wenchang Satellite Launch Center, with a first flight scheduled for early 2016, and will be commercially available.

Long March 9

To allow for long-term outer space exploration objectives, including manned Moon missions, CALT is also developing a three-stage, very heavy-lift vehicle, under the name Long March 9. Its performance would be similar to NASA's SLS, i.e. 130,000 Kg to LEO. The first flight is scheduled no earlier than the 2030s, and, like the SLS, it is not intended for the commercial market.

Japan

H-III

Intended to replace the current H-II at a lower cost, the two-stage H-III rocket will be featured in three different configurations, having zero to four strap-on solid boosters in a configuration not unlike the planned Ariane 6. Its intended performance is up to 6,500 Kg to GTO, with a first flight planned for the early 2020s from the Tanegashima launch site.

India

GSLV Mk-III

The long-sought Indian evolution of its GSLV, the GSLV Mk-III heavy lift vehicle, has been under development by ISRO since the early 2000s, with a scheduled first flight now envisioned for 2017. Composed of three stages, including a cryogenic upper stage, it is aimed at deploying satellites up to 4,000 Kg to GTO, but the vehicle has also been designed to be human-rated, in order to possibly deliver an ISRO-made exploration vehicle into orbit as well. A proposed upgrade would increase the payload capacity to 6,000 Kg to GTO.

Summary of Orbital Launch Vehicles under Development. [253]

Launch Vehicle	Performance range (Kg) LEO	SSO	GTO	GEO	Launch Site	First Flight
Europe						
Ariane 62			5,000		Guyana Space Centre	2020
Ariane 64			10,000 – 11,000		Guyana Space Centre	2020
Vega–C		1,500			Guyana Space Centre	2018
U.S.						
Falcon Heavy	53,000		21,200		CCAFS, VAFB, KSC, Brownsville	2016
Athena III	5,200 – 5,500	3,700 – 4,300			KSC , CCAFS (VAFB, WFF)	TBD
Vulcan Step 1-2	> 18,800		> 8,900	3,900	CCAFS, VAFB	2019
Vulcan Step 3	37,000		18,000	8,700	CCAFS, VAFB	2024
SLS Block 1	70,000				KSC	2018
SLS Block 2	130,000				KSC	2021
Russia						
Angara A3	14,600		2,400 – 3,600	1,000 – 2,000	Plesetsk, Vostochny	> 2020
Angara A5	24,500		5,400	3,000	Plesetsk, Vostochny	2016
Angara A5P	18,000				Plesetsk, Vostochny	2016
Angara A7	40,500		12,500	7,600	Plesetsk, Vostochny	> 2028
China						
Long March 6 series	1,500	1,000			Wenchang, Taiyuan, Jiuquan, Xichang	2016
Long March 7 series	3,000 – 10,000	5,500	1,500 – 6,000		Wenchang, Taiyuan, Jiuquan, Xichang	2016
Long March 5 series	18,000 – 25,000		6,000 – 14,000		Wenchang	2015
Long March 9	130,000				?	> 2023
Japan						
H–III			2,800 – 6,500		Tanegashima	2020
Epsilon phase 2	1,500 – 1,800	> 750			Uchinoura	> 2017
India						
GSLV Mk-III	8,000		4,000		Satish Dhawan Space Centre	2017
Israel						
Shavit LK-2		800			Palmachim	TBD
Republic of Korea						
KSLV-II		1,500			Nora	2020

[253] Data as at December 2015. Vehicles with a performance of under 500kg were not considered. Source: ESA.

Argentina						
Tronador III	1,000				Puerto Belgrano	TBD
Brazil						
VLS Alfa/Beta	500 – 800				Alcantara	2020

A.3 Overview of Major Orbital Launch Sites

Name	Location	Operator	Main Launch Vehicle
Europe			
Guyana Space Centre	French Guiana, France	CNES	Ariane 5, Vega, Soyuz-ST
U.S.			
Cape Canaveral Air Force Station	Florida, USA	USAF	Atlas V, Delta, Falcon, Athena, Minotaur, Pegasus
Kennedy Space Center	Florida, USA	NASA	Falcon 9, SLS
Vandenberg Air Force Base	California, USA	USAF	Atlas V, Delta, Falcon, Athena, Minotaur
White Sands Missile Range	New Mexico, USA	USAF	
Kodiak Launch Complex	Kodiak Island, Alaska, USA	AADC	Antares, Athena, Minotaur
Wallops Flight Facility	Wallops Island, Virginia, USA	NASA	Antares, Athena, Minotaur, Pegasus XL
Edwards Air Force Base	Mojave Desert, California, USA	USAF	Pegasus XL
Omelek Island	Kwajalein Atoll, Marshall Islands	SpaceX	Falcon 1
Reagan Test Site	Kwajalein Atoll, Marshall Islands	U.S. Army	Pegasus XL
Brownsville	Texas, USA	SpaceX	Falcon 9
Russia			
Plesetsk Cosmodrome	Mirnyi, Arkhangelsk, Russia	FSA	Angara, Soyuz, Cosmos, Cyclone 3, Rockot, Soyuz 2-1.v, Start-1
Baikonur Cosmodrome	Kzyl-Ordinsk, Kazakhstan	FSA	Proton, Soyuz, Cosmos, Cyclone 2, Dnepr, Strela
Vostochny Cosmodrome	Amurskaya, Russia	FSA	All Russian upcoming manned and unmanned LV
Yasny	Dombarovsky, Orenburg, Russia	FSA	Dnepr
Barents Launch Area	Barents Sea, Russia	VMF	Shtil, Volna
China			
Jiuquan Satellite Launch Center (Shuang Cheng Tzu)	Gansu Province (Inner Mongolia), PR China	CLTC	Long March 2C, 2D, 2F
Taiyuan Satellite Launch Center (Wuzhai)	Shanxi Province, PR China	CLTC	Long March 2C,4
Xichang Satellite Launch Center	Sichuan Province, PR China	CLTC	Long March 2C, 2E, 3A, 3B

Hainan (Wenchang Satellite Launch Center)	Hainan Island, PR China	CAS/CLTC	Long March 5, 6, 7
Japan			
Uchinoura Space Center	Kagoshima, Japan	JAXA	Epsilon
Tanegashima Space Center	Kagoshima, Japan	JAXA	H-IIA, H-IIB, H-III
India			
Satish Dhawan Space Centre	Sriharikota, Andhra Paradesh, India	ISRO	PSLV, GSLV
Other			
Puerto Belgrano Naval Base	Bahia Blanca, Argentina	Arg. Navy?	Tronador
Woomera	South Australia, Australia	RAAF	
Centro de Lançamento de Alcântara	Maranhão, Brazil	DCTA	VLS
Unnamed launch site	Semman province, Iran	ISA	Safir, Simorgh
Ayatollah Ruhollah Khomeni Space Launch Facility	Shahroud, Iran	ISA	
Palmachim Air Force Base	Palmachim, Israel	IAF	Shavit
Naro Space Center	Goheung Jeollanamdo, Rep. Korea	KARI	KSLV
Sohae Satellite Launching Station / Pongdong-ri	Cholsan, North Pyoungan, DPR Korea	KPA	Unha
Tonghae Satellite Launch Ground / Musudan-ri	Hamgyong, DPR Korea	KPA	Unha

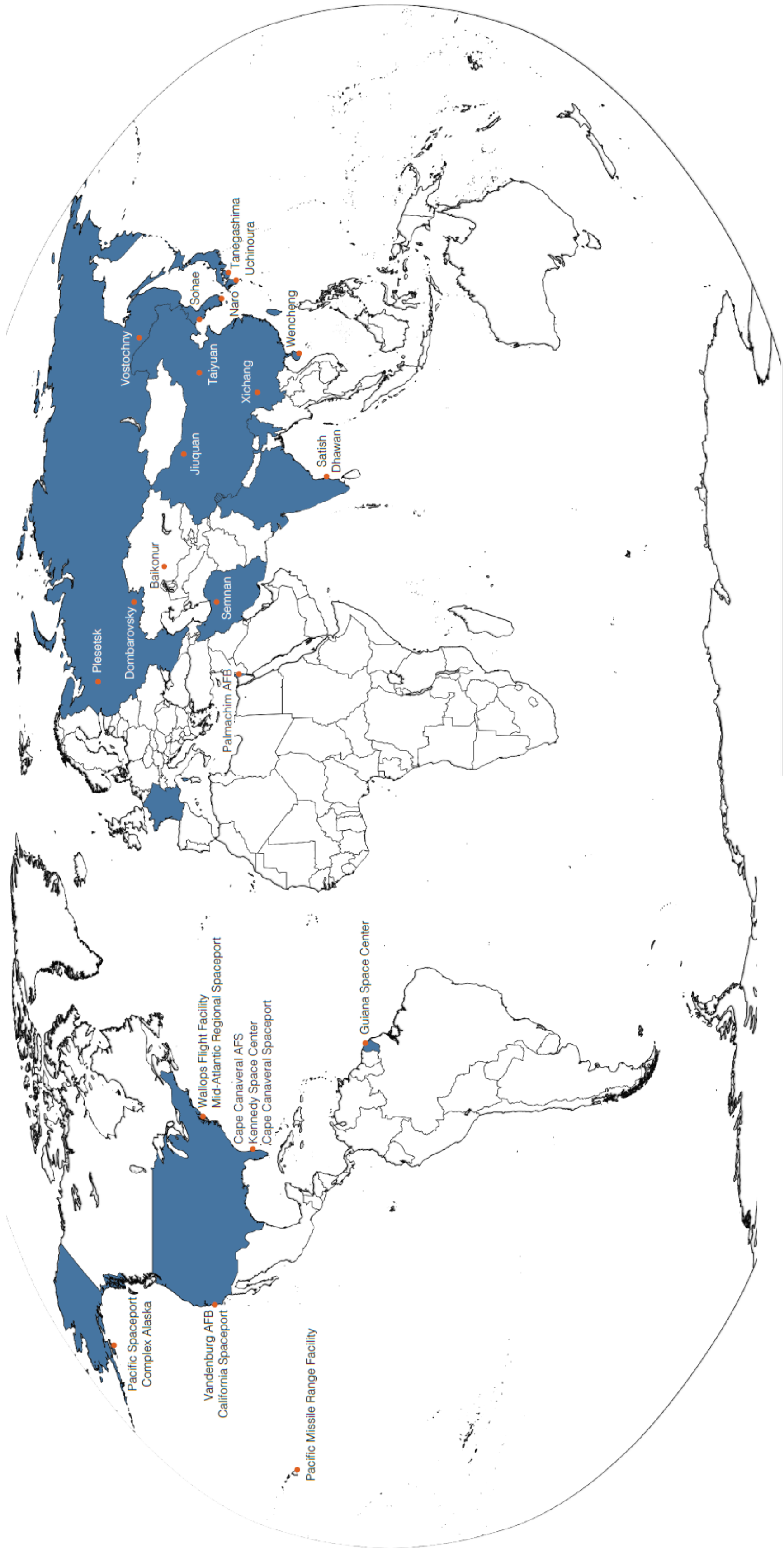

Figure 5: Map of major worldwide orbital launch sites. [254]

[254] Source: FAA. "The Annual Compendium of Commercial Space Transportation 2016. pp: 32-33.

A.4 Technical Compatibility Between Launchers And Satellite Bus[255]

LEO									
	TAS	Airbus	Orbital	LM	OHB	NG	BALL	ME	NEC
Antares			‡			‡			
Ariane 5	✓	✓			✓				‡
Athena		✓		✓					
Atlas				✓			✓		
Delta	✓	✓	✓			✓	✓		
Dnepr	✓	✓							
Epsilon								✓	✓
Falcon 9	✓	✓	✓	✓		✓		✓	
Minotaur		✓	✓			✓	✓		
Pegasus			✓			✓	✓		
PSLV		✓							
Rockot	✓	✓							‡
Soyuz	✓	✓			✓				
Vega	✓	✓							‡
Zenit		✓					✓		

GEO										
	TAS	Airbus	Orbital	LM	Boeing	SSL	OHB	NG	ME	NEC
Ariane 5	✓	✓	✓	✓	✓	✓	‡		✓	✓
Atlas	✓	✓		✓	✓	✓				
Delta	✓	✓	✓		✓	✓				
Falcon 9	✓	✓	✓	✓	✓	✓		✓	✓	
GSLV		✓								
H-IIA	✓	✓	✓	✓	✓	✓			✓	✓
Long March	✓			✓	✓	✓				
Proton	✓	✓	✓	✓	✓	✓			✓	✓
Soyuz			✓		✓				✓	✓
Zenit	✓	✓	✓	✓	✓	✓				
Angara	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡

✓ = Developed and Performed
‡ = Under Development

TAS = Thales Alenia Space
Airbus = Airbus
Orbital = Orbital ATK
LM = Lockheed Martin
Boeing = Boeing
SSL = Space Systems Loral

OHB = OHB
NG = Northrop Grumman
ME = Mitsubishi Electric
NEC = Nihon Electric Corporation
Ball = Ball Aerospace & Technology

[255] Source: La Regina, Veronica. “Business Partnership and technology transfer opportunities in the Space sector between EU and Japan”. EU-Japan Center For Industrial Cooperation. Tokyo, 08 June 2015. Author’s re-elaboration.

List of Acronyms

Acronym	Explanation
A	
ACES	Advanced Cryogenic Evolved Stage
APSCO	Asia-Pacific Space Cooperation Organization
ARTA	Ariane research and technology support programme
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ASL	Airbus Safran Launchers
ATV	Automated Transfer Vehicle
AVUM	Attitude Vernier Upper Module
C	
CBC	Common Booster Core (Delta IV)
CCAFB	Cape Canaveral Air Force Base
CCB	Common Core Booster (Atlas V)
CCDev	Commercial Crew Development (NASA Programme)
CFSP	Common Foreign and Security Policy
CGWIC	China Great Wall Industry Corporation
CNES	Centre Nationale D'Etudes Spatiales (French Space Agency)
CONAE	Comisión Nacional de Actividades Espaciales
COTS	Commercial Orbital Transportation Services (NASA programme)
CRS	Commercial Resupply Service (NASA programme)
CSDP	Common Security and Defence Policy
D	
DDTC	Directorate of Defense Trade Controls
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Space Agency)
DoD	U.S. Department of Defense
E	
EC	European Commission
ECA	Export Credit Agency
EEAS	European Union External Action Service
ELDO	European Launcher Development Organisation
ELV	European Launch Vehicle (Company)
ELV	Expendable Launch Vehicle
EELV	Expendable Launch Vehicle Program (U.S. Air Force)
EGAS	European Guaranteed Access to Space
EO	Earth Observation

Acronym	**Explanation**
ESA	European Space Agency
ESP	European Space Policy
ESPI	European Space Policy Institute
ESRO	European Space Research Organisation
EU	European Union
F	
FAA	Federal Aviation Administration
FLPP	Future Launchers Preparatory Programme
FP	Framework Programme
G	
GATS	General Agreement on Trade in Services
GDP	Gross Domestic Product
GEO	Geostationary Orbit
GSC	Guiana Space Centre
GSLV	Geosynchronous Launch Vehicle
GSO	Geosynchronous Orbit
GTO	Geostationary Transfer Orbit
H	
H2020	Horizon 2020
HTV	H-II Transfer Vehicle
HSPG	High-Level Space Policy Group
I	
ICBM	Intercontinental Ballistic Missile
IGS	Information Gathering System
ILS	International Launch Services
INSAT	Indian National Satellite System
INKSA	Iran, North Korea and Syria Non-Proliferation Act
ISA	Israel Space Agency
ISRO	India Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
ITU	International Telecommunication Union
IXV	Intermediate eXperimental Vehicle
J	
JSLC	Jiuquan Satellite Launch Center
K	
KSC	Kennedy Space Center
L	
L3S	Launceur a Trois Etages de Substitution

Acronym	Explanation
LEAP	Launchers Exploitation Accompaniment Programme
LEO	Low Earth Orbit
LMCLS	Lockheed Martin Commercial Launch Services
M	
MARS	Mid-Atlantic Regional Spaceport
MEO	Medium Earth Orbit
MHI	Mitsubishi Heavy Industries
MLA	Multiple Launch Agreement
MPCV	Multi-Purpose Crew Vehicle (Orion)
MS	Member State
MTCR	Missile Technology Control Regime
N	
NASA	National Aeronautics and Space Administration
NGL	Next Generation Launcher
NGLV	Next Generation Launch Vehicle (Vulcan)
NGSO	Non-GSO launch
NGTO	Non-GTO launcher
O	
ODA	Official Development Aid
P	
PSLV	Polar Satellite Launch Vehicle
Q	
QZSS	Quasi-Zenith Satellite System
R	
R&D	Research and Development
RLV	Reusable launch vehicle
S	
S&T	Science and Technology
SAR	Synthetic Aperture Radar
SAST	Shanghai Academy of Spaceflight Technology
SLS	Space Launch System
SRB	Solid Rocket Boosters
SSA	Space Situational Awareness
SSO	Sun-Synchronous Orbit
SSPO	Sun-Synchronous Polar Orbit
SSTO	Single stage to orbit
T	
TRL	Technology Readiness Level
TSLC	Taiyuan Satellite Launch Center

Acronym	Explanation
U	
ULA	United Launch Alliance
USML	United States Munitions List
V	
VAFB	Vandenberg Air Force Base
VECEP	VEga Consolidation and Evolution Preparation Programme
VEGA	Vettore Europeo di Generazione Avanzata
VERTA	Vega Research and Technology Accompaniment programme
W	
WTO	World Trade Organization
X	
XSLC	Xichang Satellite Launch Center

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