SCIENCE AND TECHNOLOGY BRIEFINGS
PARLIAMENTARY OFFICE FOR SCIENTIFIC AND TECHNOLOGICAL ASSESSMENT

Briefing 9 ___

# Reusable Space Launchers

___ January 2019

Source: SpaceX, Falcon 9 first stage recovery barge

## Summary

- *No country, no business segment and no individual can do without the services provided by orbiting satellites: telecommunications, defence, meteorology, geolocation, etc.*
- *The breakthrough of private space operators, particularly US company SpaceX, and the emergence of "New Space", have led to a fall in prices and intensified competition, particularly thanks to launcher recovery and reuse.*
- *The European Ariane 6 launcher, which will be operational in 2020, is not reusable. Its business plan is also not fully guaranteed in the current market context. Debate continues over the need (or not) to master reuse technologies to make sure Europe maintains its position as an autonomous space power.*
- *In addition, there is an emerging need to develop the governance of European space policy to enable clear choices.*

M. Jean-Luc Fugit, MP (National Assembly)

### Autonomous access to space

At France's instigation, the Ariane launcher programme,[1] set up in 1974, met European countries' need for autonomous access to space, as an element of their sovereignty. Independently from the US "Space Force" project,[2] the importance of this issue is clear for our defence and security needs and to guarantee our "freedom to act in space".[3] This is just as much the case as regards commercial operators, to avoid distortions of competition at Europe's expense. This vision is not universally shared, however, particularly by the Nordic and English-speaking countries. The United Kingdom does not consider a European launcher to be essential. Based on a purely financial return-on-investment approach, the UK quit the launcher programme at the time of Ariane 5.[4]

### Space: the "next trillion dollar economy"

Activities permitted by mastery of space, essentially sending satellites around the Earth, are becoming increasingly important, concern all business segments and affect daily life: telecommunications, connectivity, television broadcasting, meteorology, geolocation, Earth observation, natural disaster prevention and relief, infrastructure surveillance, security and defence, scientific knowledge, climate change monitoring, space exploration, etc.

A study by Morgan Stanley estimates that the total value of the space market – from satellite manufacturers to service providers – will more than triple, rising from $350 billion in 2017 to $1.1 trillion in 2040.[5]

### The breakthrough of reusability with SpaceX

Ariane 5's 100th launch was in September 2018. The European Ariane launcher has been the only one in continuous service for 30 years on markets open to competition, as the US space shuttle[6] failed to keep its promises and the position of Russian launchers on the market has weakened. The US shuttle, in service between 1981 and 2011, was intended to fly every week with a unit price of $30 million, but it never made more than 4 to 5 launches a year, with an estimated unit price of between $0.5 billion and $1.5 billion.[7] However, with the Falcon launchers, the private company SpaceX,[8] created by Elon Musk in 2002 – but the recipient of significant NASA support –, is on the verge of becoming the world's leading space launch company, by drastically reducing the price via highly-concentrated industrial organisation, learning from feedback and betting on reusable technologies from the beginning. Only three years after the first successful recovery attempt (end of 2015), SpaceX now recovers and reuses the first stage of its launchers from more than half of its launches.[9] According to SpaceX, the Block 5 version of Falcon 9, launched for the first time in May 2018, could be reusable up to ten times and repaired within 24 hours.[10] Many other space operators around the world have followed in their footsteps. Unlike the United States, Europe neither has a high-powered, modular-thrust and reusable engine, nor does it master stage return, which the U.S. has been working on for a decade already. In December 2014, however, European countries decided to develop the Ariane 6

launcher, scheduled to make its maiden flight in 2020, which aims to enable a reduction in the launch price by 40% to 50%. The Office, which has monitored space affairs since it was founded, has devoted two reports to the topic since 2012.(11)

**Types of recovery / reuse**
– Wings (shuttle/NASA; X-37/ USAF; White Knight / Stratolaunch; CosmicGirl and Launcher One / Virgin Orbit and Galactic; Phantom Express / Boeing, etc.)
– Parachute (United Launch Alliance's Vulcan, etc.)
– Vertical landing ("toss back"), with recovery of the 1st stage (SpaceX's Falcon 9, Blue Origin's New Glenn, CALT's Long March 8(*), CNES/DLR/JAXA's Callisto demonstrator, etc.)

**Key technologies to develop**
– Restartable engine with modular thrust
– Thermal protection of engine
– In-flight vehicle guidance and control

*(*) CALT: Chinese Academy of Launch Vehicle Technology (中国运载火箭技术研究院)*

Ariane 6 has three engines: the Solid Rocket Motor, with its powder propellant, is for auxiliary boosters and not reusable, and two cryogenic engines (liquid hydrogen and oxygen), Vulcain 2.1 for the main stage and Vinci for the upper stage, whose reusability has never been developed beyond ground testing. The Falcon 9 launchers operate with a single engine, Merlin, which is semi-cryogenic (liquid oxygen and kerosene) and reusable; only such an engine can be used on both stages.(12)

SpaceX has successfully mastered the re-entry into Earth's atmosphere of launch vehicle elements as a result of NASA and the US Department of Defense (DoD) authorising them to use technologies developed since the end of the 1980s on demonstrators such as Delta Clipper, X33/X34 and McDonnell Douglas's Aerospaceplane. In addition to very fine modulation of engine thrust, the return profile of all its physical components needs to be mastered,(13) including managing instability to prevent a very tiny error from causing incorrect inclination and disintegration in the atmosphere.

## Economic analysis

The international competition driven by SpaceX and other launcher manufacturers is jeopardising ArianeGroup's business plan. Maintaining a launcher production chain requires annual production of at least 6 and ideally 10 vehicles, but ArianeGroup laments the fact that no guarantees have been provided regarding the 3 to 5 institutional orders per year (defence, geolocation, observation, etc.). Unlike all the other space powers, there is no rule guaranteeing European preference for institutional launches.(14) Even orders on the commercial launch market (communications, observation, etc.) are uncertain for Ariane 6: the $130 million price for the launch of two satellites, recouping the cost of the industrial project, may be higher than bids by SpaceX and other competitors. SpaceX bills around $100 million per launch to NASA or the DoD,(15) but this drops to $50 million or $60 million for an equivalent launch on the commercial market. SpaceX also makes the most of generous NASA and Air Force R&D budgets. Arianespace would again like to raise the possibility of support for the exploitation of Ariane 6 on the competitive market, to make up for the absence of the five institutional launches to which the European Space Agency (ESA) committed in 2014, and the shrinking of the commercial market (scaling back of geostationary satellite orders, wait-and-see approach to satellite constellations). SpaceX's commercial practices, extensively backed by NASA and the DoD, reveal the US government's desire to guarantee domination in a segment it sees as strategic.(16)

The cost-benefit balance of reusability remains disputed at this stage. While ArianeGroup estimates that reuse of the first stage could save 10% on the launch price, the CNES(17) and SpaceX believe that this saving could be 30%.

There is a further disagreement over launch rates. The size of the US heavy orbital launch market, between 20 and 30 per year, means it can support two launcher programmes (United Launch Alliance – ULA(18) and SpaceX).(19) In addition, US law requires institutional launches to exclusively use US launch vehicles.(20) Europe only organises around ten launches per year, including a third for institutional satellites, meaning that the others have to be found on competitive markets to recoup the cost of manufacturing and launch lines.(21) It can only support a single heavy launch programme, with the operator ArianeGroup (an Airbus and Safran joint venture which has integrated Arianespace's commercialisation structure) having a monopoly situation. Long on the defensive on the grounds that the potential European launcher market did not justify the development of reusable launchers, the CNES now considers that evidence has been provided by SpaceX and there is no other option.(22) The point remains controversial, on the grounds that the reuse business model has not yet proved itself in Europe, the market does not justify it, the reduction of Ariane 6's prices is sufficient for European needs, and the current priority is the success of Ariane 6 in 2020.(23)

## New Space

The combination of the reduced cost of access to space, the increased number of private operators and breakthroughs in funding and technology – such as miniaturisation of components, electric motorisation, 3D printing or reuse – has been named "New Space". In 2002 Jeff Bezos, founder and Chairman/CEO of Amazon, created Blue Origin, which is developing the New Glenn and New Shepard reusable heavy launchers, backed by a considerable fortune with a budget

that is said to be "unlimited".[24] Furthermore, in addition to the main historical space powers (United States, China[25], Russia, Europe, Japan and India, but also Israel, Iran and both Koreas), there are now Singapore, Brazil, Saudi Arabia, the United Arab Emirates, etc.[26]

There can be no "New Space" without "Old Space", however, and it is estimated that out of the $80 billion per year of public and private investments injected into the space industry in the United States, "New Space" accounts for only $4 billion.[27] Comparing the same scope in Europe, but with an entirely different setup, total government investment in the space industry – ESA, European Commission and national space agencies – does not exceed $10 billion (€9 billion) a year.

The current period marks a certain downturn in the number of launches, as a result of uncertainty over the choice between classic heavy geostationary satellites and low-orbit micro-constellations, which have not yet proved their worth. An eventual boom in space activities is predicted by all, however, triggered by the increasing number of applications that require satellites. According to the Satellite Industry Association (SIA), the launcher segment accounts for only 1.3% of the global space economy, compared to 79% for the satellite industry.[28] Based on these relative proportions, the dispersion of launcher operators appears excessive, due to their strategic importance.[29]

## Ecological analysis

Analysis of the environmental impacts of space launches was the subject of a study by the CNES back in 2013. The flight phase itself, though spectacular, does not have the biggest environmental impact. Upstream industrial activities (manufacturing, fuel, space base) easily top that list. With Ariane 5, trajectories are restricted to free up the orbit of auxiliary launch elements within 25 years. With Ariane 6, a further step will be taken with systematic atmospheric re-entry of the upper stage after launch, at the cost of a loss in performance.

The trajectory of elements returning to Earth after launch is calculated to target defined maritime zones and their design takes account of the need to avoid generating floating wreckage.

Concerning reusable launchers, each reused element does not, by definition, need to be remanufactured and does not fall back into the sea. But SpaceX reuses only the first stages.

## What reusability for Europe?

Back in 2010, Airbus began working on a self-funded programme for partial reuse of the first stage of launchers, called ADELINE.[30] It was only in 2015, however, that the CNES and ArianeGroup decided to work on the Prometheus liquid oxygen and methane engine which would enable a ten-fold reduction in costs[31] and reusability on an as-yet undetermined launcher. The programme was then supported by the ESA,[32] with backing from Germany, Belgium, Switzerland, Sweden and Spain. After initial testing scheduled for 2020, Prometheus could be available in 2025. It is eventually set to replace the three current engines: Solid Rocket Motor (produced in Le Haillan near Bordeaux and in Colleferro near Rome); Vulcain 2.1 and Vinci (produced in Vernon, near Paris).

Mastery of launcher reuse, which may be only partial, will undoubtedly require an upgrade of Ariane 6, which would need to be equipped with a single engine, fuelled with liquid oxygen and hydrocarbons. This upgrade is made possible by the degree of maturity that the civil launcher engine industry has reached (liquid oxygen and hydrocarbons). Such a choice, which would abandon solid propulsion for civilian use, would reduce civilian-military synergies (M51 ballistic missiles) to system project management and to flight and guidance programmes.


*Source: CNES, European Callisto demonstrator*

In addition to the Prometheus engine, Europe is sponsoring two projects: Callisto and Themis. Callisto is a 1:10 scale launcher demonstrator enabling testing of first stage return, flight programmes and landing in a precise location. It is currently being developed by the CNES, DLR[33] and JAXA[34], but without the ESA or ArianeGroup. The Themis project, currently sponsored by the CNES and ArianeGroup, is a 1:1 scale demonstrator with a reusable stage propelled by Prometheus, to be proposed for funding by the ESA member countries at the end of 2019.[35] Depending on the funds raised, a first flight test could be organised before 2025.

## Conclusions and recommendations

European space policy is a major historical success that must continue, and even be reinforced. However, a certain restlessness is currently perceptible, with some even reconsidering Ariane 6's development.

- Mastery of reuse

The breakthrough of new launch vehicle manufacturers, such as SpaceX, constitutes a serious threat to the competitiveness of Europe's future Ariane 6 launcher. In addition to the industrialisation of production processes (lean management), which has already halved the price (Ariane 6, Falcon 9, etc.), the reusability of certain launcher parts could enable further price re-

ductions. However, as Europe does not yet possess technologies permitting this, there could be concerns over the European space industry being left behind, as nations' power is also exercised in space.

There is currently no consensus in Europe regarding launcher recovery and reuse technologies.

On a scientific level, it determines our collective ability to master key knowledge that would benefit a large number of fields of research and technological developments, industrial segments and services. But, on a strategic level, is it a prerequisite to preserving our autonomous access to space? The Russian space industry's struggles to modernise demonstrate that a country that no longer innovates is doomed, meaning that merely falling back on existing technologies is not an option. In terms of attractiveness for our young scientists, technological breakthroughs are most certainly key. Faced with generally-increasing European scepticism, the Ariane programme is a powerful argument.

- Financial concerns

In 2018, ESA's budget was €5.6 billion, the CNES's €1.4 billion, and DLR's space budget was €1.5 billion.[36] In its June 2018 budget proposal, the European Commission increased the space policy budget to €16 billion over the 2021-2027 period.[37]

In preparation for the next ESA ministerial conference in November 2019 in Spain, it will be important to examine possible upgrades of Ariane 6: incremental based on ongoing technological developments, then conceptual, with a new reusable launcher. Elon Musk, meanwhile, has stated that he has already spent $1 billion to develop recovery and reuse.[38] Depending on what we want to recover and how, estimated public funding needs vary between €1 billion and €3 billion.[39] The development of Ariane 6 and Vega C took €3.4 billion over five years, plus €600 million for the construction of a new launch pad at the French Guiana space centre (Kourou).[40] This spending in fact significantly boosts economic activity. The ESA has calculated that, for every €100 spent on Ariane 5 development, €320 were generated in additional economic value-added; on this basis, €50 billion of turnover was generated in the European space and non-space industries between 2000 and 2012.[41]

**What are the government's options?**
– *Status quo* (Ariane 6, Prometheus and Callisto)
– *Status quo* + Themis (€200 million)
– *Status quo* + European reusable development programme (€1 billion – €3 billion)

- Simplified governance

It appears advisable to simplify the governance of the European launcher programmes, for example with closer collaboration between the ESA and European Commission, and an industrial core comprised of the three main contributing countries (France, Germany and Italy): other ESA countries who wish to can provide support according to their skills. This development will undoubtedly lead to relaxing of the geo-return principle,[42], currently applied to the nearest 0.01% and resulting in redundant skills and duplicated investments, in favour of a (smart geo-return) system based on comparative competitiveness (fair contribution), leaving the industry free to restructure itself in optimal fashion and thus reduce prices.

It will be hard to explain to our fellow citizens why European countries are funding the design of a space launcher when they leave some of their launches to SpaceX or other global manufacturers. Finally, agreement needs to be reached on a European preference for all institutional launches by ESA countries.[43] In France, too, the 2014 reform did not resolve the tension between the different operators.

- Prospects

In addition to launchers, it should be underlined that space is the solution to major societal challenges, such as combating the digital divide and increasing knowledge of the Earth's environmental situation. Thales, for example, reckons that satellite technology would make it five to ten years quicker to connect remote zones to communication networks, at a quarter of the cost of optical fibre. ESA's ministerial conference at the end of 2019 could offer the opportunity to reassess priorities across the entire space industry (launch vehicles, satellites and services).

*OPECST websites:*
*http://www.assemblee-nationale.fr/commissions/opecst-index.asp*
*http://www.senat.fr/opecst/*

## Persons heard

*Riadh Cammoun, Vice-President, Public & Regulatory Affairs, Louis Laurent, Thales Alenia Space (TAS) Skills Centre Deputy Director, and Isabelle Caputo, Deputy Director of Institutional Relations at Thales*

*David Cavaillolès, Budget, Industry, & Space Advisor to the French Minister of Higher Education, Research, & Innovation*

*Alain Charmeau, CEO of ArianeGroup and Stéphane Israël, CEO, Alexandre Archier, Director of Public Affairs, Maxime Jambon, Executive Assistant to the Chairman, Arianespace*

*Jean-Jacques Dordain, Advisor to the President of the CNES (Centre National d'Etudes Spatiales), former Director General of the European Space Agency (ESA)*

*Morgan Guérin, European programme manager, and Arthur Sauzay, lawyer, author of the paper "Espace : l'Europe contre-attaque?", Institut Montaigne*

*Jean-Yves Le Gall, President, Jean-Marc Astorg, Launch Vehicles Director, and Pierre Tréfouret, Chief of Staff to the President, CNES*

*Daniel Neuenschwander, Director of Space Transportation, ESA*

## Contributions

Academy of Technologies – *task force featuring:*

*Jean-Jacques Dordain, Advisor to the President of the CNES; Michel Courtois, former Director of the ESA Technical Centre (ESTEC); Michel Laroche, former Deputy Director General, Research & Technology, Safran; Marc Pircher, former Director of the CNES, Toulouse Space Centre; plus consultation of Bruno Le Stradic, Director of Space Systems Engineering, Airbus Defence & Space*

## Experts consulted

*Astrid Lambrecht, Director of Research at CNRS (*Centre national de la recherche scientifique - *French National Center for Scientific Research), Director of the CNRS Institute of Physics (INP/CNRS), member of the OPECST Scientific Board*

*Marcel Van de Voorde, Professor at Delft University of Technology, Netherlands, member of the OPECST Scientific Council*

*Isabelle Sourbes-Verger, Director of Research at CNRS, Director of Research at Alexandre Koyré Centre (EHESS, CNRS, MNHN)*

*Xavier Pasco, Director of FRS (*Fondation pour la Recherche Stratégique - *Foundation for Strategic Research)*

*Hervé Grandjean, Advisor on Industrial Affairs to the French Minister for the Armed Forces*

## Références

*(1) ArianeGroup (previously Airbus Safran Launchers): https://www.ariane.group/fr/lancement-spatial/heritage-ariane/*

*(2) In June 2018, President Donald Trump announced that the DoD was to set up a sixth branch of the armed forces ("US Department of the Space Force") by 2020: https://dod.defense.gov/News/Article/Article/1598071/space-force-to-become-sixth-branch-of-armed-forces/*

*(3) See the speech by Florence Parly, French Minister for the Armed Forces, CNES, 7 September 2018: https://www.defense.gouv.fr/english/salle-de-presse/discours/discours-de-florence-parly/discours-de-florence-parly-ministre-des-armees-au-au-cnes-le-vendredi-07-septembre-2018*

*(4) However, the country part-funds the Guiana space centre and is now beginning to invest in both a "space port" and projects to launch micro-launchers from Scotland.*

*(5) Morgan Stanley, Research, 7 November 2018, "Space: investing in the final frontier": https://www.morganstanley.com/ideas/investing-in-space*

*Bank of America – Merrill Lynch is even talking about a market potentially worth 2.7 trillion by 2045!*

*Bank of America Merrill Lynch, Equity, 30 October 2017, "To infinity and beyond – Global space Primer", 101 pages: https://go.guidants.com/q/db/a2/1e1ffc185c1d44bd.pdf*

*(6) Space Transportation System (STS), commonly called the* US space shuttle.

*(7) In addition, two accidents - Challenger (1986) and Columbia (2003), in which the crew was lost - raised doubts over its reliability.*

*(8) Space Exploration Technologies Corp.: https://www.spacex.com/*

*(9) In 2018, by 30 October, nine of the 17 SpaceX missions used previously-launched Falcon 9 launch vehicles, which accounted for 53% of launches. This was a significant increase on 2017, when only 5 missions used previously-launched Falcon 9 rockets. (Source: SpaceX)*

*(10) This remains an objective. Again according to SpaceX, the last Falcon 9 launched on 8 October 2018 was reconditioned in two months. For the first time on 3 December 2018, SpaceX successfully used the first stage of a launcher for a third time. N.B. With this launch, SpaceX unsuccessfully attempted to recover the launcher's nosecone using a ship equipped with large nets. SpaceX does not disclose its repair costs.*

*(11) See the Office's reports:*

– "L'Europe spatiale: quels changements de paradigme?" *(n° 32053), submitted on 25 November 2015 by Jean-Yves Le Déaut, Catherine Procaccia and Bruno Sido;*

– "Europe spatiale: l'heure des choix" *(n° 348), submitted on 7 November 2012 by Catherine Procaccia and Bruno Sido.*

*(12) Different types of space engines:*

| | *Solid propulsion* | *Liquid propulsion* | | | | |
|---|---|---|---|---|---|---|
| *Type of rocket propellant* | *Solid* | *Two types of rocket propellants* | | | | *One type of rocket propellant* |
| *Property* | *Storable at room temperature* | *Cryogenic* | *Semi-cryogenic* | | *Storable at room temperature* | *Storable at room temperature* |
| *Composition* | *Ammonium Perchlorate + Aluminium powder + Binder* | *Liquid hydrogen (– 250°C) + Liquid oxygen (– 180°C)* | *Kerosene (room temp.) + Liquid oxygen (– 180°C)* | *Methane (– 160°C) + Liquid oxygen (– 180°C)* | *Hydrazine derivatives with liquid nitrogen peroxide* | *Hydrazine* |
| *Compatible / reuse* | *no* | *yes* | *yes* | *yes* | *yes* | *yes* |

*(Source: ArianeGroup)*

*(13) Flight algorithms, aerodynamics, landing accuracy…*

*(14) In 2018, SpaceX's Falcon 9 sent both the Luxembourgish satellite Govsat-1, dedicated to ultra-secure dual communications (external operations, exchanges between institutional and defence sites, intelligence, surveillance and reconnaissance), and the Spanish military Earth observation satellite, Paz, into orbit. Following an agreement signed in 2013 with SpaceX, this year and next year the same Falcon 9 should launch the three SARah radar reconnaissance satellites used by the German army, replacing the constellation of five SAR-Lupe satellites.*

*(15) SpaceX says that US governmental launches have mission requirements and complexities specific to government contracts, which makes comparison of launch costs between the US government and commercial end users difficult.*

*(16) See the Eurospace document "The growing US ambition for space dominance, a new challenge for European independence in space", October 2018: https://eurospace.org/eurospace-position-paper-the-growing-us-ambition-for-space-dominance-a-new-challenge-for-european-independence-in-space/*

*President Donald Trump has made US hegemony in space a military, civil and commercial strategy against any competitors, primarily China. The US army intends to retain its technological edge by focusing the R&D houses (DARPA, Strategic Capabilities Office, etc.) on disruptive capabilities. This strategy includes massive, multi-form governmental support to private US space companies: the resulting cost cuts should benefit US institutional launches and put non-US competitors in a difficult position.*

*The National Space Council, which was relaunched in June 2017 and chaired by Vice-President Mike Pence, now plays a key role in this new approach, particularly aiming to "reform outdated space policies". Three Space Policy Directives have since been enacted, particularly including SPD-2 in May 2018, streamlining regulations and supporting the development of the private sector.*

*(17) Centre National d'Etudes Spatiales*

*(18) Boeing and Lockheed Martin: https://www.ulalaunch.com/*

*(19) Out of the 85 successful orbital launches in 2017, the United States was behind 29 (34%), Russia 20 (24%), China 17 (20%), Europe 9 (11%), Japan 6 (7%) and India 4 (5%). With Falcon 9, SpaceX was behind 18 out of the 29 US launches. The other US launches were by United Launchers Alliance (Atlas and Delta) and Orbital (Minotaur and Antares). In Europe, ArianeGroup*

*was behind 6 launches with Ariane 5 (including five dual launches with two satellites launched) and 3 launches with Vega (including one dual launch). Over the first ten months of 2018, China was behind 30 launches (35.7%), the United States 26 (30.9%), Russia 11 (13%), Europe 6 (7.1%), Japan 6 (7.1%), India 4 (4.8%), and New Zealand 1 (1.2%). Source:* Air & Cosmos *n° 2618, 23 November 2018.*

*[20] A set of policies and laws exist that require U.S. government satellites to be launched on U.S. launch providers. Several U.S. law and policy statements require launch vehicles for U.S. Government satellites to be manufactured in the United States. Title 51 of U.S. Code (National and Commercial Space Programs) requires "the Federal Government [to] acquire space transportation services from United States commercial providers." It goes on to define a United States commercial provider as one that is "more than 50 percent owned by United States nationals." Additionally, Title 41 of this Code, Sections 8301-8305 (the "Buy American Act") stipulates that for an item to be considered manufactured in the United States, at least 50 percent of all its components, by cost, must be manufactured in the U.S.*

*In addition to the laws documented in U.S. Code, multiple policies exist that dictate which launch vehicles can be used by U.S. government programs. The National Space Transportation Policy (NSTP) states as a goal, "United States Government payloads shall be launched on vehicles manufactured in the United States unless an exemption is coordinated." Department of Defense Instruction (DODI) 3100.12, "Space Support," states that "DoD payloads shall be launched on U.S. manufactured launch vehicles" and that "U.S. commercial space launch services shall be utilized to the fullest extent feasible…in accordance with [the National Space Transportation Policy] and [the Commercial Space Act of 1988]."*

*"Most government launch agreements are also subject to the Federal Acquisition Regulation. The Federal Acquisition Regulation states that the place of manufacture of an item is "predominantly in the US … if the total anticipated price of offered end products manufactured in the United States exceeds the total anticipated price of offered end products manufactured outside the United States." Part 52.225-18 of the Federal Acquisition Regulation also defines the "place of manufacture" as "the place where an end product is assembled out of components."*

*"Launching U.S. government payloads on foreign soil: regulatory and policy analysis", Barbara M. Braun and Eleni M. Sims, Aerospace, Center for space policy and strategy, July 2018.*

*https://aerospace.org/sites/default/files/2018-08/Braun-Sims_ForeignLaunch_08062018.pdf*

*N.B. Government space orders are worth approximately $50 billion per year in the United States: the US space agency (NASA) 20 billion, Department of Defense (DoD) 20 billion known publicly and approximately a further 10 billion for top-secret military programmes (according to comparative data published every year by the Federal Aviation Administration – FAA). In addition to subsidies, US support can be in the form of higher-than-market launch prices, service agreements, authorised federal launch base use, or transfer of technical skills by transferring staff.*

*[21] According to ESA, the relative weight of domestic institutional launches compared to commercial or non-domestic launches by different countries or groups of countries is as follows:*

| | *Europe* | *Russia, Ukraine, Belarus* | *United States* | *China* | *Japan* | *India* |
|---|---|---|---|---|---|---|
| *%* | *34* | *62* | *73* | *59* | *15* | *17* |

*[22] Hearing of Mr. Jean-Yves Le Gall, President of the CNES.*

*[23] Particularly the Académie des Technologies, Jean-Jacques Dordain, Advisor to the President of the CNES, former Director General of ESA, Alain Charmeau, Chairman & CEO of ArianeGroup, or Stéphane Israël, Chairman & CEO of Arianespace.*

*[24] Jeff Bezos is said to have injected $1 billion per year of his personal fortune into the company.*

*[25] With more annual orbital launches than the United States for the first time in 2018, China could eventually become the principal space power, with the biggest market in the world, and the biggest financial and technological capabilities*

*[26] N.B. They do not yet have launch capability.*

*[27] Source: hearing of Mr. Jean-Yves Le Gall, President of the CNES.*

*[28] According to the* Satellite Industry Association *(SIA), based on statistics produced by Bryce Space and Technology, global space economic activity represented €348 million in 2017, including 37% for satellite services (telecommunications, Earth observation, sciences and national security), 34% for ground equipment, 23% for non-satellite services (essentially government space budgets), 4.5% for construction of satellites and only 1.3% for launchers:*
*https://brycetecsh.com/downloads/SIA_SSIR_2018.pdf*

*[29] According to the Académie des Technologies (contribution to the Office), "Though industrial activity concerning launchers remains limited, it protects another industrial activity, i.e. design, manufacturing and commercialisation of commercial satellites, but also other service activities […], which represents twenty to thirty times the launch services activity."*

*[30] Airbus Defence and Space revealed in June 2015 that it was working on the ADELINE (ADvanced Expendable Launcher with INnovative engine Economy) project. The bottom of the first stage of the rocket, once detached from its tank and the upper stage, was to be equipped with winglets and propellers that would enable it, once the rocket engine has cut out, to return to*

*Earth by flying like a drone. Accordingly, 80% of the most expensive part of the first stage could return: engine, propulsion bay, and related avionics equipment. Airbus hoped to be able to use the same engine 10 or 20 times. It also wanted to recover the upper stage, which could be converted into a space tug. Scheduled to be operational in 2030, the ADELINE project was never funded by the ESA countries.* https://www.agences-spatiales.fr/fusee-reutilisable-adeline-airbus/

(31) *Compared to the current Vulcain engine.*

(32) *The European Space Agency (ESA), which has 22 member countries, including 20 European Union Member States, plus Norway and Switzerland, is an intergovernmental organisation.*

(33) *The Germany space agency (*Deutsche Zentrum für Luft- und Raumfahrt*).*

(34) *The Japanese space agency (Japan Aerospace eXploration Agency).*

(35) *More than €200 million in funding according to the CNES.*

(36) *Excluding these two agencies' contribution to ESA, €963 million and €927 million respectively.*

(37) *Compared to €5 billion and €12 billion for the previous two programmes.*

(38) *These amounts require in-depth analysis, distinguishing between budgets allocated by NASA and equipment already available to master this technology.*

(39) *CNES estimate.*

(40) https://presse.cnes.fr/sites/default/files/migration/automne/pPressReleases/2014_12/r9488_81_cp171-2014_-_mou_cnes-esa-asl.pdf

(41) *Hearing of Mr. Daniel Neuenschwander, ESA Director of Space Transportation.*

(42) *The ESA has a "geographical return" policy, i.e. it invests in each Member State an amount approximately equivalent to said country's contribution in the form of contracts awarded to its industry for space activities.*

(43) *The signing by the European institutions, on 25 October 2018, of a joint statement on Institutional exploitation of Ariane 6 and Vega 6, is a first step in this direction:*
https://www.esa.int/Our_Activities/Space_Transportation/European_institutions_sign_Joint_Statement_on_European_Institutional_Exploitation_of_Ariane_6_and_Vega-C

*The signatories were ESA, the French National Centre for Space Studies (CNES), the German Aerospace Centre (DLR), the Italian Space Agency (ASI), the Spanish Centre for the Development of Industrial Technology (CDTI), and the Swiss Confederation. Through this Statement, the signatories express their full support to the European launcher industry and to Ariane 6 and Vega-C. They recognise the benefit of aggregating their institutional demand for launch services to ensure an autonomous, cost-effective, affordable, and reliable access to space for Europe. For the signatories, space capacities are strategically important to civil, commercial, security and defence-related policy objectives. Space is an enabler for responding to societal challenges and for stimulating job and growth creation. Europe's autonomy of action in space is conditional on autonomy in accessing space. Europe needs to maintain a leading position in this segment.*