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Introduction

Ariane 6 is set to be the next flagship launch vehicle of the European Space Agency (ESA). On 30 November 2023, after years of delays and unfortunate circumstances, ESA Director General Josef Aschbacher finally announced that the rocket's first flight will take place in the summer of 2024 (Foust, 2023d).

Ariane 6 is designed to carry into orbit payloads commissioned by private contractors, national governments, ESA member states and the European Union Space Programme (EUSPA). It aims to replace the recently retired Ariane 5 rocket, which was entrusted with the delivery of Europe's heaviest and most advanced payloads during its 117-flights-long career from 1996 to 2023 (ESA, n.d. - a).

The birth of the project and the subsequent retirement of Ariane 5 were directly related to the increase of competitiveness by private agencies such as SpaceX, which prompted ESA to reimagine Ariane in a new space economy where states' interests clash not only between each other but also with emerging non-state actors. Europe's objective is, indeed, to possess an efficient and cost-effective main launch vehicle capable of resisting competition or, at the very minimum, capable of defending Europe's independence in the launch of payloads in space.

Ariane 6 aspires to be a highly innovative vehicle qualified to carry heavier and more numerous payloads than ever before, while at the same time cutting operational costs to competition-like levels (ArianeGroup, n.d.). However, major setbacks, a Vega-C launch failure and years of delays severely hampered the programme, leaving ESA in a state of limbo where Ariane 5 has already been retired at a time when Ariane 6 is not ready yet.

Before exploring the unfortunate circumstances that orbit around the project, it is beneficial to analyse the process of Ariane 6's development and its projected capabilities.

Development and Contractors of Ariane 6

The initiative to develop Ariane 5's successor was greenlit by a ministerial meeting during the ESA Council in late 2014. The member states that are directly involved in the development of the launcher are Austria, Belgium, France, Germany, Ireland, Italy, the Netherlands, Norway, Romania, Spain, Sweden and Switzerland (ESA, n.d. - b).

The design and procurement process for the architecture of Ariane 6 is being directly overseen by ESA itself, while ArianeGroup, comprised of an even partnership between Airbus from Germany and Safran from France, was again confirmed as the prime contractor in collaboration with various other smaller European partners tasked with building rocket components (ArianeGroup, n.d.; ESA, n.d. - b). The auxiliary solid rocket boosters are being co-developed by Europropulsion, a 50/50 joint venture between ArianeGroup and Avio (ESA, n.d. - b).

ArianeGroup selected Eiffage Énergie Systèmes for the construction of an automated factory capable of manufacturing engine nozzles for the rocket, in collaboration with EOS' expertise on engine injector heads (Aerospace Technology, n.d.). Thales Alenia Space and SABCA are some of the other major contractors working on propulsion systems; their responsibilities are, respectively, thrust vectoring actuators electronics and thrust vectoring controls systems. In addition, Réaltra Space supervises onboard live telemetry and Arteche is in charge of relay systems supply (Aerospace Technology, n.d.).

As it was for Ariane 5, the European Space Agency will manage launch requirements for institutional missions such as those of member states and EUSPA, while industry representatives are expected to identify the analogous requirements for the commercial market (ESA, n.d. - b). In 2016, ESA signed an agreement worth €3 billion with ArianeGroup, at the time still known as Airbus Safran Launchers, and the French Space Agency (CNES) for the development of Ariane 6 and its launch complex in Europe's Spaceport in Kourou, French Guyana (Aerospace Technology, n.d.).

Ariane 6's Technical Characteristics, Mission Profile and Payload Capabilities

Ariane 6 will be a 60-metre-tall expendable, modular and heavy-lifting launcher weighing up to 900 tonnes when fully loaded and capable of flying in two main configurations: Ariane 62 and Ariane 64. Ariane 62 will utilise two P120C strap-on solid rocket boosters (SRBs), carrying 10,300kg to low Earth orbit (LEO) or 4,500kg to the further away geostationary transfer orbit (GTO). Meanwhile, the Ariane 64 configuration will have a doubled auxiliary power with four SRBs, carrying an even heavier payload weighing up to 20,600kg to LEO or 11,500kg to GTO (ESA, n.d. - b; Aerospace Technology, n.d.). Ariane 62 will house payloads in 14m-sized or 20m-sized fairings, while the more powerful Ariane 64 will only deliver payloads that require the 20m-sized fairing. Both available fairings sit on the very tip of the rocket with a diameter of 5,4m and protect the payload during ascent shocks, thanks to a carbon fibre-polymer composite shell (ESA, n.d. - b). The fairing is then jettisoned when the rocket reaches an altitude where atmospheric friction is no longer a concern.

Ariane 6 will be comprised of two liquid fuel core stages plus a solid propellant booster stage consisting of the above-mentioned SRBs in radial symmetrical attachment to the lower core stage (ESA, n.d. - b; Aerospace Technology, n.d.). In order to carry the rocket from the launch pad to the upper atmosphere, the lower stage relies on up to 135 tonnes of combined thrust provided by one liquid-fuelled, Ariane 5-derived Vulcain 2.1 engine and by two or four solid-propelled P120C SRBs (ESA, n.d. - b). The SRBs are then depleted and detached from the core stage during the first part of the ascent. When the lower stage runs out of fuel, it is discarded in a vertical separation to let the upper stage continue the gravity turn and payload orbit insertion.

The upper stage draws power from the four-times re-ignitable Vinci engine, fuelled by cryogenic liquid oxygen and hydrogen (ESA, n.d. - b; Aerospace Technology, n.d.; ArianeGroup, n.d.). The upper stage's multiple ignition technology gives Ariane 6 the capability to deliver different payloads in different orbits, allowing for a greater number of satellites per mission, greater efficiency and cost reductions in operations and satellite complexity (Aerospace Technology, n.d.; ArianeGroup, n.d.).

Payload carrier structural elements will allow small satellites under 200kg to 'piggyback' the space ascent of the main payload, opening opportunities of launch ridesharing for small companies, which otherwise would not afford a dedicated mission (ESA, n.d. - b). The last ignition of the Vinci engine could be saved to safely deorbit the upper stage, as to have closer to zero impact on space debris orbiting Earth. Having now reached a general understanding of the characteristics of Ariane 6, the next paragraph divulges into the contextual drawbacks that link these technical specifications to European politics.

Major Setbacks for Ariane 6: Political Meddling, Technical Delays and Global Calamities

On 6 November 2023, ESA held an inter-ministerial meeting during Seville's Space Summit on the next generation of European launchers, Ariane 6, and Vega-C. It appears that German, French and Italian ministers have finally resolved long-standing disputes over launch sites, budgeting and schedules of future Ariane 6 flights (Fonte, 2023; ESA, 2023). Some key words emerging from the summit were: "paradigm shift" (Berger, 2023b), "relaunch" (Fonte, 2023) and even, quoting ESA Director General Josef Aschbacher: "light at the end of the tunnel" (Hepher, 2023). This shows Europe's strong will to regain its access to space after the drawbacks of the last few years, resulting in ESA and EUSPA temporarily losing the means to independently send payloads in space since July 2023. Just a month after the meeting, in fact, Aschbacher followed with the announcement of a possible Ariane 6 inaugural launch between 15 June and 31 July 2024 (Foust, 2023d; Hepher & Lipinski, 2023).

France apparently managed to lobby more public support for the rocket, brokering €340 million in yearly grants for the project, while promising to reduce industry costs by 11% (Hepher & Fonte, 2023; Hepher, 2023; Fonte, 2023). This agreement should ensure the future production of a second batch of Ariane 6 launchers, appeasing German concerns about the sustainability of Airbus' contracts and the weight of France in the programme (Hepher & Fonte, 2023). Italy was also apparently satisfied with promises of up to €21 million worth of annual support for its domestically produced Vega-C rocket, after demanding a bigger role for Avio in the ArianeGroup-dominated ESA (Hepher & Fonte, 2023; Fonte, 2023).

For context, the generational transition from Ariane 5 to Ariane 6 and from Vega to Vega-C has been quite troubled. Ariane 5 ended its career with prestigious missions, such as this April's launch of Jupiter Icy Moons Explorer (JUICE) and the 2021 launch of NASA's James Webb Space Telescope (ESA, n.d. - c; ESA, n.d. - d). Ariane 5 proved to be one of the most reliable launches on the market, boasting a 96% success rate in its 117 flights completed in the span of twenty years (Anderson, 2023). Great expectations for its successor, Ariane 6, have been kept on hold for four years, as its first flight was originally planned for 2020, the year of the unforeseen Covid-19 pandemic (Fonte, 2023).

PA few years later, another global event sabotaged Europe's access to space, as the Russian invasion of Ukraine stalled collaboration with Moscow's space agency, Roscosmos. The war ultimately compromised Europe's access to the extremely reliable Soyuz rocket, forcing the European Commission to cancel future launches of EUSPA's Galileo, Europe's Global Navigation Satellite System (GNSS), which had extensively relied on Soyuz launches from French Guyana (Posaner & Cerulus, 2023). Recent news suggested that the European Commission was in the final stages of finalising a deal with SpaceX for the launch of two Galileo satellites, originally planned for Ariane 6 (Foust, 2023c).

During Ariane 6's four-year delay, Vega Consolidation (Vega-C), Ariane's Italian-built junior partner, made its debut in succession of the Vega rocket. After a positive test flight, Vega-C was unfortunately lost during its maiden commercial mission on 12 December 2022 (France24, 2022). The programme has been on hold since. Furthermore, the prime contractor for Vega-C, Avio, reported additional problems emerging from a Zefiro 40 test fire earlier this June, the same engine that malfunctioned during the rocket's first mission (Foust, 2023b). As an immediate consequence, Vega-C will probably return to fly in 2024 and the EarthCARE spacecraft launch, an ESA Earth science mission, has been moved from Vega-C to SpaceX's Falcon 9 (Foust, 2023c). Ariane 6 hot fire test runs suffered severe delays until a final success on 23 November 2023 (Emir, 2023). The crucial general propellant capability test was also finally successful this October after having been delayed twice (Rabie, 2023; Jones, 2023b). With the completion of these capability assessments, the road is now opened for the aforementioned long-awaited inaugural launch, now planned for mid-2024 (Hepher & Lipinski, 2023).

Figure 1 – Europe's rockets (Photo credit: ESA - D. Ducros). From left to right: Vega (about to be retired), Vega-C (flight suspended until 2024), Soyuz (now unavailable), Ariane 5 (Retired), Ariane 62 (coming in 2024), Ariane 64 (coming in 2024)

The Irrefutable Importance of Ariane 6 for European Scientific, Military and Strategic Interests

The long wait for Ariane 6 and Vega-C put the very future of European space strategic interest at stake. EUSPA and ESA have already been forced to rely on SpaceX for important scientific payloads in the past, and more will follow in the next two years. In 2020, the private company placed into orbit Sentinel-6A Michael Freilich, which is an oceanographic satellite part of EUSPA's Copernicus programme tasked with measuring rising sea levels. The second part of the mission, Sentinel-6B, is planned for 2025, and will once again fly on a Falcon 9 (Costa, 2020). Still, the mission is the result of a collaboration with NASA, so the adoption of an American rocket is not too surprising.

However, in July ESA's Euclid space telescope had to fly with SpaceX not out of choice, but because Ariane 5 was just days away from its retirement. Euclid is designed to explore dark energy and dark matter in galaxies up to 10 billion light-years away and it was the most expensive payload ever carried by a Falcon 9 (ESA, n.d. - f). In 2024, SpaceX was commissioned with two other high-profile payloads: the already mentioned Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) and another mission, Hera, tasked with a post-impact survey of NASA's DART asteroid deflection test (Earth Online, n. d.; Hera Mission, n.d.).

Nonetheless, the most sensitive payload by far are the two Galileo satellites that will fly on a Falcon 9 in 2024. Although Galileo is the only Global Navigation Satellite System (GNSS) in the world to not be military-operated, some of its technology is particularly sensitive to European strategic interests and still benefits military applications due to its dual-use nature. The exact requirements for Galileo's military domain are not publicly available, but EUSPA and ESA are looking to sign an ad hoc legally binding security agreement with the United States and SpaceX on this matter (Hecker et al., 2018; Posaner & Cerulus, 2023).

SpaceX's Fierce Competition

The company's business model has been extremely successful because of a fundamental strength that no other space actor, state-owned or private, has currently mastered to such a level: reusability. All previous traditional launchers such as those from the Ariane rocket family, with the notable exception of the retired Space Shuttle Orbiter Vehicle, were expendable, meaning that every stage of the rocket was simply discarded mid-air after exhausting its duty and rebuilt from scratch for the following mission. However, SpaceX's Falcon 9 rocket has been capable of recovering and re-flying its first stage since 2014, dramatically reducing cost operations and, consequently, pricing for clients. At the time of writing, SpaceX has managed to recover 236 Falcon 9 first stages via vertical powered landings, counting 211 total re-flights (SpaceX, n.d. - a). SpaceX has also successfully flown the Falcon Heavy rocket variant, also largely reusable, and is planning to operate a fully reusable superheavy launch system for future solar system-wide missions, Starship. Ariane 6 will be capable of putting a maximum of 20,600kg to low earth orbit for an estimated price of $4.7 thousand per kilogramme, a capacity that Falcon 9 could only reach in an expendable configuration, meaning on condition of not reusing its first stage (Brown, 2022; Howell, 2023). However, Falcon 9 could still have an economical edge by re-flying and not recovering a booster from a previous mission or by undercutting Ariane in the market of smaller payloads. Therefore, in its best conditions, Falcon 9 could deliver a slightly smaller payload than Ariane, but at a guaranteed price of $2.7 thousand per kilogramme (Howell, 2023).

In addition, SpaceX's Falcon Heavy, albeit completing only eight flights so far, has been proven capable of delivering 63,800kg to LEO while reusing the three Falcon 9 boosters, which make up its first stage, for as little as $1.6 thousand per kilogramme (Brown, 2022; SpaceX, n.d. - b; Howell, 2023). Finally, the future Starship system aims to bring 100,000kg to LEO, whilst simultaneously becoming the world's most powerful rocket and the world's first fully reusable launcher system, reducing costs even more. On 18 November 2023, SpaceX conducted a second Starship test flight, in which the rocket reached space for the first time and successfully demonstrated hot-staging. SpaceX later terminated the flight after losing control of both stages (Dinner, 2023).

Ariane 6's Role as an Alternative in the Private Space Market

Although SpaceX's achievements in corporate profits are impressive, it is important to remain focused on Ariane 6's real purpose, which is to serve the interests of EU member states. Ariane 6 competing power is not a simple matter of EUR per kilogramme as another nonquantifiable currency, interest, will probably make this rocket indispensable for a variety of actors, not only for European states. Ariane 6 will soon be, in fact, ESA's workhorse for the largest single commercial launch contract in history. This order will entail a total of over 80 launches mainly split among ESA, Blue Origin and United Launch Alliance to deploy Amazon's 3,236-strong Kuiper satellite constellation. Ariane 6 will be in charge of 18 of these launches (Foust, 2023a; ArianeGroup, 2022), while recent indiscretion speculates that SpaceX will take care of three more (Wattles, 2023).

Jeff Bezos, the founder of Amazon, overwhelmingly chose Ariane 6 over Falcon 9 not because of pricing or availability, but because SpaceX's Falcon 9 and Starlink constellation satellites are direct competitors of private space operator Blue Origin, another company he founded. Interestingly, the personal rivalry between Bezos and Musk became so fierce that Amazon shareholders went as far as suing their own company for ignoring SpaceX's vastly reliable and inexpensive rockets as a viable option (Sheetz, 2023; Wattles, 2023). It should not be underestimated, then, how much Ariane 6 could be relevant, not only as a means for European states' interests but also for the equilibrium of private space markets.

All things considered, Ariane 6 may be delayed, but it is off to an impressive start. A few weeks ago, during the ministerial meeting in Seville, ESA member states raised the production queue of future launchers from 16 to 42 units, as numerous institutional and commercial payloads are already crowding the schedule (Hepher & Fonte, 2023). The competition with private space operators is fierce, but Ariane 6 has the potential to become an important player in the new space arena, boasting a record-breaking commercial debut that directly benefits from private rivalries. Moreover, in the upcoming deal with Amazon, ESA plans to deploy 40 satellites per launch in an excellent display of Ariane 6's new capabilities. This could be an excellent opportunity to attract potentially interested commercial contractors.

Furthermore, the reduced availability of Russia's Soyuz removes a trusted launcher partner from Europe, but could also represent an opportunity for former Soyuz contractors to consider Ariane 6 and Vega-C as alternatives (Lo Campo, 2023). Finally, it should be noted that even though SpaceX is highly competitive, Ariane 6 is set to cut its launch costs by circa 40% compared to Ariane 5 (Simpson, 2023). Some commentators contest this claim, especially citing heavy subsidies that ESA member states are expected to provide for the rocket, but a factual evaluation will only be possible at the moment of the rocket's full operability (Berger, 2023a).

Europe's Bid for a Reusable Rocket: Ariane Next and SALTO

Regarding the matter of a reusable European rocket, during a conference in 2021, French Economy Minister Bruno Le Maire went so far as to state that: "In 2014 there was a fork in the road, and we didn't take the right path. [...] We should have made the choice of the reusable launcher. We should have had this audacity" (Posaner, 2021). In retrospect, Ariane 6 was probably designed as a traditional launch vehicle because the stars had not yet aligned for a public actor to venture into the space reusability arena. It should be kept in mind that ESA has to balance public funds responsibility and member states' industry interests, which are not always prone to risky innovation. This was especially true back in 2014, a time when rocket reusability was just being pioneered. Furthermore, delays are frequent in state-funded space agencies. For example, NASA's SLS rocket was delayed by six years and is now long over its budget projections (Jones, 2023a).

Once again, Ariane 6 has the right premises to be a formidable launcher, but, by the time of its retirement, rocket reusability will probably be an irrefutable staple of space competitiveness – some claim it already is. Europe ought to not remain behind in the new space race for reusability, cost-efficiency and liberalisation in the access of space. Now that Europe will soon ensure an independent means to reach space again for the next two decades, reusability should become a top priority for ESA's future technology. ArianeGroup, indeed, is already working on a solution by developing Ariane Next, a possible reusable successor to Ariane 6.

Ariane Next has one main objective: halving the operational costs of Ariane 6 by the 2030s through the reusability of the rocket's first stage (CNES, 2020). ESA's Future Launchers Preparatory Programme (FLPP) chose Europe's first liquid methane engine, Prometheus, over a liquid oxygen alternative after a long debate on how to address propulsion concerns (Patureau de Mirand et al., 2019; ESA, n.d. - e). Themis, the reusable first stage demonstrator, already conducted a successful hot-fire test with Prometheus in June 2023 (Iacopino, 2023). The project is managed by reuSable strAtegic space Launcher Technologies & Operations (SALTO), a consortium involving twenty-six industrial partners and twelve countries, under the coordination of ArianeGroup and with funding from the European Commission's Horizon Europe programme (SALTO, n.d. - a).

Future SALTO demonstrators will be capable of performing short take-offs, 250-metre-high altitude hovering, and controlled landings. These so-called 'hop-tests' are expected to be hosted by 2025 at the Reusability test facility at Esrange Space Center in Kiruna, Sweden (Cowing, 2023; SALTO, n.d. - b). The Esrange Space Center was inaugurated in January 2023 by the Swedish King Carl XVI Gustaf, the President of the European Commission Ursula von der Leyen and the Swedish Prime Minister Ulf Kristersson. Esrange stands as the first orbital launch complex in the contiguous European Union (Iacopino, 2023; SALTO, n.d. - b).

Concluding Remarks

Needless to say, the fact that Europe has to rely on a private third party for its most sensitive payloads is of major concern. As discussed in this paper through the analysis of different political and technological scenarios, the gap in European space access autonomy is starting to show its most dire strategic drawbacks. At the same time, it is also very clear that ESA and European institutions have recognised the urgency of regaining independence in space.

ESA's inter-ministerial meeting during this November's European Space Summit gave new promising momentum for Ariane 6's debut by solving disputes among participating member states. Moreover, ESA managed to broker a contract with Amazon, providing a great starter role for Ariane 6 in the domain of private space competition vis-à-vis the agency's latest dependence on SpaceX. Ariane 6 has completed crucial tests for flight eligibility, culminating with the already mentioned successful long-duration hot-fire static test on 23 November 2023 and with the announcement of an upcoming maiden flight set for next summer (Emir, 2023; Foust, 2023d). Finally, interest in the valorisation of Ariane Next and SALTO is a testimony to Europe's realisation of the importance of rocket reusability in the agenda of future European space policy.

Overall, it could be argued that the drawbacks of Ariane 6's development are being positively interpreted by ESA and EUSPA as a lesson rather than a defeat, building an important starting point to address upcoming challenges. Perhaps, the long-awaited "light at the end of the tunnel", in the words of ESA Director General Josef Aschbacher (Hepher, 2023), is finally about to shine on a renewed European future in the darkness of space, hopefully by August 2024. The eyes of the continent are now pointed at the sky, looking for that light in the engine plume of an Ariane 6 circling a blue firmament of twelve golden stars.

References

Aerospace Technology. (n.d.). Ariane 6 Launch Vehicle. Retrieved November 23, 2023, from: https://www.aerospace-technology.com/projects/ariane-6-launch-vehicle/.

Anderson, C. E. (2023, July 11). Goodbye to Ariane 5. National Air and Space Museum. https://airandspace.si.edu/stories/editorial/goodbye-ariane-5#:~:text=Its%20117%20launches%20over%20more,reliable%20launchers%20on%20the%20market.

ArianeGroup. (2022, April 5). Arianespace signs unprecedented contract with Amazon for 18 Ariane 6 launches to deploy Project Kuiper constellation. Retrieved November 23, 2023, from: https://www.arianespace.com/press-release/arianespace-signs-unprecedented-contract-with-amazon-for-18-ariane-6-launches-to-deploy-project-kuiper-constellation/.

ArianeGroup. (n.d.). How do you build Ariane 6 rockets?. Retrieved November 23, 2023, from: https://www.ariane.group/en/news_kid/how-do-you-build-ariane-6-rockets/.

Berger, E. (2023a, October 12). Oops—It looks like the Ariane 6 rocket may not offer Europe any launch savings. Ars Technica. https://arstechnica.com/space/2023/10/oops-it-looks-like-the-ariane-6-rocket-may-not-offer-europe-any-launch-savings/.

Berger, E. (2023b, November 6). Ariane 6 cost and delays bring European launch industry to a breaking point. Ars Technica. https://arstechnica.com/space/2023/11/ariane-6-cost-and-delays-bring-european-launch-industry-to-a-breaking-point/.

Brown, M. (2022, January 24). Ariane 6 vs. SpaceX: How the rockets stack up. Inverse. https://www.inverse.com/innovation/ariane-6-vs-spacex.

CNES. (2020, September 15). [Lanceurs] Ariane Next Regarde Vers La Prochaine Décennie. Retrieved November 25, 2023, from: https://ariane6.cnes.fr/fr/lanceurs-ariane-next-regarde-vers-la-prochaine-decennie.

Costa, J. (2020, December 20). NASA Awards Launch Services Contract for Sentinel-6B Mission. NASA. https://www.nasa.gov/news-release/nasa-awards-launch-services-contract-for-sentinel-6b-mission/#:~:text=The%20Sentinel%2D6B%20mission%20currently,continuity%20of%20ocean%20topography%20measurements.

Cowing, K. (2023, March 16). SALTO project will advance forward Europe's first reusable rocket. SpaceRef. https://spaceref.com/space-commerce/salto-project-will-advance-forward-europes-first-reusable-rocket/.

Dinner, J. (2023, November 18). SpaceX Starship megarocket launches on 2nd-ever test flight, explodes in 'rapid unscheduled disassembly' (video). Space.com. https://www.space.com/spacex-starship-second-test-flight-launch-explodes.

Earth Online. (n.d.). EarthCARE. Retrieved November 25, 2023, from: https://earth.esa.int/eogateway/missions/earthcare.

Emir, C. (2023, November 24). ESA's Ariane 6 rocket aces critical hot-fire test. Interesting Engineering. https://interestingengineering.com/science/esa-ariane6-static-fire-test.

ESA. (2023, November 2). Watch the Space Summit live. Retrieved November 23, 2023, from: https://www.esa.int/About_Us/Corporate_news/Watch_the_Space_Summit_live.

ESA. (n.d. -a).Ariane 5. Retrieved November 23, 2023, from: https://www.esa.int/Enabling_Support/Space_Transportation/Launch_vehicles/Ariane_5.

ESA. (n.d. - b).Ariane 6. Retrieved November 23, 2023, from: https://www.esa.int/Enabling_Support/Space_Transportation/Launch_vehicles/Ariane_6.

ESA. (n.d. - c).Juice factsheet. Retrieved November 24, 2023, from: https://www.esa.int/Science_Exploration/Space_Science/Juice_factsheet.

ESA. (n.d. - d).webb. Retrieved November 24, 2023, from: https://www.esa.int/Science_Exploration/Space_Science/Webb.

ESA. (n.d. - e). Unveiling vehicles and technologies for future space transportation. Retrieved November 25, 2023, from: https://www.esa.int/Enabling_Support/Space_Transportation/Future_space_transportation/Unveiling_vehicles_and_technologies_for_future_space_transportation?s.

ESA. (n.d. - f). euclid launch kit. Retrieved November 25, 2023, from: https://esamultimedia.esa.int/docs/science/Euclid-LaunchKit.pdf.

Fonte, G. (2023, November 6). Italy, France and Germany agree on launches of Ariane 6 and Vega-C. Reuters. https://www.reuters.com/technology/space/italy-france-germany-agree-launches-ariane-6-vega-c-2023-11-06/.

Foust, J. (2023a, September 12). Kuiper launch companies say they can meet Amazon's schedule. SpaceNews. https://spacenews.com/kuiper-launch-companies-say-they-can-meet-amazons-schedule/.

Foust, J. (2023b, October 2). ESA delays Vega C return to flight to late 2024. SpaceNews. https://spacenews.com/esa-delays-vega-c-return-to-flight-to-late-2024/.

Foust, J. (2023c, November 7). EU finalizing contract with SpaceX for Galileo launches. SpaceNews. https://spacenews.com/eu-finalizing-contract-with-spacex-for-galileo-launches/.

Foust, J. (2023d, November 30). ESA sets mid-2024 date for first Ariane 6 launch. SpaceNews. https://spacenews.com/esa-sets-mid-2024-date-for-first-ariane-6-launch/#:~:text=At%20a%20Nov.%2030%20briefing,in%20the%20spring%20of%202024.

France24. (2022, December 21). Vega-C rocket lost shortly after lift-off in French Guiana. France24. https://www.france24.com/en/live-news/20221221-vega-c-rocket-lost-shortly-after-lift-off-in-french-guiana.

Hecker, P., Bestmann, U., Schwithal, A., & Stanisak, M. (2018, October). Galileo Satellite Navigation System. EPRS – European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/STUD/2018/614560/EPRS_STU(2018)614560_EN.pdf.

Hepher, T. (2023, October 31). Europe's space agency boss sees progress on Ariane 6 launcher. Reuters. https://www.reuters.com/technology/space/europes-space-agency-boss-sees-progress-ariane-6-launcher-2023-10-31/.

Hepher, T., & Fonte, G. (2023, November 7). Europe targets competitive shake-up in space launch deal. Reuters. https://www.reuters.com/technology/space/europe-urged-not-repeat-tech-underdog-role-ahead-space-talks-2023-11-06/.

Hepher, T., & Lipinski, P. (2023, November 30). Europe's new Ariane 6 rocket to launch June 15-July 31, 2024. Reuters. https://www.reuters.com/technology/space/europes-new-ariane-6-rocket-launch-between-june-15-july-31-2024-2023-11-30/.

Hera Mission. (n.d.). Hera Mission. Retrieved November 25, 2023, from: https://www.heramission.space/.

Howell, E. (2023, July 3). Ariane 5's Final Flight – A Look Back as Ariane 6's Costly Succession Looms. SpaceRef. https://spaceref.com/space-commerce/ariane-5-final-flight-look-back-ariane-6-costly-succession-looms/#:~:text=Will%20Ariane%206%20be%20worth,9%20at%20%242.7%20per%20kilogram.

Iacopino, L. (2023, August 8). SALTO: the new European project ready to work with reusable rockets. SALTO. https://salto-project.eu/salto-the-new-european-project-ready-to-work-with-reusable-rockets/.

Jones, A. (2023a, May 26). NASA's Artemis moon rocket will cost $6 billion more than planned: report. Space.com. https://www.space.com/nasa-sls-megarocket-cost-delays-report

Jones, A. (2023b, September 1). Crucial test of Europe's long-delayed Ariane 6 rocket delayed. Space.com. https://www.space.com/esa-ariane-6-testing-delay

Lo Campo, A. (2023, April 19). Vega-C, il razzo italiano attende di ripartire. BFCspace. https://bfcspace.com/2023/04/19/vega-c-il-razzo-italiano-attende-di-ripartire/.

Patureau de Mirand, A., Bahu, J. M., & Louaas, E. (2019). Ariane Next, a vision for a reusable cost efficient European rocket. EUCASS. https://www.eucass.eu/doi/EUCASS2019-0949.pdf.

Posaner, J. (2021, January 15). Europe's lack of rocket 'audacity' leaves it scrambling in the space race. Politico. https://www.politico.eu/article/europe-arianespace-rocket-space-race/#:~:text=%E2%80%9CThe%20European%20space%20adventure%20is,should%20have%20had%20this%20audacity.%E2%80%9D.

Posaner, J., & Cerulus, L. (2023, April 17). EU turns to Elon Musk to replace stalled French rocket. Politico. https://www.politico.eu/article/eu-elon-musk-replace-stalled-france-rocket-galileo-satellite/.

Rabie, P. (2023, September 5). Launch Uncertainty Lingers as Ariane 6 Rocket Undergoes Engine Test. Gizmodo. https://gizmodo.com/ariane-6-rocket-european-space-agency-delays-1850805673.

SALTO. (n.d. - a). SALTO - reuSable strAtegic space Launcher Technologies & Operations. Retrieved November 25, 2023, from: https://salto-project.eu/.

SALTO. (n.d. - b). Test facility. Retrieved November 25, 2023, from: https://salto-project.eu/test-facility/.

Sheetz, M. (2023, September 1). Bezos snubbed Musk's SpaceX for huge satellite launch contract, Amazon shareholder says. CNBC. https://www.cnbc.com/2023/09/01/bezos-snubbed-musk-spacex-satellite-contract-lawsuit.html.

Simpson, C. (2023, July 11). Ariane 5 retirement leaves Europe facing an 'acute launch crisis'. Spaceflight Now. https://spaceflightnow.com/2023/07/11/ariane-5-retirement-leaves-europe-facing-an-acute-launch-crisis/.

SpaceX. (n.d. - a). Falcon 9. Retrieved December 4, 2023, from: https://www.spacex.com/vehicles/falcon-9/.

SpaceX. (n.d. - b). Falcon Heavy. Retrieved November 24, 2023, from: https://www.spacex.com/vehicles/falcon-heavy/.

Wattles, J. (2023, December 1). Amazon taps SpaceX for satellite launch even though Jeff Bezos is right there. CNN Business. https://edition.cnn.com/2023/12/01/business/amazon-spacex-kuiper-launch-scn/index.html.