ARCHIVED REPORT

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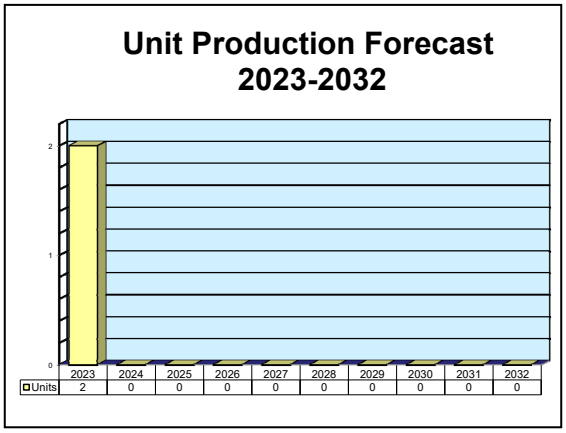
Ariane 5

Outlook

- Ariane 5 launched three times in 2020, 2021, and 2022
- Ariane 5's final launch occurred in July 2023
- Ariane 5's final payloads were the Heinrich Hertz and Syracuse 4B satellites



Orientation

Description. The Ariane 5 is a European heavy-lift expendable launch vehicle (ELV).

Sponsor. Arianespace of Evry, France, operates the Ariane 5. Arianespace shareholders include French space agency CNES, as well as other French companies and companies from Belgium, Denmark, Germany, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland.

Status. Operational. Arianespace conducted its first commercial Ariane 5 launch in December 1999.

Total Produced. Arianespace conducted 117 Ariane 5 launches through 2023.

Application. The baseline Ariane 5 (generic) launch vehicle can place payloads weighing 6,800 kilograms into geostationary transfer orbit (GTO). The Ariane 5 ECA can launch 8,700 kilograms to GTO.

Price Range. Ariane 5 rockets cost approximately $140 million to $160 million, depending on the configuration. Arianespace typically books between $180 million and $200 million in revenue per Ariane 5 launch.

Contractors

Prime

Airbus Defence and Space	http://www.airbus.com, 61 Route de Verneuil, BP 3002, Les Mureaux, France, Tel: + 33 01 39 06 12 34, Prime
Arianespace	http://www.arianespace.com, Boulevard de l'Europe, BP 177, Evry-Courcouronnes, France, Tel: + 33 1 60 87 60 00, Fax: + 33 1 60 87 63 04, Email: info@arianespaceonline.com, Second Prime

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Subcontractor

Airbus Defence and Space	http://www.airbusdefenceandspace.com, 6, rue Laurent Pichat, Cedex 16, Paris, France, Tel: + 33 1 77 75 80 00 (Vehicle Equipment Bay)
Avio Aero	http://www.avioaero.com, Via I Maggio, 99, Rivalta di Torino, Torino, Italy, Tel: + 39 011 00 82111, Fax: + 39 011 00 82000, Email: transmissions@avioaero.it (Solid Rocket Insulation)
Beyond Gravity Sweden AB, (formerly RUAG Space)	http://www.beyondgravity.com/en, Solhusgatan 11, Gothenburg, Sweden, Tel: + 46 31 735 00 00, Fax: + 46 31 735 40 00 (Modular Payload Adapters)
Daimler AG	http://www.daimler.com, Mercedesstrasse 137, Stuttgart, Germany, Tel: + 49 711 17 0, Fax: + 49 711 1722 244, Email: dialog@daimler.com (Upper Stage)
Europropulsion SA	http://www.avio.com/en/about-us/group/europropulsion/, 11 rue Salomon de Rothschild, Suresnes, France, Tel: + 33 1 46 97 83 83, Fax: + 33 1 40 99 10 48 (Solid Rocket Motor)
IberEspacio	http://www.iberespacio.es, Magallanes, 1, 1a Planta, Madrid, Spain, Tel: + 34 91 444 15 00, Fax: + 34 91 445 17 64, Email: iber@iberespacio.es (Hydraulic & Pneumatic Auxiliary System for Propulsion Facility)
MT Aerospace AG	http://www.mt-aerospace.de, Franz-Josef-Strauss-Strasse 5, Augsburg, Germany, Tel: + 49 821 505 01, Fax: + 49 821 505 1000, Email: pr@mt.aerospace.de (Propellant Tanks)
Rheinmetall Air Defence AG	http://www.rheinmetall-defence.com, Birchstrasse 155, Zurich, Switzerland, Tel: + 41 44 316 2211, Fax: + 41 44 311 3154, Email: info@ocag.ch (Fairing)
Safran Space Engines	http://www.safran-aircraft-engines.com, 1 avenue Hubert Curien, Vernon, France, Tel: + 33 02 32 64 88 00, Fax: + 33 02 32 64 88 90 Defunct (Vulcain 2 Main Engine)

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 75 Glen Road, Suite 302, Sandy Hook, CT 06482, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. The Ariane 5 launch vehicle features a large cryogenic stage called the EPC (Étage Principal Cryogénique). The EPC is 30 meters tall and operates for a total of 589 seconds. The EPC includes the mounting locations for the Ariane 5's two solid boosters. Once the main cryogenic stage is ignited on the pad and the two solid boosters are jettisoned in flight, the stage continues as the sole source of propulsion for an additional 459 seconds of powered flight. At the end of the EPC burn, the stage re-enters the atmosphere and disintegrates. The EPC is powered by a single Vulcain liquid-propellant rocket engine burning liquid oxygen and liquid hydrogen. The launcher's cryogenic fuel tank has a diameter of 5.4 meters and holds 130 metric tons of liquid oxygen and 25.5 metric tons of liquid hydrogen.

Fitted to the cryogenic first stage are two 30-meter, three-segment solid-propellant booster stages called EAPs (Étage d'Accelération Poudre). The EAPs propel the 725-metric-ton Ariane 5 from the launch pad with an acceleration of 0.5 *g* at liftoff. Each EAP is loaded with 240 metric tons of solid propellant. The EAPs deliver a combined thrust of 1,370 metric tons at liftoff, or more than 90 percent of the total launcher's thrust at the start of flight.

The Ariane 5's upper stage – designated EPS (Étage à Propergols Stockables), or storable propellant stage – is powered by a single reignitable Aestus engine, which uses monomethyl hydrazine (MMH) and nitrogen tetroxide (N_2O_4). The engine burns for a total of 18.3 minutes.

Mission avionics are housed in the Ariane 5 vehicle equipment bay (VEB), a cylindrical structure that rests on top of the EPC, providing data processing, guidance, stage sequencing, telemetry, tracking, and other functions. The VEB features a pair of ring laser gyros for inertial reference and guidance, as well as two attitude control system (ACS) clusters, each with three 400 N thrusters.

The Ariane 5 features several satellite-carrying structures, depending on payload size. The External Structure for Dual Launches (known by its French acronym, Speltra) is sized for large single or multiple satellite loads, typically in the 3- to 4.5-metric-ton class. The structure can house a 4.6-meter-high satellite, on

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which a truncated cone for another satellite sits. A shorter Speltra to accommodate satellites 3.1 meters in height is also available, as is a stretched Speltra to handle satellites up to 6.1 meters high.

The Internal Structure for Dual Launches (Sylda 5) has a useful interior diameter of 4 meters and comes in six versions to accommodate satellites in the lower position, with a maximum height of 2.9 to 4.4 meters.

The Ariane Structure for Auxiliary Payloads (ASAP) platform is designed to carry mini- or micro-satellites as secondary payloads. The ASAP can be placed on top of the upper stage or on the Speltra or Sylda structures.

Locating the ASAP under a primary payload allows the structure to carry up to eight micro-satellites, each weighing less than 120 kilograms. Mounting the ASAP inside the Sylda permits the deployment of as many as four mini-satellites weighing up to 300 kilograms each, or two 300-kilogram mini-satellites and six 120-kilogram micro-satellites.

The Ariane 5's payload fairing is made of carbon-fiber-reinforced plastic skins and an aluminum honeycomb core. Two fairings are available, depending on the payload configuration, with the longest version 17 meters long and capable of accommodating payloads more than 9.6 meters high.

The Ariane launch complex, ELS-3, was constructed at Arianespace's Guiana Space Center in Kourou, French Guiana, for Ariane 5 missions. The facility has an Ariane 5 solid-rocket-booster processing area, complete with a vertical test stand featuring a flame trench 200 meters long, 35 meters wide, and 60 meters deep.

	Metric	U.S.
Dimensions		
Rocket overall length	45-55.4 m	147-181.7 ft
Booster length	31.16 m	103.6 ft
Booster diameter	3.05 m	10 ft
Stage 1 length	30.7 m	100 ft
Stage 1 diameter	5.4 m	17.7 ft
Stage 2 length	3.3 m	11.2 ft
Stage 2 diameter	4 m	13.1 ft
Weight		
Rocket launch weight	745-750 tonnes	821-826.7 tons
Solid booster gross mass (each)	277.5 tonnes	305 tons
Stage 1 gross mass	170.8 tonnes	188.2 tons
Stage 2 gross mass	12.5 tonnes	13.8 tons
Performance		
Solid booster thrust (each)	5,904 kN (vacuum)	1,328,400 lbst
Stage 1 thrust	900 kN (sea level)	202,500 lbst
Stage 2 thrust	29 kN (vacuum)	6,525 lbst
Payload to 550 km, 28.5°	18,000 kg	39,682 lb
Payload to 407 km, 51.6° (Space Station)	16,000 kg	35,274 lb
Payload to 800 km, 98.6°	12,000 kg	26,455 lb
Single payload to GTO	6,800 kg	14,991 lb
Dual payload to GTO	5,900-6,400 kg	13,000-14,110 lb

Propulsion

Stage 0	2	Europropulsion strap-on solid rocket boosters, 11,808 kN
Stage 1	1	SEP HM60 Vulcain liquid rocket engine, 900 kN
Stage 2	1	DaimlerChrysler Aerospace Aestus liquid rocket engine, 29 kN

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An Ariane 5 ECA lofts the JCSAT-10.

Source: Arianespace

Variants/Upgrades

The prospect of launching larger satellites prompted the European Space Agency (ESA) to develop the Ariane 5 Plus program (beginning in 1998), with the goal of increasing the payload capacity of the Ariane 5 while also lowering its launch price. This was a three-step process. The first step covered the first year of activities. The second covered initial development of the Vinci engine, upgrade of the initial ground segment, and full development of the versatile version of the existing upper stage, together with completion of the Ariane 5 ECA version, bringing its lift capacity to approximately 10,000 kilograms in GTO. The third step was to complete development of the Vinci engine, upgrade the ground segment, develop the Ariane 5 ECB version, and launch this version for the first time, bringing the GTO lift capacity to 12,000 kilograms for a single mission.

Cryogenic Main Stage and Solid Boosters. As part of the Ariane 5 Evolution program, the cryogenic main stage and solid rocket boosters were upgraded. The Vulcain 2 produces 1,353.4 kN, an improvement of more than 50 percent over the previous Vulcain powerplant.

The solid rocket boosters now carry an additional 2,400 kilograms of propellant in the upper cast segment, increasing the motor's maximum thrust to 7,002.2 kN.

Ariane 5 ECA. The Ariane 5 ECA upgrade includes the liquid-hydrogen- and liquid-oxygen-burning ESC-A (Étage Supérieur Cryogenique) upper stage borrowed from the HM-7B engine that is used on the Ariane 4's third stage. The ECA provides the Ariane 5 with a payload capability of 9,100 kilograms to GTO (with the Sylda structure) and 10,500 kilograms while carrying a single satellite. The rocket uses the Ariane 5 Vulcain 2 lower stage engine.

The ECA failed on its flight debut in December 2002 when the Vulcain 2 experienced a dramatic pressure drop in the cooling system. It was determined that the wall of the upper part of the Vulcain 2's nozzle had started to deform under load and heated until it cracked. The first abnormalities were detected 58 seconds into flight. With exhaust gases exceeding 3,000°C and the cooling system in the nozzle becoming increasingly less effective, leaks and deformations accumulated. Finally, the engine's thrust was no longer on the same axis as the launcher, causing a loss of control three minutes into the flight. The command to self-destruct was then sent.

The Vulcain's contractor, Snecma, designed corrective measures, and the first modified nozzle was tested on Snecma's engine test stand in Vernon, France.

The primary modifications were an enhanced cooling system, a mechanical strengthening of the nozzle structure, and additional thermal protection.

The ECA+ uses a slightly different engine on the second stage. This engine is known as ESC-D H14.7 / HM-7B. This variant is currently the only one flying.

Ariane 5 ECB. Also known as the ESC-B, this version was designed with the Vulcain 2 lower stage engine, a new Vinci upper stage engine, and 25,000 kilograms of liquid hydrogen and liquid oxygen. The ECB would have the capability for multiple in-flight restarts (compared to the ECA, which fires only once during flight). Using expander cycle-type technology and featuring an extendable nozzle, the Vinci engine would produce 152 kN of thrust.

ECB development was placed on hold following the ECA failure in December 2002. The program remains officially on hold.

Ariane 5 Versatile (ES). The ES (Étage Storable) was specifically designed for the launch of International Space Station (ISS) automated transfer vehicles (ATVs); other missions are possible for the ES but not likely, according to Arianespace. The only variant currently in use appears to be the ECA+. The current Ariane 5 upper stage was modified to allow 7,300 kilograms to be carried in a dual-satellite (Speltra) configuration to GTO. Carrying single satellites of up to 8,000 kilograms to GTO is also possible with the "versatile" storable propellant upper stage, which is able to conduct ballistic coasts as well as perform multiple restarts.

Primarily geared toward missions to low-Earth orbit (LEO) and medium-Earth orbit (MEO), the Versatile upper stage can also be used to deliver payloads to GTO or directly to geostationary orbit. This model made its debut in 2008, launching the first ISS ATV, Jules Verne.

Ariane 5 Midlife Evolution (ME). The Midlife Evolution was a proposed program to upgrade the payload mass to orbit capability of the Ariane 5 by about 20 percent. The upgrade would also include a restartable upper stage. The ME program was canceled in November 2014.

Program Review

Background. Development of the Ariane 5 heavy-lift launch vehicle was approved by ESA in 1985. The first full-scale test-firing of the booster's EAP solid rocket motor took place at the Guiana Space Center in 1993, followed in 1994 by the first test-firing of the Vulcain main cryogenic propellant engine.

Arianespace ordered 14 Ariane 5 vehicles in 1995. During the same year, the ESA Council approved the Ariane 5 Evolution program, which improved the booster's performance through the early part of the decade. Arianespace placed a follow-on order for an additional 20 boosters in 1999.

A Billion-Dollar Setback

ESA suffered a major setback when the first flight of an Ariane 5 ended less than a minute after it began. The rocket, which was carrying a $500 million ESA science payload called Cluster, veered from its assigned flight path just 40 seconds into its launch, prompting ground controllers to send the booster a self-destruct command.

An inquiry board investigating the loss revealed that the accident was caused by specification and design errors in the software of the inertial reference system. The result was a complete loss of guidance and attitude information.

Fixing the problems pushed the Ariane 5's second flight into late 1997. The second mission was judged a partial success after the rocket's Vulcain engine shut down prematurely, leaving the Maqsat H dummy communications satellite in a lower-than-planned GTO. Analysis of the incident revealed that the booster experienced an excessively high roll rate brought on by tiny welding imperfections in the main engine nozzle, causing the boundary layer of the main jet to spiral.

Commercial Operations Begin in 1999

The first commercial launch of an Ariane 5 occurred in December 1999. It placed ESA's 4,000-kilogram, 10-foot-tall X-ray Multi-Mirror (XMM) spacecraft observatory into an elliptical orbit with a perigee of 827 kilometers and an apogee of 113,946 kilometers, inclined 40°. The XMM is equipped with three telescopes and performs X-ray astronomy missions.

Ariane 5 Wins ISS Contract. ESA awarded Arianespace a contract in November 2000 to supply nine Ariane 5 ELVs to launch automated transfer vehicles to the International Space Station. ATVs, which weigh approximately 46,000 pounds, deliver supplies to the ISS. Launches began in 2008.

Ariane 5 Failures

In July 2001, an Ariane 5 launch carrying the BSAT-2b for BSAT of Japan and ESA's Artemis spacecraft ended in failure. An anomaly of the storable propellant second stage (EPS) caused a 20 percent decrease in thrust. An independent inquiry board convened by Arianespace found that a combustion instability during upper stage ignition resulting from water in the flow lines had caused the Ariane 5 to place its payloads into the wrong orbits. In response to the failure, the Ariane 5 was equipped with cryogenic drying techniques and a helium line to flush the flow lines before ignition.

After a seven-month hiatus, an Ariane 5 successfully launched a satellite using the modified techniques. However, in December 2002, an Ariane 5 – carrying the Eutelsat Hot Bird 7 and the experimental Stentor satellite on flight 157 – experienced another failure. A minute and a half into flight, the Vulcain 2 engine experienced a pressure drop in the cooling system. Three minutes into the flight, the engine speed changed,

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causing the launch vehicle to go out of control and self-destruct 800 kilometers off the coast of French Guiana. Two reasons were found for the failure: a nozzle had deformed under load and cracked, and, due to its large size, the Vulcain 2 engine had not been exhaustively tested on the ground before flight.

The Vulcain's contractor, Snecma Moteurs, designed corrective measures, and the first modified nozzle was tested to validate the design on Snecma's engine test stand in Vernon, France. The primary modifications were an enhanced cooling system, a mechanical strengthening of the nozzle structure, and additional thermal protection.

Following the flight 157 failure, Arianespace revised its plan to phase out the baseline version of the Ariane 5, known as the 5G (Generic). The Ariane 5G successfully launched two satellites in April 2003: the Indian Insat 3A and the U.S. Galaxy XII. Another successful launch followed in June 2003, when an Ariane 5G placed the Optus C1 and BCSAT 2C into orbit. The Ariane 5G continued its success with the launch of the Insat 3E, the e-Bird, and Europe's SMART-1 Lunar orbiter in September 2003. The latter marked the final Ariane 5 mission in 2003.

Vinci Engine Tested. Hot-firing tests of the Vinci cryogenic upper stage engine were conducted on July 27, 2005, with a successful burn lasting 60 seconds. This was the longest duration test since trials had begun, and the first carried out under full test conditions. The trials were carried out in the P4.1 test stand of the German Space Agency (DLR) in Lampoldshausen, Germany, a facility built to perform hot-firing tests under near-realistic space conditions.

Ariane 5 Plus Program Succeeded by ACEP

The Ariane 5 improvement program, known as Ariane 5 Plus, was replaced with a follow-on called the Ariane Consolidation and Evolution Program (ACEP). This new program developed improvements to the Ariane 5 ECA and associated ground operations. The main goal of the ACEP was to reduce the cost of the Ariane 5 to ensure its future competitiveness. The ACEP also focused on development of the Vinci M3 engine, which is essentially identical to the M2. The M3 would be a reignitable cryogenic upper stage engine that does not require a gas generator to drive two liquid-fuel turbopumps. The expected performance of the M3 is 39,650 lbst (vacuum), with a specific impulse of 465 seconds. It was expected to fly by 2016 or 2017.

Ariane 5 ES Put into Service

In March 2008, ESA successfully launched its first automated cargo spacecraft carrying supplies for the International Space Station. An Ariane 5 ES lifted off from Kourou, French Guiana, and placed the automated transfer vehicle, Jules Verne, into a 260-kilometer orbit. The ATV is the largest and most sophisticated spacecraft built by Europe and is capable of carrying several tons of cargo, including food, water, and propellant. The actual docking of the ATV to the ISS took place in early April to avoid conflicts with the STS-123 shuttle mission that also launched in March.

In 2011, the Ariane 5 Midlife Evolution upgrade program successfully completed a Preliminary Design Review (PDR).

In 2013, Airbus was awarded $554 million worth of contracts to develop components for the Ariane 5 and Ariane 6. In November 2014, Germany agreed to drop its demand for an upgraded Ariane 5, terminating the Ariane 5 ME program. Europe will instead focus on developing the Ariane 6.

Among recent activity, during a January 25, 2018, launch, the wrong values were programmed into the inertial reference unit, causing the Ariane 5 to carry its two payloads into the wrong orbital incline. The satellites were able to use their own propellant systems to correct the mistake.

COVID-19

The COVID-19 pandemic that emerged in 2020 shut down the Kourou launch facility for some time. As a result, there were no Ariane 5 launches between March and July 2020. Launches have since resumed, but there have been delays, especially with the Ariane 6. This will likely push total replacement of the Ariane 5 back about a year.

Fairing Separation Troubles

In addition to the pandemic, there was speculation that launch delays might have been caused by issues with Ariane 5. Arianespace confirmed these suspicions and stated that there had in fact been issues with the separation of the fairing in two flights.

These issues did not affect the missions, however, which were both successful. The problem is reportedly high vibration during fairing separation. Since the James Webb Space Telescope is set to launch on an Ariane 5, there has been some concern. However, there has since been an Ariane 5 launch with no reported issues.

Final Flight

On July 5, 2023, the Ariane 5 flew for the final time. With the Heinrich Hertz and Syracuse 4B satellites as payloads, the mission was a success. This final flight marks the beginning of Ariane 6 launches; however, this launch vehicle has had some delays. Ariane 6 is slated to launch for the first time in 2024.

Forecast Rationale

The Ariane 5 is one of the primary launch vehicles for commercial geosynchronous communications satellites. Other major players in the commercial market include the ILS Proton and the SpaceX Falcon 9. The Ariane 5 also provides launches for European military and civil government satellites and spacecraft.

Despite its strong position in the market, the Ariane 5 faces a changing competitive landscape that has forced Arianespace to respond. One factor is the emergence of SpaceX as an especially strong competitor. The Hawthorne, California-based company has been gaining market share by offering low prices.

However, despite serious competition from SpaceX, it appears that Ariane 5 is still able to hold its own. In an article published in mid-2019, it was announced that Ovzon had decided to use Arianespace rather than SpaceX. Ovzon, a satellite broadband company headquartered in Sweden, received a better deal to use Ariane 5 rather than Falcon Heavy for a launch that was scheduled in 2021.

Because SpaceX focuses on the reusability of its rockets, the cost for a launch is, in theory, lower. However, Falcon Heavy began launches in 2018, and perhaps cost savings have yet to take effect. Ovzon's switch to Arianespace over SpaceX may be anomalous, as there is another factor limiting the Ariane 5's future appeal.

The growth of the small satellite market and the increasing number of satellites launched to low-Earth orbit might prove detrimental to the Ariane 5 program. The Ariane 5 is optimized to carry heavy satellites to geosynchronous orbit; therefore, it will garner some orders, but in a limited market.

In response to these threats, European nations now plan to replace the Ariane 5 with the Ariane 6. Ariane 6 production will be spread among fewer locations, lowering manufacturing costs. In addition, the Ariane 6 will share components with Europe's smaller Vega, further increasing efficiencies of scale. Finally, the Ariane 6 will be built in multiple variants, allowing Arianespace to sell different size launch vehicles to customers based on their needs. That will allow Arianespace to better compete with SpaceX and to accommodate various sizes of satellites.

Ariane 5 has launched its last mission. Despite delays with Ariane 6, Ariane 5 will likely never be built again. Therefore, next year's edition of this report will be archived.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR UNIT PRODUCTION												
Designation or Program		High Confidence				Good Confidence			Speculative			
	Thru 2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Airbus Defence and Space												
Ariane 5 ECA												
	43	2	0	0	0	0	0	0	0	0	0	2
Total	43	2	0	0	0	0	0	0	0	0	0	2