The Ariane-5 ECA Heavy-Lift Launcher

Lift-off of the Ariane-5 ECA for its qualification flight L 521 from the European Spaceport in French Guiana

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Ariane-5 ECA made a flawless qualification flight on 12 February 2005, heralding this version of the launcher's readiness to enter the launch-services market. This major step forward was the result of more than two years of very intense efforts within the framework of the Ariane Recovery Plan, endorsed by the ESA Council on Ministerial Level in May 2003, after the failure of the ECA version's maiden flight in December 2002. The recovery involved ESA, CNES, Arianespace and European Industry in a consolidated effort to establish this launcher as the European launch-services 'workhorse' for many years to come.

Introduction

ESA's Ariane Development Programme is funded by 14 Participating States. Ariane-5 has been launched 21 times to date from the European Spaceport (CSG) in Kourou, French Guiana, with four of those launches dedicated to the flight-qualification of the various versions. The commercial flights are prepared and operated by Arianespace, which orders the production launchers from European Industry.

As the new heavy-lift version of the Ariane-5 family, Ariane-5 ECA provides a 35% increase in payload performance compared with the baseline Ariane-5 G version. It is optimized and qualified for dual-launch missions to Geostationary Transfer Orbit (GTO), but specific adaptations are foreseen to make it flexible enough for other specific launch missions and orbits other than GTO.

The need for a larger version of the Ariane-5 launcher was identified in the 1990s, when market forecasts revealed that the launch-services market would have to cope with larger satellites. The Ariane philosophy today is to provide cost-efficient double-launch opportunities and so to follow the predicted market evolution a more powerful version had to be considered. The birth of Ariane-5 ECA has been the result of development activities conducted within the framework of two programmes: the Ariane-5 Evolution Programme, and the Ariane-5 Plus Programme. The aim of the former was to improve the performance of the launcher's lower composite, consisting of the boosters, the central EPC stage (Etage Principal Cryotechnique), and the Vulcain main engine. The latter concentrated on the development of new upper stages, of which the ESC-A (Etage Superieur Cryotechnique A) has become the upper-stage of Ariane-5 ECA.

The launch of Ariane-5 ECA as seen from the tracking station at CSG

The Ariane-5 Recovery Plan

Following the failure of the maiden Ariane-5 ECA flight, a Recovery Plan was proposed by the ESA Director General and subsequently adopted at the Council Meeting at Ministerial Level in May 2003. This Ariane-5 Recovery Plan was intended to:
- Re-establish the qualification status of the Ariane-5 ECA version.
- Provide Arianespace with the capability to manage its current backlog of commercial missions with the 'gap-filler' Ariane-5 G+ during 2004 and qualification of the 'back-up' Ariane-5 GS version.
- Ensure the European institutional missions, and in particular the ESA missions through the EGAS Ariane-5 Programme.

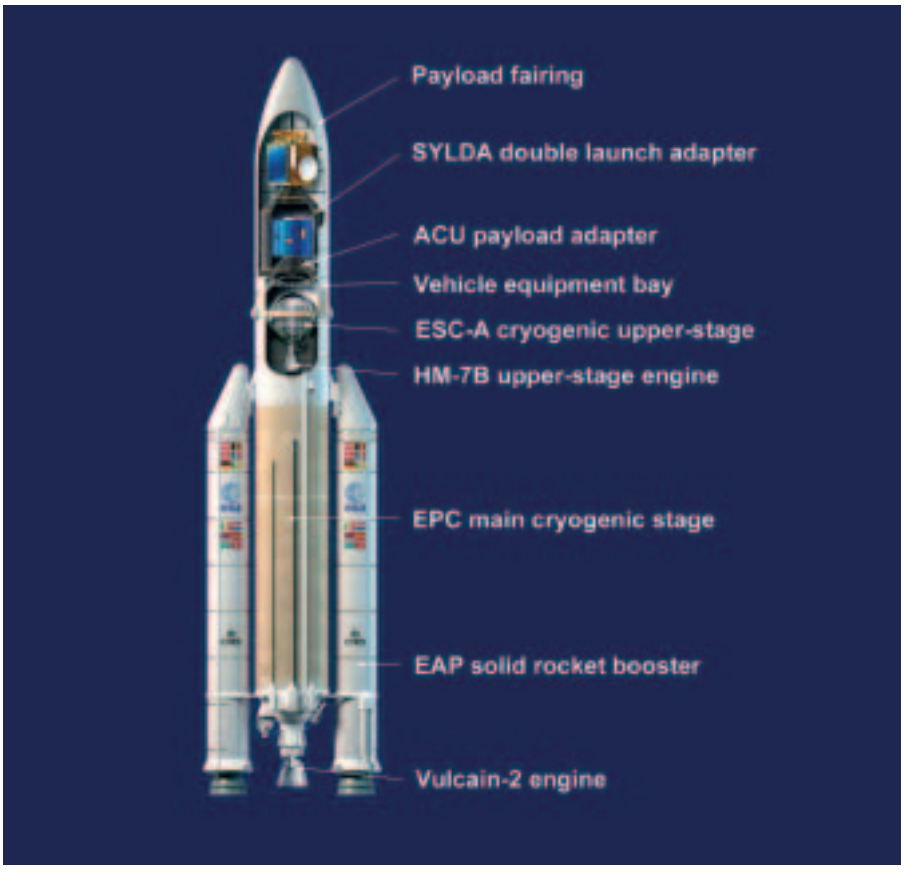
To this end, the Recovery Plan consisted of a scenario based on establishing the Ariane-5 ECA version as the 'workhorse' for Arianespace, and back-up scenarios for each milestone of the baseline scenario. In the baseline scenario, the following development activities were identified:
- Consolidation of the Vulcain 2 engine.
- Consolidation of the ESC-A upper stage.
- Qualification flight of the Ariane-5 ECA version (flight L521)
- Restarting of the production of new generic launchers (Ariane-5 GS)
- Qualification of the EPS upper stage for a re-start capability for the launch of ATV and qualification of the related Ariane-5 ES-ATV.

Closure of these activities in 2004/5 was the major objective, in order to be able to proceed with the Ariane-5 ECA qualification flight, to launch the three Ariane-5 G+ launchers, and to initiate the qualification and production processes for the Ariane-5 GS launcher.

Ariane-5 ECA was launched for the first time on 11 December 2002, but this maiden flight failed due to a malfunction in the new Vulcain-2 main engine. A Recovery Plan was endorsed by the ESA Ministerial Council in May 2003 to allow the improvements to be made that resulted in the successful L521 qualification flight on 12 February 2005.

Ariane-5 ECA

The Ariane-5 ECA vehicle stands 50.5 metres tall in double-launch configuration with the long fairing installed on top. It weighs 780 tons at lift-off and delivers a maximum thrust of 13 000 kiloNewtons. The launcher consists of a lower- and an upper-composite. The lower-composite is made up of the central EPC stage (Etage Principal Cryotechnique) with the new Vulcain-2 engine, and the two EAP solid-rocket boosters (Etage d'Acceleration à Poudre) attached laterally to the central



The main elements of the Ariane-5 ECA launcher

stage. The upper-composite consists of the Ariane-5 ESC-A (Etage Superieur Cryotechnique A) upper-stage with its HM-7B engine, the Vehicle Equipment Bay (VEB), the ACU payload adapters (Adaptateur Charge Utile) and the payload fairing. For double launches, the upper satellite is installed on the SYLDA (Système de Lancement Double Ariane).

The EPC central stage

The EPC central stage (Etage Principal Cryotechnique) is 31 metres long and has a diameter of 5.4 metres. It weighs 188 tons, 173 tons of which is propellant (148 tons of LOX and 25 tons of LH_2). The EPC is powered by the new Vulcain-2 engine, which provides 20% more thrust than its predecessor. The Vulcain-2 is ignited from the start to work for a maximum of 540 seconds prior to separation of the ESC-A upper-stage.

The Vulcain-2 main engine

Vulcain-2 is a new engine based on the Vulcain-1 of the generic Ariane-5 model. The new engine provides more thrust – 1350 kN compared with the 1100 kN of Vulcain-1 – and forms the basis of the launcher's central stage in its evolution configuration. The engine and in particular its nozzle extension have undergone major reworking in the past two years in implementing recommendations from the technical-review commissions to reach qualification status, involving in particular:

– Reduction of nozzle-extension wall temperature.
– Mechanical reinforcement of the upper nozzle-extension section.
– Assessment of fatigue behaviour of the exhaust-gas torus.
– Assessment of Vulcain-2 aerodynamic loads on the nozzle extension and shortening of the latter to reduce excitation.
– Increasing the number of circumferential mechanical stiffeners to improve the lower-end ovalisation behaviour.

The analyses have been accompanied by extensive development tests under the most extreme conditions, and have been verified by appropriate qualification tests on the P5 (DLR-Lampoldshausen) and P50 (SNECMA-Vernon) test-stands. A further series of tests has been performed using a specially developed Load Simulation Device (LSD) on the P5 test-stand. This device, consisting of a tight skirt around the nozzle extension, allowed near-flight conditions to be simulated, with a vacuum level of 200 mbar and the introduction of ovalisation loads (70 tons), whilst the engine performed a hot run under maximum load conditions.

The solid-rocket boosters

Attached to the central stage are the two EAP solid-rocket boosters, each of which weighs 280 tons, including 240 tons of propellant. The boosters are 31.6 metres high and have a diameter of 3 metres. The maximum thrust from each booster in vacuum is 7080 kN and they operate for 140 seconds. They are ignited 7 seconds after initiation of the Vulcain-2 engine start-up sequence and provide 90% of the lift-off thrust. The EAPs are of the evolution type, with the top segment of

The Vulcain-2 engine and its major modifications after completion of the reworking activities conducted in the framework of the Ariane Recovery Plan

Time	Event
T_0 – 7s	Start of the ignition sequence for the Vulcain-2 engine
T_0	Ignition of the solid-rocket boosters and lift-off
T_0 + 65s	Maximum dynamic pressure
T_0 + 140s	Extinction and separation of the solid-rocket boosters
T_0 + 188s	Separation of the payload fairing
T_0 + 530s	Extinction of Vulcain-2 engine and separation of the EPC
T_0 + 535s	Ignition of ESC-A upper-stage HM-7B engine
T_0 + 1480s	Extinction of the upper-stage engine and entry into a ballistic phase prior to separation of the first of the payloads in GTO

each booster carrying an extra 2 tonnes of solid propellant to generate a higher lift-off thrust.

The ESC-A upper stage

The upper composite of the Ariane-5 ECA launcher uses the newly developed ESC-A upper stage. Its LOX tank and HM-7B engine are heritage items from the Ariane-4 H10 cryogenic third stage. The LH_2 tank, however, is a new design using elements from the Ariane-5 main stage (EPC). The stage's wet mass is 19 tons with 14.6 tons of propellant (LOX and LH_2), which provides a maximum of 970 seconds of propelled flight. The 5.4 metre diameter of ESC-A corresponds to that of the central main stage. The HM-7B cryogenic engine provides a thrust of 65 kN in vacuum, with a specific impulse of 447 seconds. A launcher attitude-control system and roll-control system are installed with the ESC-A stage.

The Vehicle Equipment Bay

The Vehicle Equipment Bay (VEB) is a cylindrical, 5.4 metre diameter, carbon-fibre structure installed on top of the central stage. It houses the electrical equipment and the guidance, navigation and inertia platforms to control the launcher.

The fairing, SYLDA double-launch structure and payload adapters

The payload on top of the Ariane-5

The Ariane-5 launcher family

launcher is protected by a payload fairing during the atmospheric flight phases. It is a lightweight carbon-sandwich structure and is produced in three lengths to accommodate different sizes of payloads. The fairing length may be further increased in height by adding cylindrical sections (Adaptateur Cylindrique, or ACY).

The so-called SYLDA (Système de Lancement Double Ariane) is installed underneath the fairing in double-launch configuration. One passenger payload is installed inside the SYLDA, and the other sits on top of it. The SYLDA too is available in various lengths to accommodate satellites of different sizes.

Payload adapters (Adaptateur Charge Utile, or ACU) with various diameters are available to mount the payloads to the 3936 mm interfaces of the upper stage and of the SYLDA.

Ariane-5 ECA Launch Sequence

The launching of Ariane-5 ECA follows the sequence defined since the first Ariane-5 launches, with the timing of the various events depending on the number and masses of the satellites onboard, their intended orbital parameters, and the associated payload insertion criteria. The accompanying table shows a typical sequence for an Ariane-5 ECA launch to Geostationary Transfer Orbit (GTO).

The Ariane-5 Launcher Family

Ariane-5 ECA is supplemented by two further models of Ariane-5, which are presently in the qualification process and whose qualification flights are foreseen in 2005 and 2006, namely:

– Ariane-5 GS, and
– Ariane-5 ES-ATV.

Ariane-5 GS

The GS version of the launcher is based on the Ariane-5 Generic launcher, with the Vulcain-1 engine and elements of the lower composite based on the evolution configuration. The re-partitioning of the LOX and LH_2 propellants in the central stage (EPC) has been carefully matched to the specific mixture ratio of the Vulcain-1 engine. This GS version has been introduced as a backup to the ECA version and will be produced in only limited numbers.

Ariane-5 ES-ATV

The ES-ATV version has been introduced specifically to allow for the launch of the ATV (Automated Transfer Vehicle) to the International Space Station (ISS), in a 51.6 degree, low-Earth orbit (LEO). It can deliver a 20 ton payload to this orbit using a 'bi-boost' strategy. Ariane-5 ES is based on the evolution-type lower composite with the Vulcain-2 engine. The upper-stage is the EPS from the generic Ariane-5 launcher, qualified for three ignitions, two for the in-orbit insertion of the ATV, and a further boost for the de-orbiting of the upper stage.

Conclusion

Having now successfully completed its initial qualification flight, Ariane-5 ECA will make at least one more flight in 2005, together with the first flight of the new Ariane-5 GS. The first qualification flight of the Ariane-5 ES-ATV carrying 'Jules Verne' is currently expected to take place in mid-2006.

It is foreseen to stabilise the Ariane operating frequency at six launches per year, the majority of which will be Ariane-5 ECA flights. Consolidation of this version of the launcher as the European launch-services 'workhorse' for the coming years has been and remains a major programme objective. r