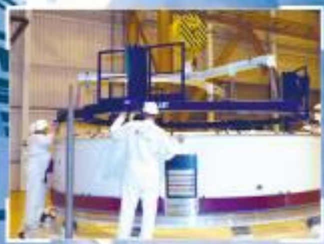
KOUROU

July 2014

# ARIANE 5

Data relating to Flight VA219 by Hugues LANTERI




**ATV-5**

**Georges LEMAITRE**

arianespace
service & solutions

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# Flight VA219
## Ariane 5 ES/ATV – Payload: ATV

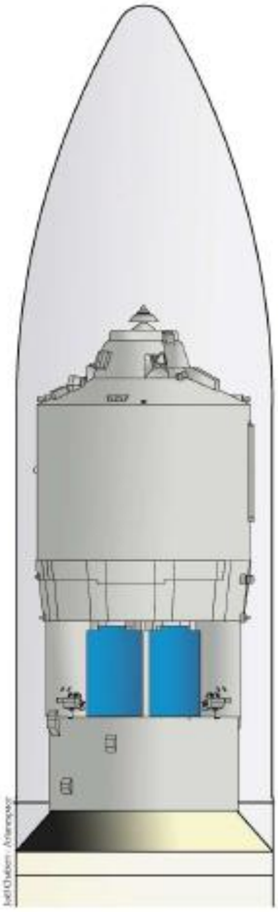
# Content

# 1. Introduction

Flight 219 is the **74th Ariane 5 launch** and the third in 2014. It follows on from a series of **59** consecutive successful **Ariane 5** launches. An **Ariane 5 ES**, with a reignitable 3rd stage, will be used for this flight.

Flight 219 is a commercial mission for Ariane 5. The **L593** launcher is the 19th to be delivered by **Airbus Defence and Space** to **Arianespace** as part of the PB production batch. The PB production contract was signed in March 2009 to guarantee continuity of the launch service after completion of the PA batch comprising 30 launchers. The PB production batch comprises 35 A5ECA launchers, including 5 A5ES launchers, and covers the period from 2010 to 2016. On 14th December 2013, it was extended by an order for a further 18 ECA launchers, scheduled for launch as of 2017.
L593 is the fifth of the A5ES series and the forty-ninth complete launcher to be delivered to **Arianespace**, integrated and checked out under **Airbus Defence and Space** responsibility in the Launcher Integration Building (BIL).

In a single-payload configuration, with a long pattern fairing, it will carry the fifth **ATV** (Automated Transfer Vehicle) cargo carrier for the European Space Agency (**ESA**), to deliver supplies to the International Space Station (ISS).



Installed inside the long pattern fairing built by: **RUAG Aerospace**

The **ESA ATV Cargo Carrier** built by: **Airbus Defence and Space**

mounted on a dedicated **SDM** (**S**eparation and **D**istancing **M**odule) adapter, with a diameter of 3936 mm on top of the **EPS** and the **VEB**.

Operations in the Final Assembly Building (BAF) and actual launch operations on the ARIANE 5 launch pad (ELA3) are coordinated by **Arianespace**.

# 2. Launcher L593


## Description

The upper composite is mounted on the main cryogenic stage (EPC) and incorporates:

- Carbon-structure **Vehicle Equipment Bay**
- Storable Propellant Stage **EPS**, P2000
- **Fairing**

The lower composite incorporates:

- **EPC (H175)** main cryogenic stage with the new Vulcain 2 engine
- two **EAP (P240)** solid propellant strap-on boosters, supporting the central body

## Type-C main cryogenic stage

The EPC is over 30 m high. It has a diameter of 5.4 m and an empty mass of only 14.1 metric tons. It essentially comprises:

- large aluminium alloy tank;
- thrust frame transmitting engine thrust to the stage;
- forward skirt connecting the EPC to the upper composite, and transmitting the thrust generated by the two solid propellant strap-on boosters

**Liquid helium sub-system capacity**
© Airbus Defence and Space

Compared with the Ariane 5 "generic" version of the main stage, the main changes are integration of the Vulcain 2 engine (generating 20% more thrust than the Vulcain 1), lowering of the tank common bulkhead, and strengthening of the forward skirt and thrust frame structures. As in the case of the previous A5 ECA launcher (L521) used for flight 164, the Vulcain 2 has undergone a number of changes, principally to the nozzle (shortened and strengthened) and the cooling system (dump-cooling).

The tank is divided into two compartments containing 175 tons propellant (approximately 25 tons liquid hydrogen and 149.5 tons liquid oxygen). The Vulcain 2 engine delivers of the order of 136 tons thrust, and is swivel-mounted (two axes) for attitude control by the GAM engine actuation unit. The main stage is ignited on the ground, so that its correct operation can be checked before authorising lift-off.

The main stage burns continuously for about **528 s**, and delivers the essential part of the kinetic energy required to place the payloads into orbit.

The main stage also provides a launcher roll control function during the powered flight phase by means of the SCR (roll control system).

On burnout at an altitude of **137 km** for this mission, the stage separates from the upper composite and falls back into the Atlantic Ocean, between the Azores and Spain.

## Solid propellant strap-on boosters

Each booster is over 31 m high, and has a diameter of 3 m and an empty mass of 38 tons. Each booster contains 240 tons solid propellant, and essentially comprises:

- booster case assembled from seven steel rings,
- steerable nozzle (pressure ratio $\Sigma = 11$), operated by a nozzle actuation unit (GAT),
- propellant in the form of three segments.

**Equipment displayed at the Paris Air Show in 2001**

The boosters (EAP) are ignited 6.05 s after the Vulcain engine, i.e. 7.05 s from $H_0$. Booster thrust varies in time (approx. 600 tons on lift-off or over 90% of total thrust, with a maximum of 650 tons in flight). EAP burn time is about **137 s**, after which the boosters are separated from the EPC by cutting the pyrotechnic anchor bolts, and fall back into the ocean.

Compared with the Ariane 5 "generic" version of the booster stage, the main changes include the elimination of one GAT cylinder, overloading of segment S1 to increase thrust on lift-off, and the use of a reduced mass nozzle (*this reduces the mass of the structure by about 1.8 ton*).

### Storable Propellant Stage

The role of the EPS is to deliver the additional energy required to inject automatic payloads into the target orbit, and ensure their correct orientation and separation.
The EPS stage for the A5/ES version is identical to the EPS used on the A5G+ and A5/GS launchers.

It comprises:

- four tanks containing up to 10 tonnes of propellant (MMH and $N_2O_4$),
- a reignitable **Aestus** engine delivering 2.7 tonnes of thrust in a vacuum, and its two-axis swivelling nozzle for steering.

To optimise performance for this mission, the EPS has a propellant load of **5.222 tonnes**. The Aestus engine will be ignited twice before separation of the ATV (the engine will burn for a total of about **520 s**) and then a third time for **15 s** to deorbit the composite.

The first EPS ignition is preceded by helium chill-down of the Aestus engine, pressurisation of the EPS tanks and EPS propellant packing operations.

Photo:

EPS undergoing integration on the launcher. Note the yellow propellant tanks and the black spherical helium tanks.

## Vehicle Equipment Bay

The Vehicle Equipment Bay (VEB) comprises:

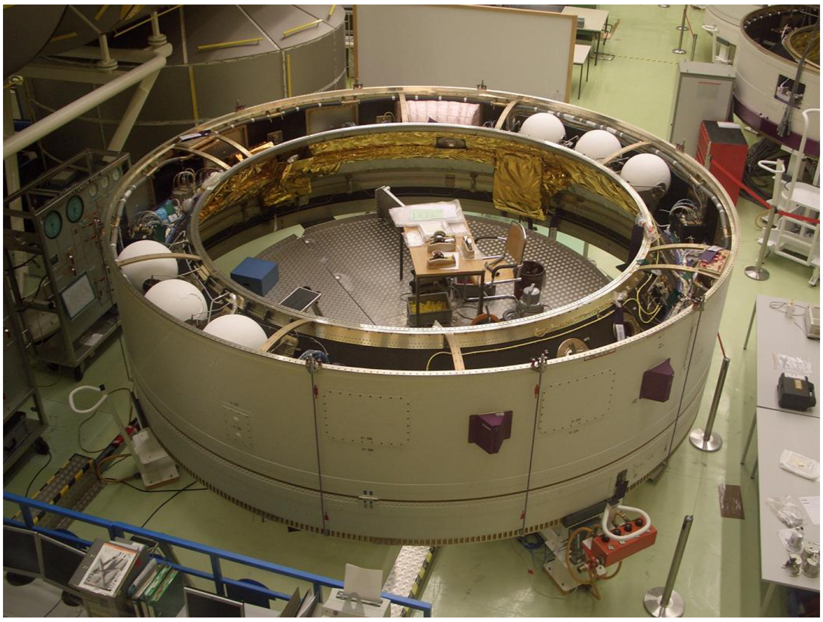
- a cylindrical structure around the EPS, housing some of the electrical equipment necessary for the mission (two OBCs, two inertial guidance units, sequencing electronics, electrical power supplies, telemetry equipment),
- a hydrazine attitude control system (SCA), used for roll control during the EPS powered flight phases and for triple-axis control during ballistic flight.

Moreover and specifically for this mission, the GNSS/OCAM experiment was added, consisting of a new GPS system being tested and 2 video cameras designed more specifically to film the fairing and ATV separation.

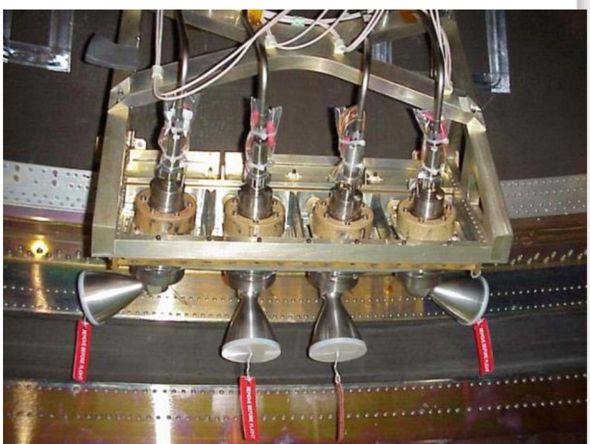
The structure of the vehicle equipment bay comprises a honeycomb/carbon skin sandwich and the separation system uses "dual-plate" technology. It has been reinforced for the ATV by comparison with the structure used for A5G+ and A5/GS, as the inner cone has to carry the mass of the ATV.

The major change concerns the use of electrical equipment identical to that used for version A5+ECA (2 OBC, 2 SRI-ND – new definition inertial reference system, telemetry with UCTM-D).

For this particular mission, the SCA was adapted to be able to manoeuvre the assembly [launcher + payload] in particular extended mission conditions: 6 hydrazine cylinders are installed instead of the usual 3; the SCA also has 4 axial thrusters instead of 2.



Bremen: VEB001D vehicle equipment bay before delivery to Kourou
© photo Airbus Defence and Space BREMEN



SCA VUS
© Photo Airbus Defence and Space BREMEN

## Nose fairing

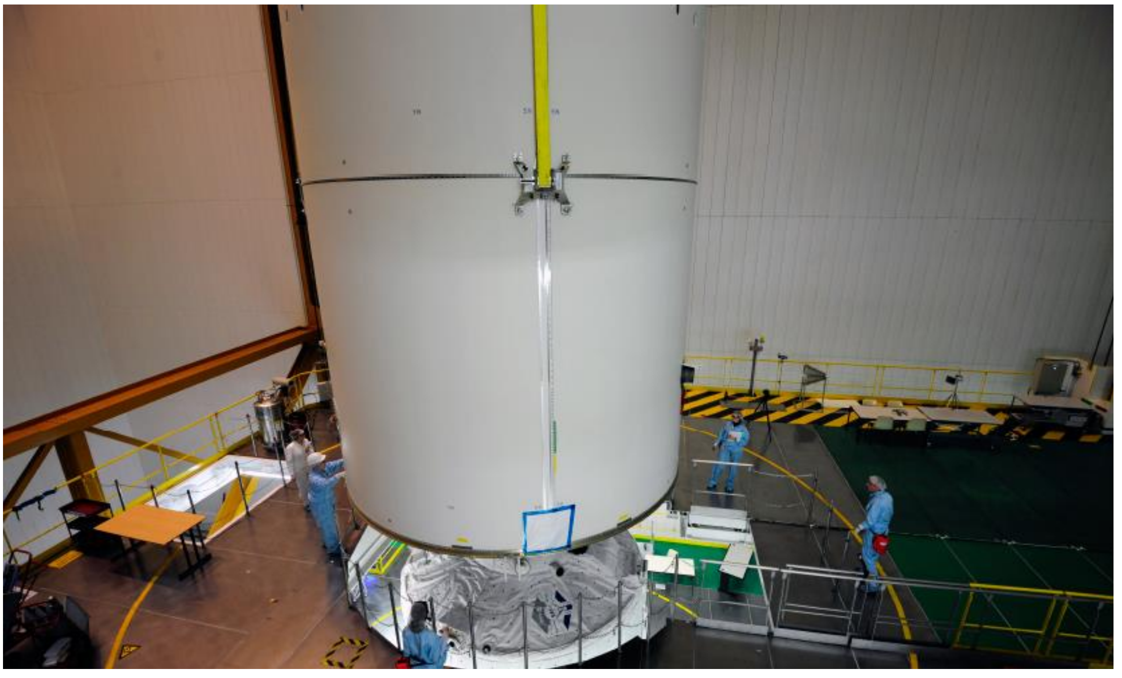
The ogival nose fairing protects the payload during the atmospheric flight phase (acoustic protection on lift-off and during transonic flight, aerothermodynamic flux).

A long pattern fairing is used for this mission. It has a height of 17 m and a diameter of 5.4 m.

The fairing structure includes two half-fairings comprising 10 panels. These sandwich panels have an expanded aluminium honeycomb core and two carbon fibre/resin skins.

The fairing is equipped with an HSS3+ separation system in order to reduce shock levels at separation.

The fairing is separated from the launcher by two pyrotechnic devices, one horizontal (HSS) and the other vertical (VSS). The vertical device imparts the impulse required for lateral separation of the two half-fairings



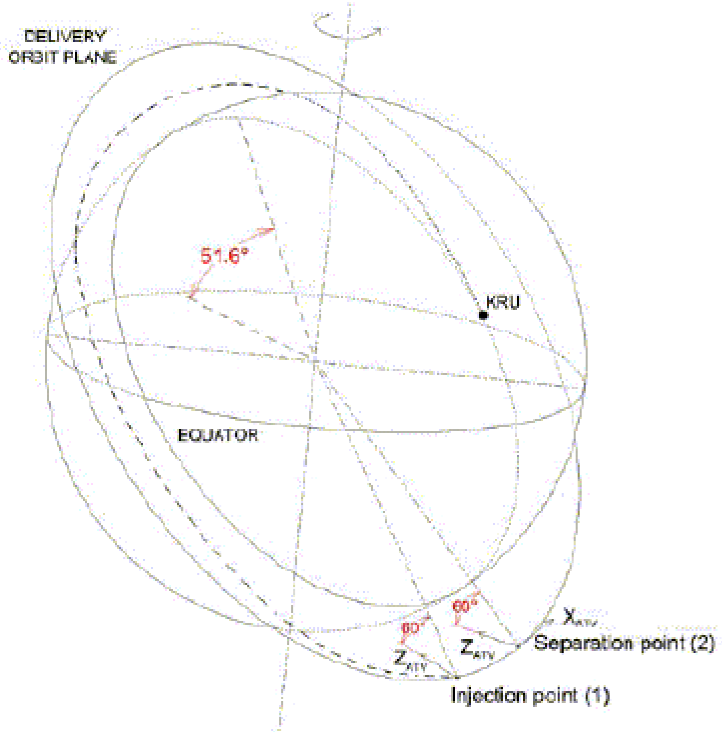
Installing the fairing on the ATV-5
© ESA

# 3. Mission VA219

## Payload mission

The main mission of flight VA219 is to inject the **ATV (Automatic Transfer Vehicle)** payload into a circular low Earth orbit (LEO) of 260 km, for rendezvous with the International Space Station, followed by deorbiting of the upper composite.

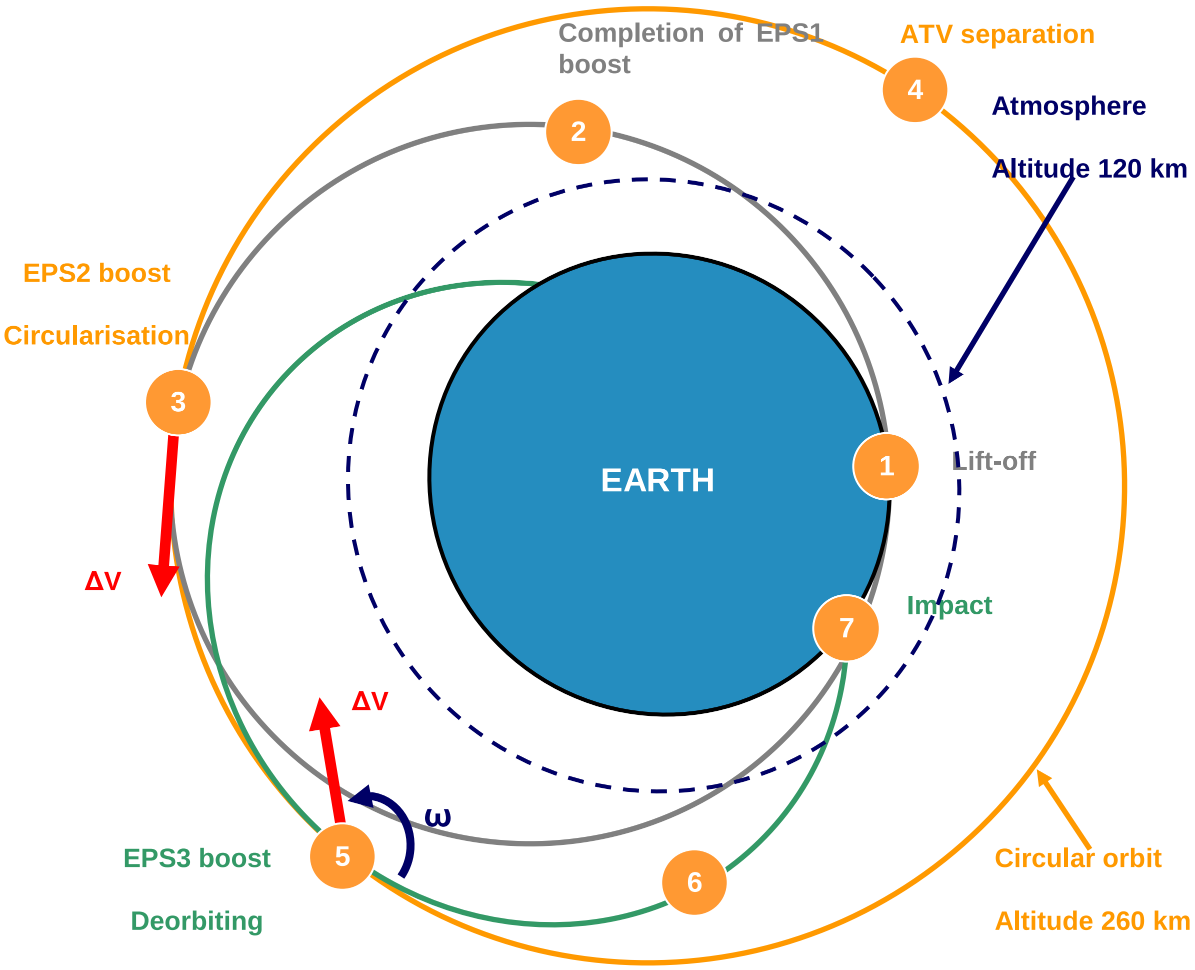
| | | |
|---|---|---|
| Apogee altitude | 260 | km |
| Perigee altitude | 260 | km |
| Inclination | 51.63 | ° |
| Perigee argument | free | ° |
| Ascending node longitude | free | ° |




The angle of inclination is defined according to that of the ISS. The longitude of the ascending node was selected so that the track of the instantaneous point of impact passes about 60 km south of Paris.

The mass of the **ATV** is **19,896 kg**. Taking account of the mass of the SDM adapter and the GNSS/OCCAM system, the mission requirement corresponds to a total launcher performance of **20,294 kg** for injection into the orbit described above.

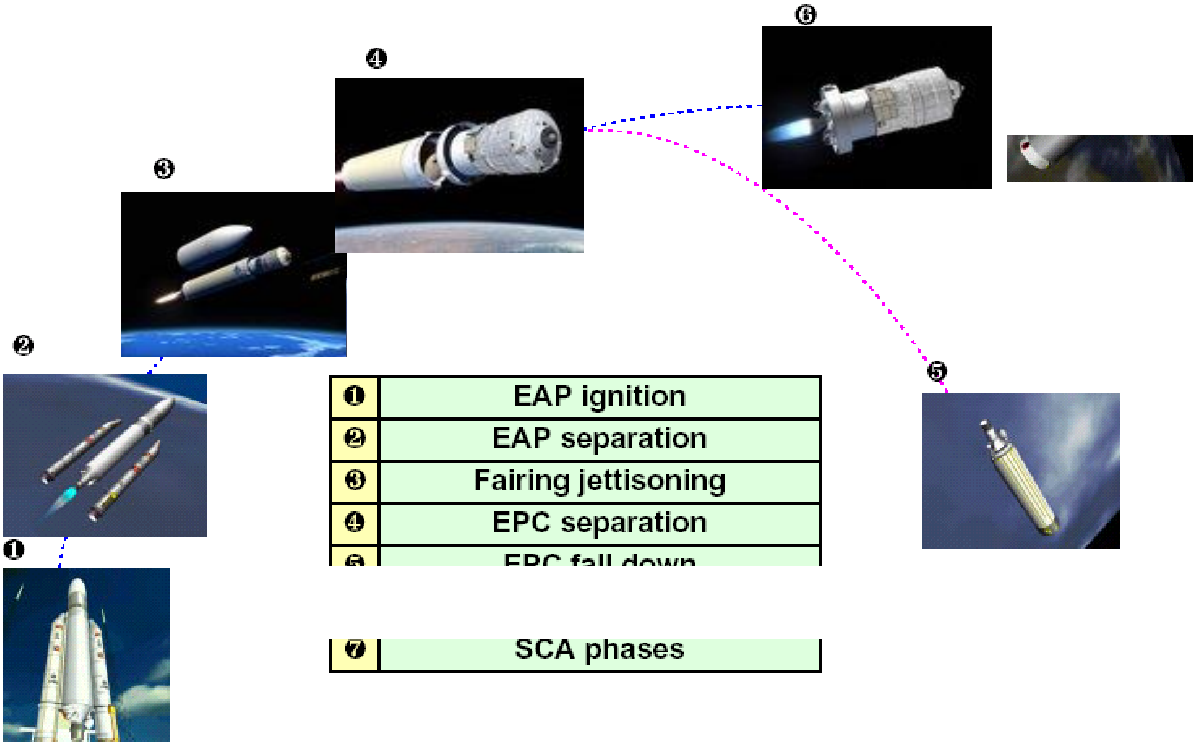
To optimise performance for this mission, the EPS will be ignited twice (twin-boost mission) before separation of the ATV and a third time to deorbit the upper composite, as shown in the following diagram:




| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| EPC phase | EPC separation | SCA1 phase | 1st boost EPS1<br>2 | SCA2 phase | 2nd boost EPS2<br>3 | Preparation ATV separation<br>4 | Deorbiting 3rd boost EPS3<br>5 | Preparation for passivation<br>6 |

**SCAFIN Phase** (Preparation ATV separation; Deorbiting 3rd boost EPS3; Preparation for passivation)


## Flight phases




Taking $H_0$ as the basic time reference (when the hydrogen valve of the EPC Vulcain engine combustion chamber opens), Vulcain ignition occurs at $H_0$ + 1 s. Confirmation of nominal Vulcain operation authorises ignition of the two solid propellant boosters (EAP) at $H_0$ + 7.05 s, leading to launcher lift-off.

*Lift-off mass is about **773 tons**, and initial thrust 13000 kN (of which 90% is delivered by the EAPs).*

After a vertical ascent lasting 5 s to enable the launcher to clear the ELA3 complex, including the lightning arrestor pylon in particular, the launcher executes a **tilt operation** in the trajectory plane, followed by a **roll operation** 5 seconds later to position the plane of the EAPs perpendicularly to the trajectory plane. The launch azimuth angle for this mission is **39.21**° with respect to North.

The "EAP" flight phase continues at **zero angle of incidence** throughout atmospheric flight, up to separation of the boosters.

*The purpose of these operations is to:*

- *optimise trajectory and thus maximise performance;*
- *obtain a satisfactory radio link budget with the ground stations;*
- *meet in-flight structural loading and attitude control constraints.*

The EAP separation sequence is initiated when an acceleration **threshold** is **detected** ($\gamma$ = 6.15 $m/s^2$ for this mission), when the solid propellant thrust level drops. Actual separation occurs within one second.

This is reference time ***$H_1$***, and occurs at about ***$H_0$ + 143.2 s*** at an altitude of ***66 km*** and a relative velocity of ***2053 m/s***.

For the remainder of the flight (EPC flight phase), the launcher follows an attitude law controlled in real time by the on-board computer, based on information received from the navigation unit. This law optimises the trajectory by minimising burn time and consequently consumption of propellant.

*The* ***fairing*** *is jettisoned during the "EPC" flight phase as soon as aerothermodynamic flux levels are sufficiently low not to impact the payload (at an altitude of* ***110 km****).*

The **EPC powered flight** phase is aimed at a **predetermined orbit**, established in relation to safety and performance requirements

Shutdown of the Vulcain engine occurs when the following target orbit characteristics have been acquired:

| | | |
|---|---|---|
| Apogee altitude | 140.6 | km |
| Perigee altitude | -1248.8 | km |
| Inclination | 51.20 | ° |
| Perigee argument | -152.63° | |
| Ascending node longitude | -2.75 | ° |

This is time reference **$H_2$**. It happens at **$H_0$ + 527.7 s**.

The main cryogenic stage (EPC) falls back into the Atlantic Ocean after separation (see below), breaking up at an altitude of between 80 and 60 km under the loads generated by atmospheric re-entry.

The stage must be depressurised (**passivated**) to avoid any risk of explosion of the stage due to overheating of residual hydrogen. A hydrogen tank lateral nozzle, actuated by a time delay relay initiated on EPC separation, is used for this purpose.
This lateral thrust is also used to spin the EPC, and thus limit breakup-induced debris dispersion on re-entry.
The Main Cryogenic Stage (EPC) angle of re-entry is **-1.8°**, and the longitude of the point of impact is **15.6° W** (off the Iberian peninsula)

The subsequent **"EPS1"** powered **flight phase** lasts about 8 minutes and 11 seconds. This phase is terminated by a command signal from the OBC, when the computer estimates, from data calculated by the inertial guidance unit, that the **target orbit** has been acquired. For performance optimisation reasons, the EPS will carry a 5.222 tonne load of storable propellant. This first burn will be used to acquire an elliptical orbit with a 255 km apogee and a 137 km perigee.

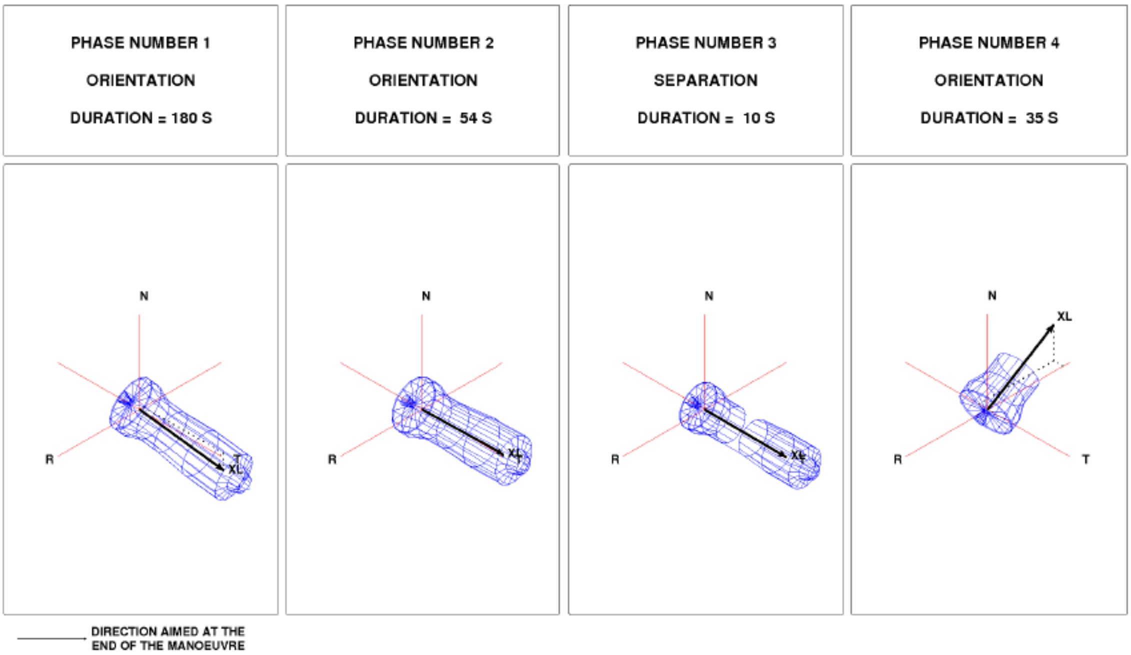
*This is time reference* ***$H_3$****. It happens at* ***$H_0$ + 1032.4 s.***

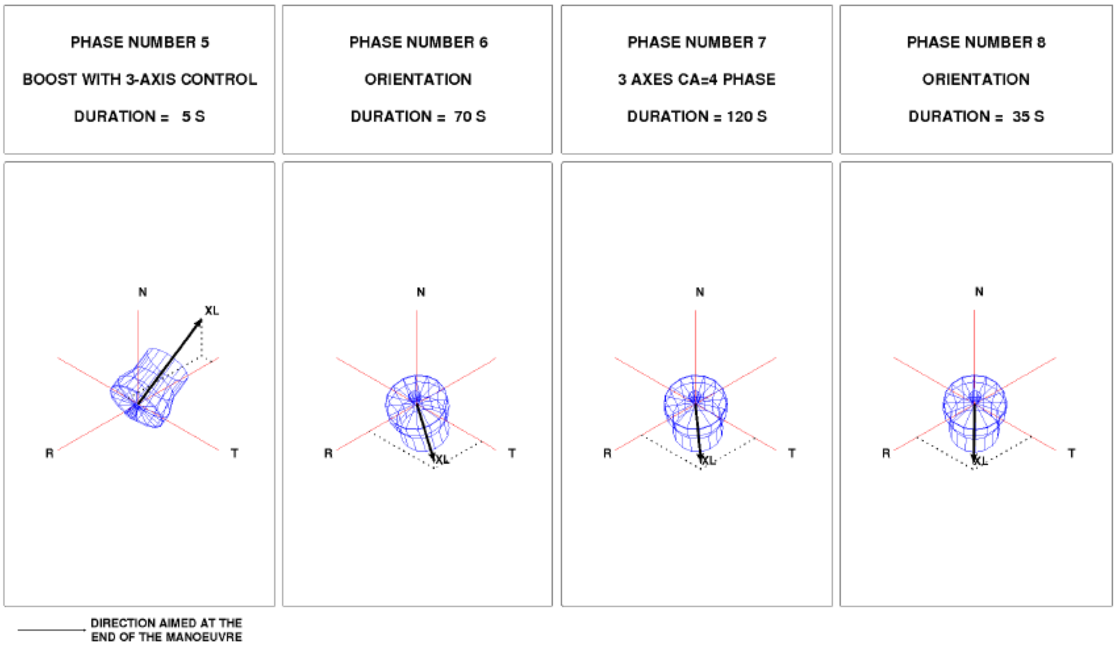
After **42** minutes intermediate ballistic flight, a second burn lasting **28** seconds, **the "EPS2" flight phase**, will be used to circularise the orbit at an altitude of 260 km.

The purpose of the following **ballistic phase** is to ensure:

- pointing in the requisite direction for the **ATV** (alignment with the TDRS antenna)
- separation of the **ATV ($H_{4.1}$)**,

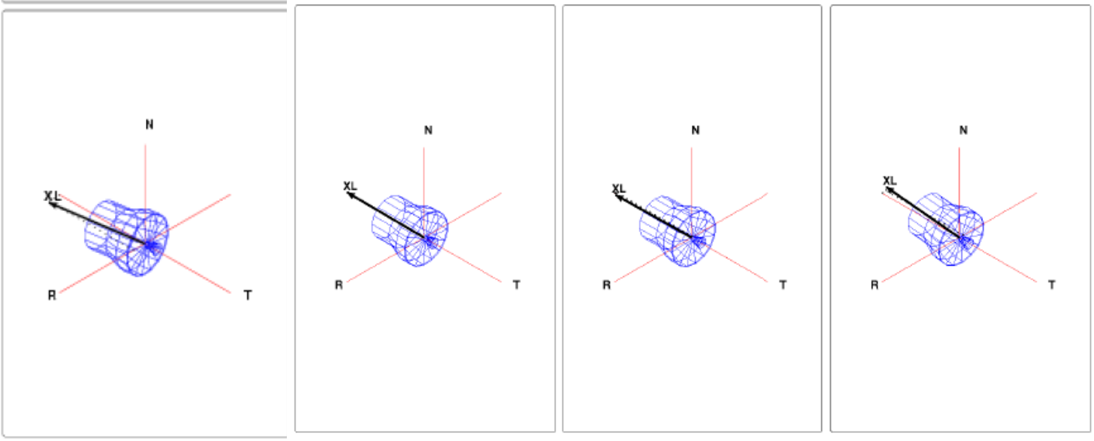
while providing short to medium-term management of the mutual distancing of objects in orbit and avoiding any risk of the SCA polluting the payload. ATV separation takes place about **4 minutes** later.



**One hour and 20 minutes** after ATV separation, a third EPS burn lasting **15 seconds** will take place to deorbit the composite. It will fall back into the Pacific, mid-way between the coasts of New Zealand and Mexico.

| PHASE NUMBER 16 | PHASE NUMBER 17 | PHASE NUMBER 18 | PHASE NUMBER 19 |
|---|---|---|---|
| SPIN UP WITH NUTATION CONTROL TO 30. ° /S | SPIN UP TO 9.4 ° /S | BOOST WITH NUTATION CONTROL | SPIN UP WITH FIXED UNBALANCE TO 60. ° /S EPS REIGNITION |
| DURATION = 35.000 S | DURATION = 100 S | DURATION = 25 S | DURATION = 15 S |



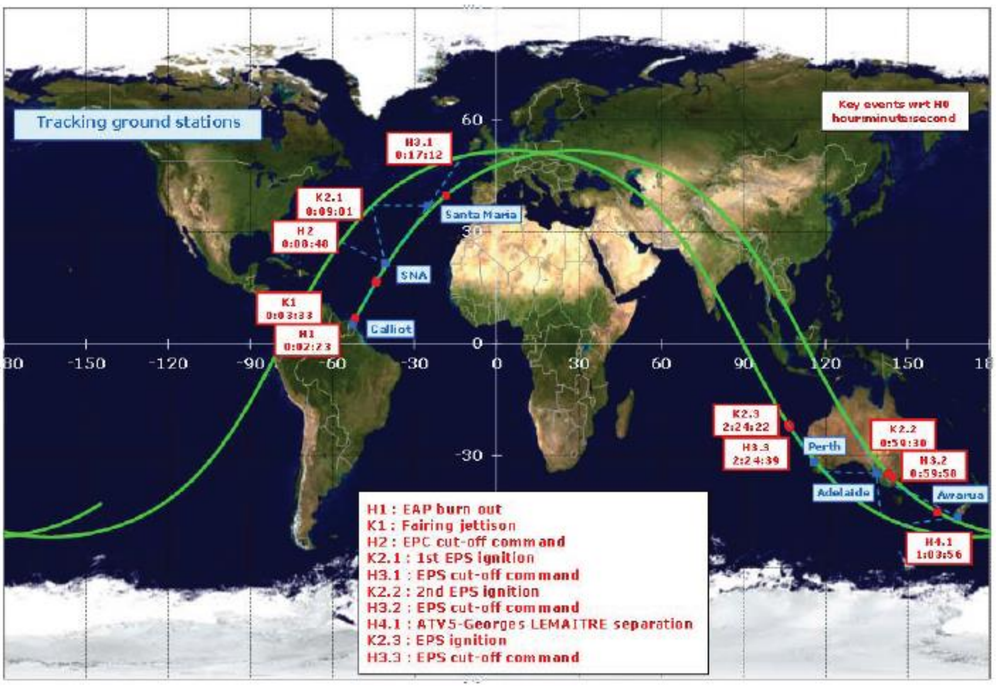
# Data relating to Flight VA219

Owing to the heavily inclined trajectory over the Equator (51.6°), **the launcher will be monitored and telemetry data collected** during the mission by the **Kourou/Galliot** stations, an **SNA (Ariane Naval Station)**, the **Azores, Adelaide and Perth** (Australia) stations and **Invercargill** (New Zealand).

The TDRSS satellite (altitude of 35,786 km, longitude of 174° W) will also be used to monitor the ATV from EPS-2 shutdown to ATV separation.

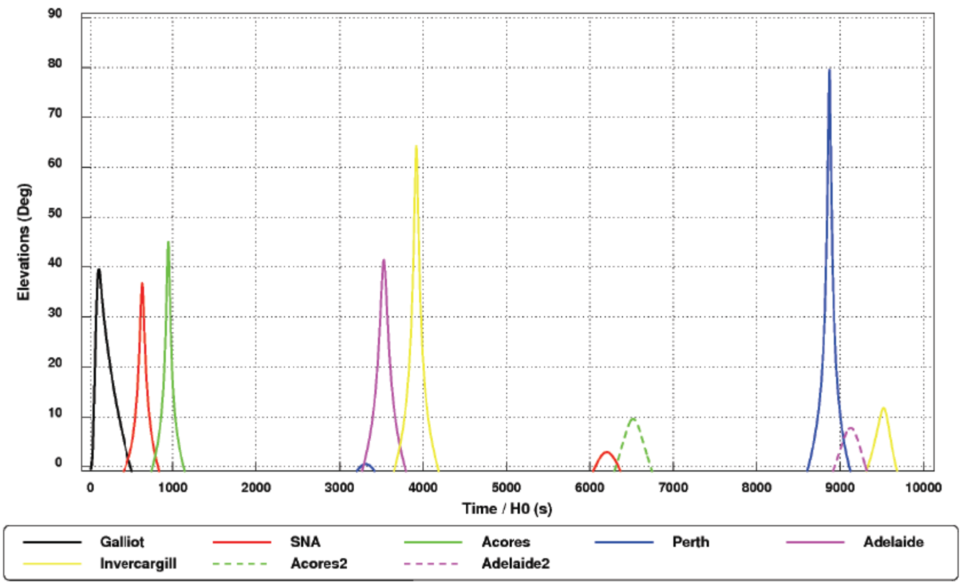
The launcher will overfly Europe about 20 minutes after lift-off, or at about 02:04 on 30 July, following launch at 01:44 CET (Paris time).

### Situation of Stations and main flight events




Source Arianespace – **C**ontrôle **V**isuel **I**mmédiat (real-time visual control)

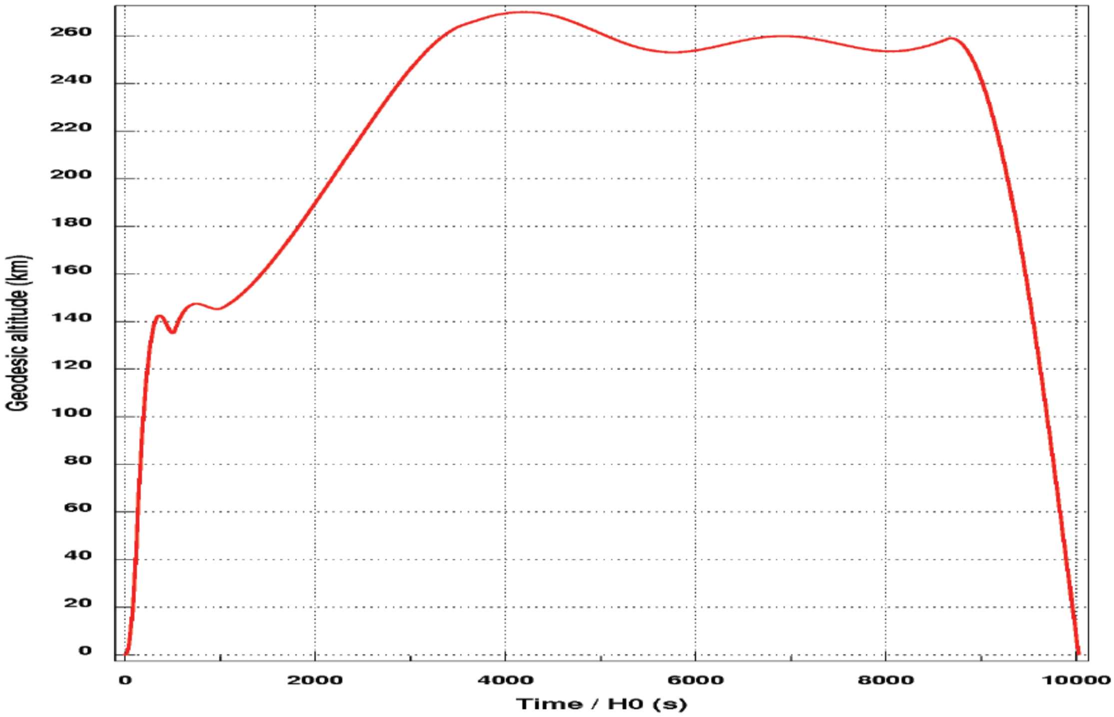
### Station visibility



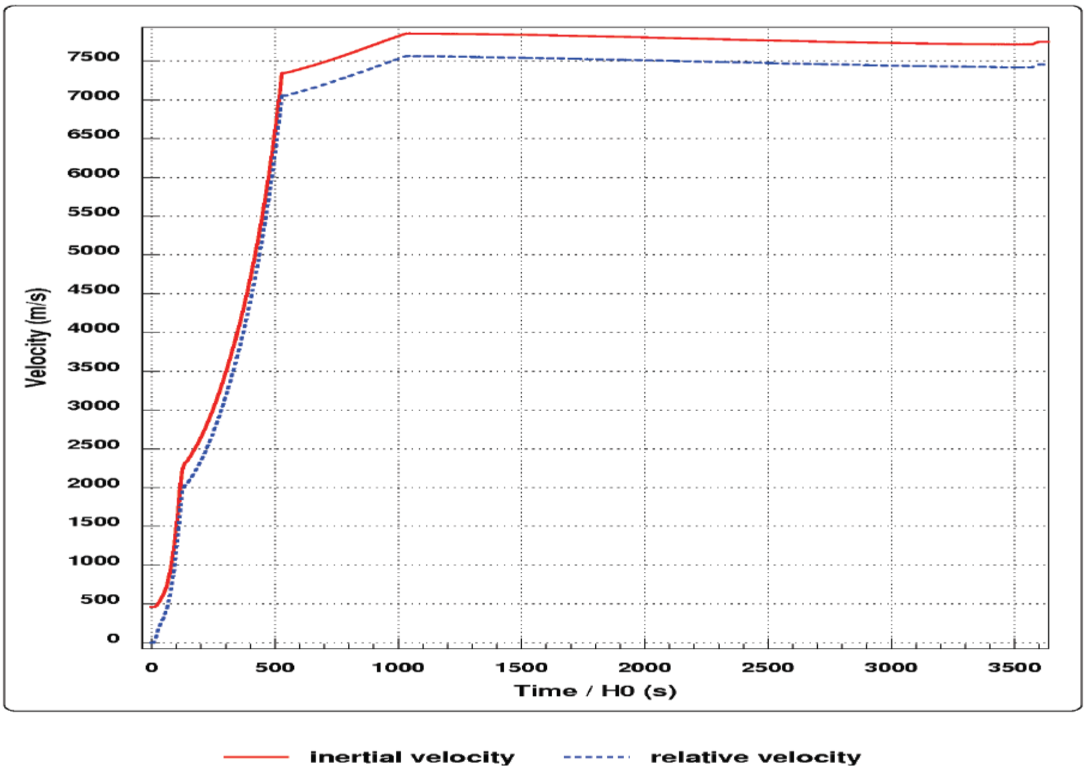
# Data relating to Flight VA219

The following plates present changing launcher altitude and velocity during the flight:

Geodetic altitude




Relative and inertial velocities



# 4. Georges Lemaître

### Inventor of the “primeval atom” theory, known as the "Big Bang"

**Georges Lemaître** (1894-1966) Belgian astrophysicist and priest. He was one of the pioneers of modern astrophysics, which developed in the early 20th century thanks to **Einstein’s** theory of general relativity and the observations made possible by the progress achieved in instruments and computing power. Since ancient times, the universe had been considered to be unchanging. The Russian theorist **Alexandre Friedmann** was the first to postulate an expanding universe as a possible solution for Einstein’s equations, as early as 1922. Using the Mount Palomar large telescope, the American **Edwin Hubble** observed in 1929 that remote galaxies were moving apart. Georges Lemaître also looked for solutions to Einstein’s equations and made the link with Hubble’s observations. He deduced a ratio between the distance and speed of the Galaxies and, in 1927, described *“a homogeneous universe of constant mass and increasing radius”.* Lemaître worked further on his theory and, in 1931, published the hypothesis of the "**primeval atom**". As he was a priest, some saw in this a desire to reconcile science and religion. Yet Lemaître makes a clear distinction between the philosophical concept of “creation” and the “beginning”, a simple physical marker. This overly modern theory had many critics, including Fred Hoyle who disparagingly referred to it as the "**Big Bang**", thus popularising it under this name! It was only in 1965 that the critics were silenced, with the observation of the cosmic microwave background radiation that had been postulated by the theory. It should also be noted that, in his work, Lemaître used the first computers and was an expert in numerical calculation.

### The "Big Bang" theory in brief!

In the beginning, at the explosion of the "**primeval atom**", all the matter of the universe was concentrated in a single point, at an inconceivable temperature. The universe expanded uniformly, thereby cooling down. As the temperature dropped, matter was able to become organised. This is the chronology: The "Big Bang" model describes what happens $10^{-43}$ seconds after the “explosion", when the temperature reaches $10^{32}$ degrees (Planck temperature). The universe then consists of a “soup” of quarks and electrons. At $10^{-6}$ seconds, the temperature is lower than $10^{9}$ degrees. The protons and neutrons form, followed, at about 100 seconds, by light atomic nuclei.

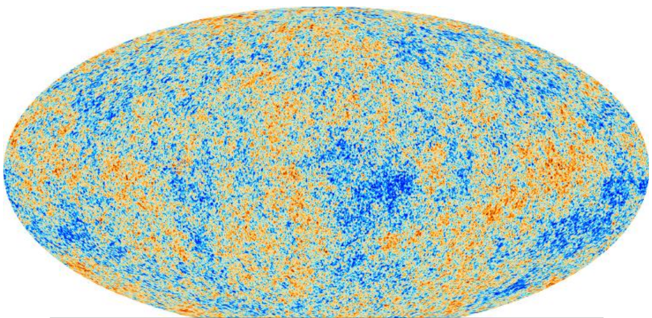


Image of the “cosmic microwave background” seen by the Planck space telescope, launched by Ariane 5 L546

The scale then changes: after 100,000 years, matter is sufficiently diluted for light to be able to escape. This creates the “cosmic microwave background” radiation which can still be observed. After a million years, atoms are created, then galaxies, one billion years later. Today, 13.7 billion years have elapsed ...

# 5. The ATV cargo carrier

"The last but not the least"

## Programme and Mission

At the Ministerial Conference in Toulouse in 1995, Europe officially undertook to take part in the International Space Station, by providing the Columbus laboratory (launched in February 2008) and an automatic transfer vehicle, the ATV, launched by the Ariane A5/ES version. France remains one of the main contributors to this programme.

The first flight (flight V181), of ATV "Jules Verne", took place on 9th March 2008.
The second flight, (flight V200), of ATV "Johannes Kepler", took place on 16th February 2011.
The third flight, (flight V205), of ATV "Edoardo Amaldi", took place on 23rd March 2012.
The fourth flight (flight V213), of ATV "Albert Einstein", took place on 5 June 2013.

## Profile of a typical mission of the ATV cargo carrier:

This begins with its launch into orbit on board an Ariane 5 from the CSG. After separation from the launcher, its motors are ignited and its navigation systems activated, to inject it into a transfer orbit

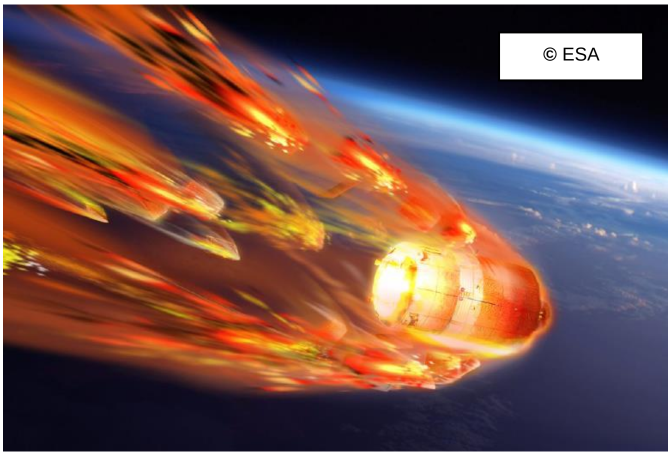
After three to five days in orbit, the Cargo carrier is within sight of the Station. Its computers then carry out the final approach manoeuvres, which take two orbits to complete. The relative velocity of the two bodies is then a few centimetres per second, even though both vessels are travelling at an orbital speed of about 28,000 km/h.

The docking process is fully automated. In the event of a problem, the ATV computers or the Station crew can trigger the pre-programmed collision avoidance manoeuvre, which is totally independent of the main navigation system. For a launch on 31 July, **docking** is expected on **12 August**.

The ATV Control Centre (ATV-CC) in Toulouse during flight Ariane 5 – ATV-4
© ESA

Once the ATV is docked, the Station crew can enter the Integrated Cargo Carrier to unload the cargo: food, scientific equipment and maintenance gear. The propellant tanks are connected to the Station; air (oxygen, nitrogen) is released directly into the ISS' atmosphere; the crew also pumps the water from the ATV tanks to the ISS' own tanks.

Once the resupply mission is completed, the ATV will become a “flying waste-bin”, with the Station's waste being gradually stored in it (this waste will burn up at the same time as the ship itself during atmospheric re-entry). After the Station crew closes the hatch, the ATV will separate automatically on 25 January 2015.

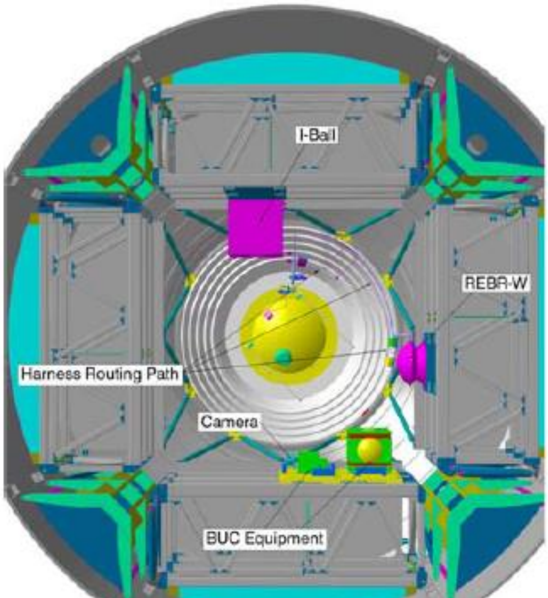

© ESA

Its engines will then de-orbit it, with atmospheric re-entry on 10th February 2015 at a shallower angle than for the previous flights, in order to perform the "Shallow re-entry" experiment as part of the preliminary studies for ISS re-entry.

Various experiments (comprising accelerometers, IR cameras, etc.) will be positioned by the ISS crew in the ATV: REBR-W for NASA, I-Ball for JAXA and BU for ESA.

The measurements collected will be automatically transmitted by the “Iridium” communication satellites constellation. They will be used to observe the destructive shallow re-entry of the ATV and provide data allowing a better estimation of the debris areas when the ISS re-enters.

The ATV’s mission is not to carry humans into space, but the ISS crew will have access to its pressurised module once docked with the Station, without having to wear space suits.




Positions of the experiments inside the ATV
© Airbus Defence and Space

## The vehicle

The **ATV** comprises two modules:

- an avionics and propulsion model, referred to as the Spacecraft, responsible for in-orbit navigation using four main engines and 28 small thrusters for attitude control. After docking, the ATV can participate in attitude control operations for the ISS, desaturate its inertia wheels, execute space debris avoidance manoeuvres and boost the Station orbit to offset the effects of aerodynamic drag.

- a pressurised Integrated Cargo Carrier module which docks with the ISS. It has a volume of 48 $m^3$ and is of modular design. This pressurised module carries eight racks for storing equipment in bags of differing size. It is equipped with tanks for drinking water, propellant for the Station propulsion system and air (oxygen and nitrogen) for the crew. The “nose” of the ATV contains the various approach systems, and the docking mechanism built in Russia.

The principal characteristics of the ATV are as follows:

| | |
|---|---|
| *** Dimensions** | • height: 9.8 m - main structure diameter: 4.5 m<br>• in-orbit span: 22.3 m (solar panels deployed) |
| *** Mass** | • lift-off (including SDM and GNSS/OCAM) 20,293 kg<br>• dry (structure) 9,857 kg<br>• propellants: 4,356 kg of which 2,118 kg for the ISS |
| *** Power** | • 5.20 kW (4.60 kW at end of life)<br>• batteries: 4 x NiCd and 4 x $LiMnO_2$ |
| *** Propulsion** | • bi-propellant: MMH – MON3 (4 main thrusters of 490 N) |
| *** Stabilisation** | • triple-axis stabilisation<br>• MMH - $MON_3$ bi-liquid attitude control (220N) (4 groups of 5 thrusters and 4 sets of 2 thrusters) |
| *** Transmission capacity** | • Antennas:<br>- TDRS TM/TC: S band<br>- GPS: L band<br>- TM/TC proxy link: S band<br>- KURS radar: C band |
| *** A. Einstein cargo configuration** | • Cargo dry mass: 2,683 kg<br>• Oxygen: 100 kg<br>• Water: 848 kg<br>• ISS propellants: 860 kg |
| *** Ground stations** | • ATV Control Centre: Toulouse, using:<br>- TDRSS network and ARTEMIS satellite<br>- NASA and RSC (Moscow) control centres via the ISS |
| **Estimated lifetime is 6 months (docked with the ISS)** | |

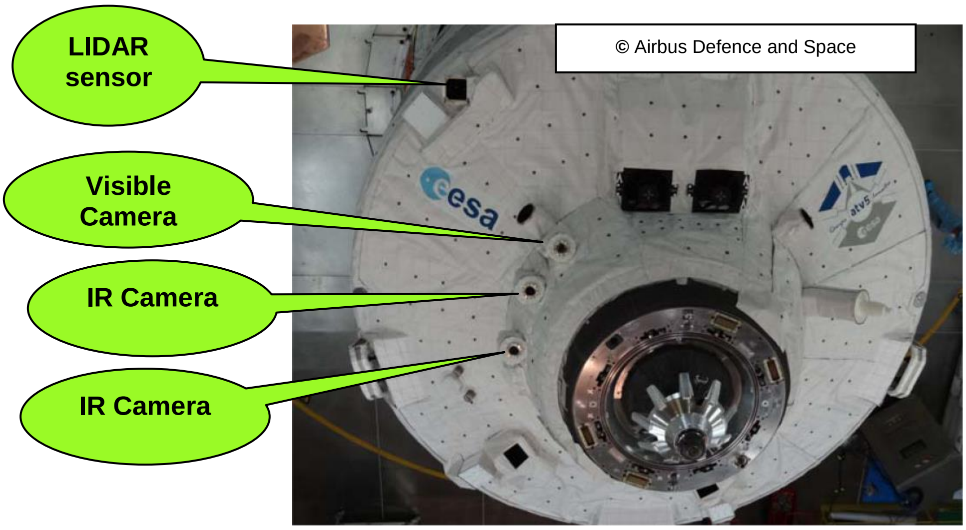
**The LIRIS Demonstrator (Laser Infra-Red Imaging Sensors)**:

Studies are currently being carried out on the “non-cooperative rendezvous", a practical example of which would be the retrieval of a broken down satellite (unmanned). The purpose of the LIRIS Demonstrator, developed by **Airbus Defence and Space** with the support of **ESA**, is therefore to test new navigation sensor technologies, with ATV’s rendezvous with the ISS offering a unique opportunity in a space environment.

LIRIS comprises 2 experiments from subsidiaries of **Airbus Defence and Space**:

- 2 “infrared” cameras and one “visible” camera, supplied by **Sodern**
- a LIDAR (laser sensor providing 3D images) supplied by **Jena-Optronik**.

The ATV was modified so that these sensors could be installed at the front.



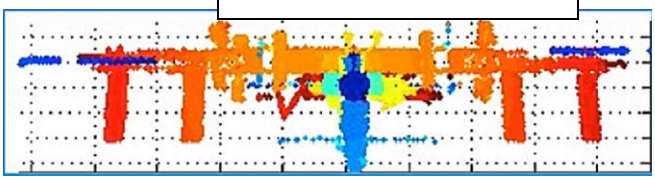

© Airbus Defence and Space

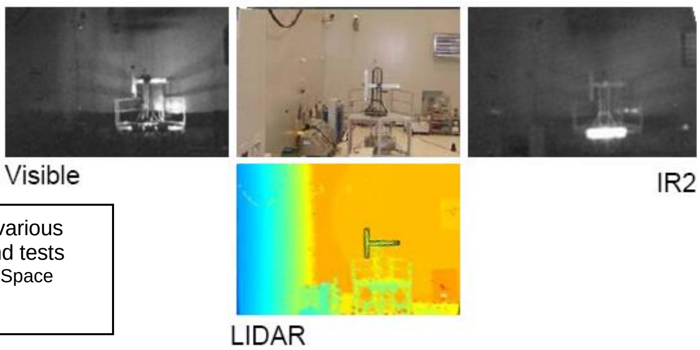
The sensors will be activated during the approach phase and will “photograph” the ISS, with the images being transmitted to recorders carried on-board the ATV, for subsequent removal by the crew after docking with the ISS.

They will then be returned to Earth on a Russian Soyuz vehicle and sent to **Airbus Defence and Space.** The data will then be analysed jointly by **Sodern**, **Jena-Optronik** and **Airbus Defence and Space**.

Simulated view of the ISS with the Sodern IR sensor

Simulated view of the ISS by a LIDAR
© Jena-Optronik






Images seen by the various sensors during ground tests
© Airbus Defence and Space

## ATV programme participants:

A total of 30 European, Russian and American companies share the work on building the ATV vehicles under the direction of Astrium ST. Development activities are shared between:

Astrium ST (France)
- prime contractor for development of the ATV space segment
- system and vehicle engineering
- algorithms and flight software for guidance, navigation and control
- algorithms and flight software for efficient automated operation of the vehicle
- development of test platforms and resources
- verification and qualification of the vehicle and its external interfaces

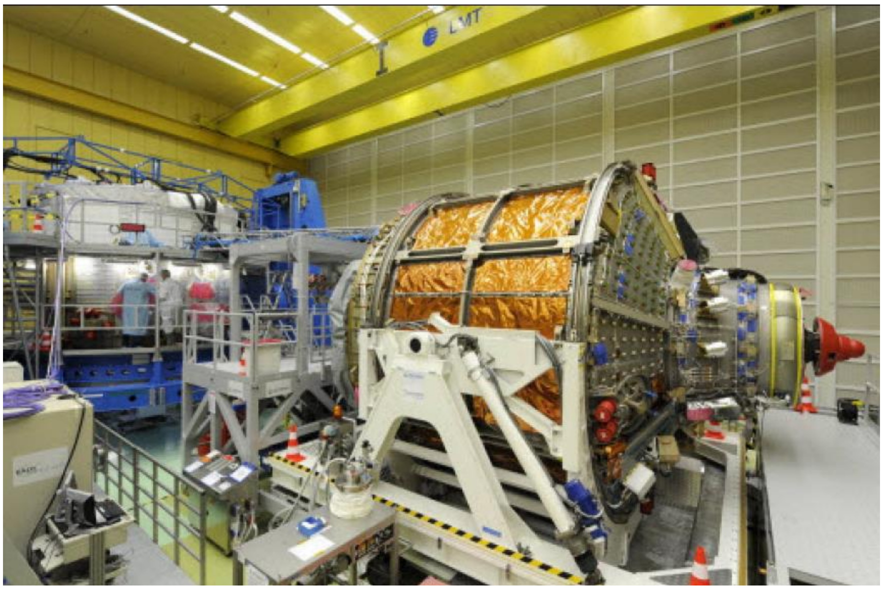
Alcatel Alenia Space (Italy)
- development and integration of the Cargo Carrier
- thermal studies in support of the system and vehicle engineering function

Airbus Defence and Space (Germany)
- propulsion and reboost sub-system
- integration of the Spacecraft and vehicle

Airbus Defence and Space (France)
- avionics sub-system
- integration of the avionics bay

RUAG Aerospace (Switzerland)
- Spacecraft structures

Dutch Space (Netherlands)
- solar panels



ATV-5 integration in Bremen
© Airbus Defence and Space

Kourou: Fuelling the ATV-5

© Copyright © Airbus Defence and Space GmbH

Kourou: Loading the ATV-5 cargo

© ESA

# 6. Launch campaign

Principal phases of the Flight VA219 launch campaign:

| | |
|---|---|
| *Arrival of the ATV in Pariacabo* | *29 October 2013* |
| EPC depreservation and erection in the launcher integration building (BIL) | 22 April |
| Transfer of Solid Booster Stages (EAP) from BSE → BIL | 22 and 23 April |
| Mating of the EAPs with the EPC | 24 April |
| Depreservation and erection of the VEB | 28 April |
| Depreservation and erection of the EPS | 28 April |
| Launcher Synthesis Control | 15 May |
| Launcher acceptance by Arianespace | 26 May |
| Transfer from BIL to BAF | 05 June |
| *Transfer of the ATV to BAF* | 24 June |
| ATV integration on the launcher<br>Mounting the fairing around the ATV | 26 June<br>11 July |
| SCA fuelling | 21 July |
| EPS fuelling with MMH<br>EPS fuelling with $N_2O_4$ | 23 July<br>23 July |
| General rehearsal | 24 July |
| Arming of the launcher<br>Flight Readiness Review | 25 and 26 July<br>26 July |
| Launcher transfer from the BAF to the Pad (ZL3)<br>Fuelling of the EPC helium sphere | 28 July<br>28 July |
| Final countdown $H_0$ | 29 July |

Kourou: hoisting the EPC in the Launcher Integration Building (BIL)
© ESA/ARIANESPACE/Service optique CSG

Kourou: transfer of a Solid Booster Stage EAP from BSE to BIL
© ESA/ARIANESPACE/Service optique CSG

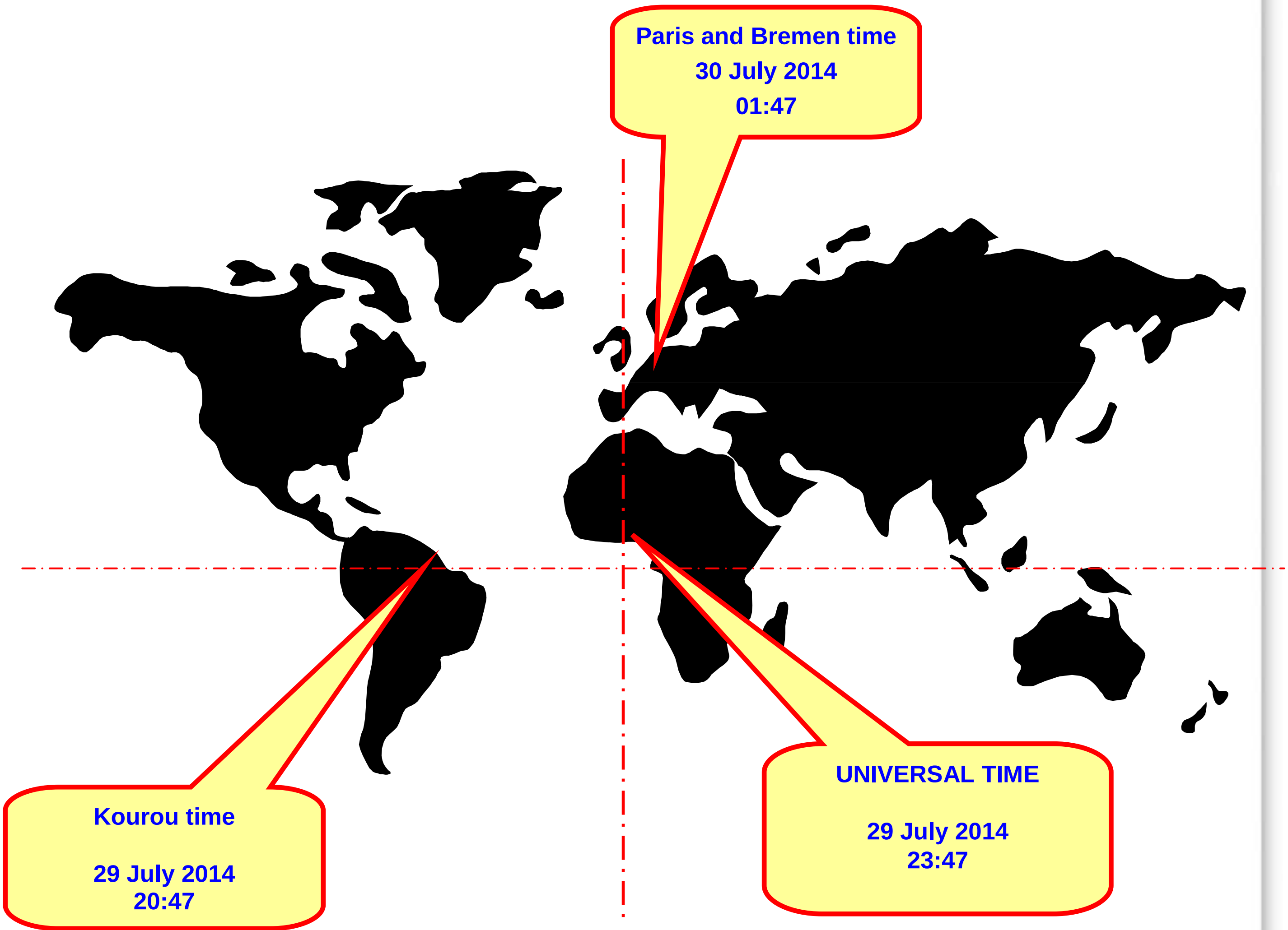
ATV-5 suspended
© ESA

Kourou: hoisting the EPS onto the EVB in the BIL
© ESA/ARIANESPACE/Service optique CSG



# 7. Launch window

For a launch on **29 July 2014**, **$H_0$** is at **23:47 mn 38 seconds (*)** U.T.
There is no launch window for this mission.




Hour $H_0$ decreases by about 23 minutes per day over the following days.
On 30 July 2014, launch is planned at 23:25 mn 04 s (UT).

**(*) The times are confirmed 48h before the flight by the Toulouse Control Centre according to the latest ISS trajectory calculations.**


# 8. Final countdown

The final countdown includes all operations for preparation of the launcher, satellites and launch base. Correct execution of these operations authorises ignition of the Vulcain engine, followed by the solid propellant boosters at the selected launch time, as early as possible inside the launch window for the satellites. The countdown terminates with a synchronised sequence managed by the Ariane ground checkout computers, starting at H0 - 7 min. In some cases, a pre-synchronised sequence may be necessary to optimise fuelling of the main cryogenic stage (*). If a countdown hold pushes time H0 outside the launch window, the launch is postponed to D+1 or D+2, depending on the nature of the problem and the solution adopted.

| | |
|---|---|
| $H_0$ - 7 hours 30 | **Checkout** of electrical systems, red status indicators and countdown time<br>**Flushing** and configuration of the **EPC** and **Vulcain** engine for fuelling and chill-down |
| $H_0$ - 6 hours | **Final preparation of the launch pad:** closure of doors, removal of safety barriers, configuration of the fluid circuits for fuelling.<br>**Loading of the flight program**<br>**Testing of radio links** between the launcher and BLA<br>**Alignment of inertial guidance units** |
| $H_0$ - 5 hours | **Evacuation of personnel from the launch pad**<br>**Fuelling of the EPC** in four phases:<br>pressurisation of the ground tanks (30 minutes)<br>chill-down of the ground lines (30 minutes)<br>fuelling of the stage tanks (2 hours)<br>topping up (up to synchronised sequence) |
| $H_0$ - 5 hours | **Pressurisation of the attitude control and command systems:**<br>(GAT for the EAPs and GAM for the EPC) |
| $H_0$ - 3 hours | **Chill-down of the Vulcain engine** |
| $H_0$ - 30 minutes | **Preparation of the synchronised sequence** |
| $H_0$ - 7 minutes | **Beginning of the synchronised sequence (*)** |

## Synchronised sequence

These operations are controlled exclusively and automatically by the ELA3 operational checkout-command (CCO) computer. During this sequence, all the elements involved in the launch are synchronised by the “countdown time” distributed by the CSG.

During the initial phase (up to $H_0$ - 6s), the launcher is gradually switched to its flight configuration by the CCO computer. If the synchronised sequence is placed on hold, the launcher is returned automatically to its configuration at $H_0$ - 7 min.

In the second irreversible phase of the sequence ($H_0$ - 6 s to $H_0$ - 3.2 s), the synchronised sequence is no longer dependent on CSG countdown time, and operates on an internal clock.

The final phase is the launcher ignition phase. The ignition sequence is controlled directly by the on-board computer (OBC). The ground systems execute a number of actions in parallel with the OB ignition sequence.



| FLUID SYSTEMS | ELECTRICAL SYSTEMS |
|---|---|
| **$H_0$ - 6 min 30s**<br>Termination of topping up (LOX and $LH_2$)<br>LOX and $LH_2$ topped up to flight value<br>Launch pad safety flood valves opened | **$H_0$ - 6 min 30s**<br>Arming of pyrotechnic line safety barriers<br><br>**$H_0$ - 6 min**<br>Shutdown of EPS tanks electric heating |
| **$H_0$ - 4 min**<br>Flight pressurisation of EPC tanks<br>Isolation of tanks and start of EPC ground/OB interface umbilical circuit flushing | |
| | **$H_0$ - 3 min 30s:** Calculation of ground $H_0$ and verification that the second OBC has switched to the observer mode<br>**$H_0$ - 3 min**<br>$H_0$ loaded in the 2 OBCs<br>$H_0$ loaded in OBCs checked against ground $H_0$ |
| **$H_0$ - 2 min:** Vulcain 2 bleeder valves opened<br>Engine ground chill-down valve closed | **$H_0$ - 2 min 30s:** Electrical heating of EPC and VEB batteries, and electrical heating of the Vulcain 2 ignition system shut down |
| | **$H_0$ - 1 min**<br>Launcher electrical power supply switched from ground to OB |
| **$H_0$ - 30s**<br>Verification of ground/OB umbilical circuit flushing<br>EPC flue flood valves opened | **$H_0$ - 37s**<br>Start-up of ignition sequence automatic control system<br>Start-up of OB measurement recorders<br>Arming of pyrotechnic line electric safety barriers |
| **$H_0$ - 16.5 s**<br>Pressurisation of POGO corrector system<br>Ventilation of fairing POP and VEB POE connectors and EPC shut down | **$H_0$ - 22s**<br>Activation of launcher lower stage attitude control systems<br>Authorisation for switchover to OBC control |
| **$H_0$ - 12 s** Flood valves opening command | |

# 9. Flight sequence

| time/$H_0$ (s) | time/$H_0$ (mn) | event | altitude (km) | speed (m/s) | mass (t) |
|---|---|---|---|---|---|
| 7.30 | 0‘ 07‘’ | Lift-off | --- | | 773.0 |
| 12.70 | 0‘ 13‘’ | Start of tilt manoeuvre | 0.098 | 39 | 744.6 |
| 17.05 | 0‘ 17‘’ | Start of roll manoeuvre | 0.342 | 76 | 721.1 |
| 37.05 | 0‘ 37‘’ | End of roll manoeuvre | 3.6 | 252 | 620.9 |
| 48.2 | 0‘ 48‘’ | Transsonic (Mach = 1) | 6.6 | 323 | 578.1 |
| 68.2 | 1‘ 08‘’ | Speed at Pdyn max | 13.6 | 530 | 497.1 |
| 111.7 | 1‘ 52‘’ | Transition to $\gamma_{max}$ (41.6 $m/s^2$) | 39.2 | 1590 | 305.8 |
| 143.2 | 2‘ 23‘’ | Transition to $\gamma$ = 6.15 m/s² "$H_1$" | 66.1 | 2053 | 249.4 |
| **144.0** | **2‘ 24‘’** | **EAP separation** | **66.7** | **2055** | **174.7** |
| ----- | | EPC powered flight | | | |
| 212.5 | 3‘ 33‘’ | Fairing jettisoned | 109.7 | 2432 | 149.9 |
| *485.0* | *8' 05"* | *Acquisition Ariane Naval Station* | *135.5* | *5954* | *60.6* |
| *515.0* | *8' 35"* | *Lost Galliot* | *135.6* | *6680* | *50.7* |
| 527.7 | 8‘ 48‘’ | EPC burnout ($H_2$) | 136.6 | 7032 | 46.6 |
| **533.7** | **8‘ 54‘’** | **EPC separation** | **137.3** | **7056** | **28.5** |
| ---- | | EPS powered flight | | | |
| 540.7 | 9’ 01‘’ | EPS ignition (K2.1) | 138.1 | 7055 | 28.5 |
| *745.0* | *12’ 25”* | *Acquisition Azores* | *147.4* | *7244* | *26.6* |
| *790.0* | *13 10”* | *Lost Ariane Naval Station* | *147.3* | *7293* | *26.2* |
| 917.3 | 15’ 17” | End roll orientation | 145.6 | 7436 | 24.9 |
| 924.4 | 15’ 24” | Start of blowdown | 145.5 | 7444 | 24.9 |
| **1032.4** | **17’ 12‘’** | **EPS-1 burnout ($H_{3\text{-}1}$)** | **145.9** | **7564** | **23.9** |
| ---- | | Intermediate ballistic phase | | | |
| *1120* | *18’ 40* | *Lost Azores* | *148,1* | *7562* | *23.9* |
| 1202 | 20’ 02” | "Barbecue" phase | 150.7 | 7559 | 23.9 |
| 2043 | 34’ 03” | Despin then reorientaion | 192.5 | 7507 | 23.9 |
| 2066 | 34’ 26” | Barbecue phase | 193.7 | 7506 | 23.9 |
| 3066 | 51’ 06” | Despin then reorientation | 249.2 | 7438 | 23.9 |
| 3280 | 54' 40" | *Acquisition Adelaide* | 257.8 | 7428 | 23.9 |
| 3327 | 55’ 27” | Spin then boost | 259.4 | 7426 | 23.9 |
| **3570** | **59’ 30”** | **Second EPS ignition (K2.2)** | **264.9** | **7420** | **23.9** |
| **3598** | 59’ 58” | **EPS-2 burnout (H3.2)** | **265.2** | **7454** | **23.6** |

| time/$H_0$ (s) | time/$H_0$ (mn) | event | altitude (km) |
|---|---|---|---|
| - - - - | | “Ballistic” phase | - - - |
| 3600 | 60’ 00’’ | Phase 1: Start of ATV orientation | 265.3 |
| 3661 | 1:01’ 01’’ | *Acquisition Awarua* | 266.1 |
| *3751* | 1:02’ *31”* | *Lost Adelaide* | 267.2 |
| 3781 | 1:03’ 01’’ | Phase 2: 2nd orientation for TDRS antenna pointing | 267.6 |
| **3837** | **1:03’ 57’’** | **ATV separation** | **268.2** |
| 3851 | 1:04’ 11’’ | Composite avoidance manoeuvres (orientation, controlled boost, etc.) | 268.3 |
| 4186 | 1:09’ 46’’ | *Lost Awarua* | 270.0 |
| 4451 | 1:14’ 11’’ | Barbecue phase | 269.1 |
| 8277 | 2:17’ 57’’ | Composite despin – orientation in the direction of the deorbiting boost | 254.4 |
| 8501 | 2:21’ 41’’ | Propellant packing phase (spin at 30°/s, then 9.4°/s then spun boost for reignition) | 256.6 |
| 8641 | 2:24’ 01’’ | *Acquisition Perth* | **258.9** |
| **8662** | **2:24’ 22’’** | **Third EPS ignition (K2.3)** | **259.0** |
| **8677** | **2:24’ 37’’** | **EPS-3 burnout (H3.3)** | **259.1** |
| 8915 | 2:28’ 15’’ | EPS passivation | 249.7 |

*Note: This provisional flight sequence is coherent with the stage propulsion laws available at the time of drafting this document.*

# 10. Airbus Defence and Space and the ARIANE programmes

**Airbus Defence and Space** is a division of **Airbus Group** formed by combining the business activities of Cassidian, Astrium and Airbus Military. The new division is Europe's number one defence and space enterprise, the second largest space business worldwide and among the top ten global defence enterprises. It employs some 40,000 employees generating revenues of approximately €14 billion per year.

The new Business Line **Space Systems** is **the European leader in space transportation, orbital infrastructures and satellite systems**, formed from the current Astrium Divisions Space Transportation and Satellites. **Space Systems** will be the global No. 1 for commercial launchers and the European leader for satellites and orbital systems. **Space Systems** will serve institutional customers like the European Space Agency (ESA), national space agencies, national Defence ministries, civil and defence organisations, and commercial customers.

With design, production and testing resources that are on a par with the best in the world, **Space Systems** has at its disposal all the skills and key technologies needed to develop and operate major space systems: from launcher to delivery of a satellite in orbit, including the construction, installation and in-orbit management of the Columbus laboratory on the International Space Station.

**Space Systems** provides Europe with independent access to space as Ariane 5 lead contractor and supplies an integrated and tested launcher to Arianespace, which markets the launch services. It provides the main components of Ariane 5: all the stages, the vehicle equipment bay, the Sylda adapter, the flight software, the mission analysis and numerous sub-assemblies. Its staff are also currently working on defining the new generation of European launchers, Ariane 5ME and Ariane 6.


**Airbus Defence and Space** delivers **Arianespace** a launcher tested in its configuration when it leaves the Launcher Integration Building (BIL) in French Guiana, that is to say comprising:


**Integration Site in Les Mureaux**

- the main cryogenic stage (EPC) integrated on the Les Mureaux site. This site is located near Cryospace, an AIR LIQUIDE – ASTRIUM GIE (economic interest group) which manufactures the main stage propellant tanks. Also nearby is the functional simulation facility where **Airbus Defence and Space** developed the launcher's electrical system and software, and its guidance-attitude control and navigation system.


**Aquitaine site**

- the solid propellant booster (EAP) stages are integrated in the French Guiana Space Centre by Europropulsion in dedicated buildings with the MPS solid propellant motor supplied by Europropulsion, adding electrical, pyrotechnic, hydraulic, parachute recovery and other elements supplied from Europe. This is the first time a major part of the launcher is built in French Guiana.


**Integration Site in Bremen**

- an Upper Composite integrated in Bremen, comprising the version-A cryogenic upper stage (ESC-A), the vehicle equipment bay (VEB) and the Payload interface cone. The other German sites at Ottobrunn near Munich, and Lampoldshausen, supply the combustion chambers for Vulcain – Ariane 5's main engine – and the Aestus motor for the basic versions of the upper stage,

- the Ariane 5 Dual Launch System SYLDA 5 (**SY**stème de **L**ancement **D**ouble **A**riane5), a carrier structure allowing dual satellite launches, which is integrated on the Les Mureaux site and adapted to the particularities of the customers' payloads,
- the flight program tested at Les Mureaux, the data of which result from the mission analysis process also conducted by **Airbus Defence and Space**.

**Airbus Defence and Space** is moreover responsible for providing **Arianespace** with the launcher preparation requirements through to take-off, and therefore offers services relative to operations and technical support to guarantee launchability.

**Airbus Defence and Space** possesses the multidisciplinary expertise required to control a program of this complexity:

- program management: risk, configuration, dependability and documentation management,
- technical management: approval of the definition and qualification of launcher elements, overall coherence control and interface management,
- system engineering: integrated system (aerodynamic, acoustic, thermal, structural, flight mechanics, guidance and attitude control and POGO correction) studies, and testing (acoustic, thermal, dynamic and electrical models),
- flight data analysis after each launch.

| | | |
|---|---|---|
| Airbus Defence and Space web site | : | www.spece-airbusds.com/ |
| Arianespace web site | : | www.arianespace.com |