Satellites
Space Transportation
Services

KOUROU

May 2009

ARIANE 5

Data relating to Flight 188 by Stéphane LEBOUCHER

ARIANE 5 PRIME CONTRACTORSHIP AND INTEGRATOR

HERSCHEL

PLANCK

arianespace

All the space you need

EADS astrium

Flight 188
Ariane 5 – Satellites: HERSCHEL - PLANCK

Content

1. Introduction

Flight 188 is the 44th Ariane 5 launch and the second in 2009. An **ARIANE 5 ECA** (**C**ryogenic **E**volution type **A**), the most powerful version in the ARIANE 5 range, will be used for this flight.

Flight 188 is a scientific mission for Ariane 5. Launcher 546, the 40th production phase ARIANE 5, is the eighteenth of the 30 **PA** contract launchers, for which **ASTRIUM** is production prime contractor. 546 is consequently the nineteenth complete launcher to be delivered to **Arianespace**, integrated and checked out under **ASTRIUM** responsibility in the Launcher Integration Building (BIL).

In a dual-payload configuration using the SYLDA 5 "F" (4.9m high) system and a long pattern fairing (total height: 17m), the launcher is carrying the scientific satellites **HERSCHEL** in the upper position and **PLANCK** in the lower position.

Installed inside the long pattern fairing built by: **OERLIKON SPACE**

HERSCHEL built by prime contractor: **THALES ALENIA SPACE**

Strapped to a type **PAS 2624VS** adaptor built by: **SAAB**

Located inside the **SYLDA 5 F** built by: **ASTRIUM ST**

PLANCK built by prime contractor: **ORBITAL Sciences Corp.**

Strapped to a type **PAS 2624VS** adaptor built by: **SAAB**

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

2. Launcher L546

Description

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

- **Fairing**
- **SYLDA 5** payload carrier structure,
- The **Upper Composite**, which comprises:
    - **ESC-A** cryogenic upper stage,
    - **Vehicle Equipment Bay**
    - **3936 cone**,

The lower composite incorporates:

- **EPC (H175)** main cryogenic stage with the new Vulcain 2 engine,
- two identical **EAP (P240)** solid propellant strap-on boosters secured on either side of the EPC.

Type C main cryogenic stage:

The EPC is over 30m high. It has a diameter of 5.4m 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 boosters.

Liquid helium sub-system capacity
© ASTRIUM ST

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 authorizing lift-off.

The main stage burns continuously for about 535s, 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 213km for this mission, the stage separates from the upper composite and falls back into the Atlantic Ocean.

Type B solid propellant strap-on boosters:

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

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


Equipment displayed at Paris Air Show 2001

The boosters (EAP) are ignited 6.05s after the Vulcain engine, i.e. 7.05s 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 140s, 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 tonnes.*). *This launch will use welded segment MPS solid rocket motors for the seventh time, following L534/flight 174, L536/flight 176, L537/flight 177, L538/flight 179 and L540/V183 and L545/V187.*

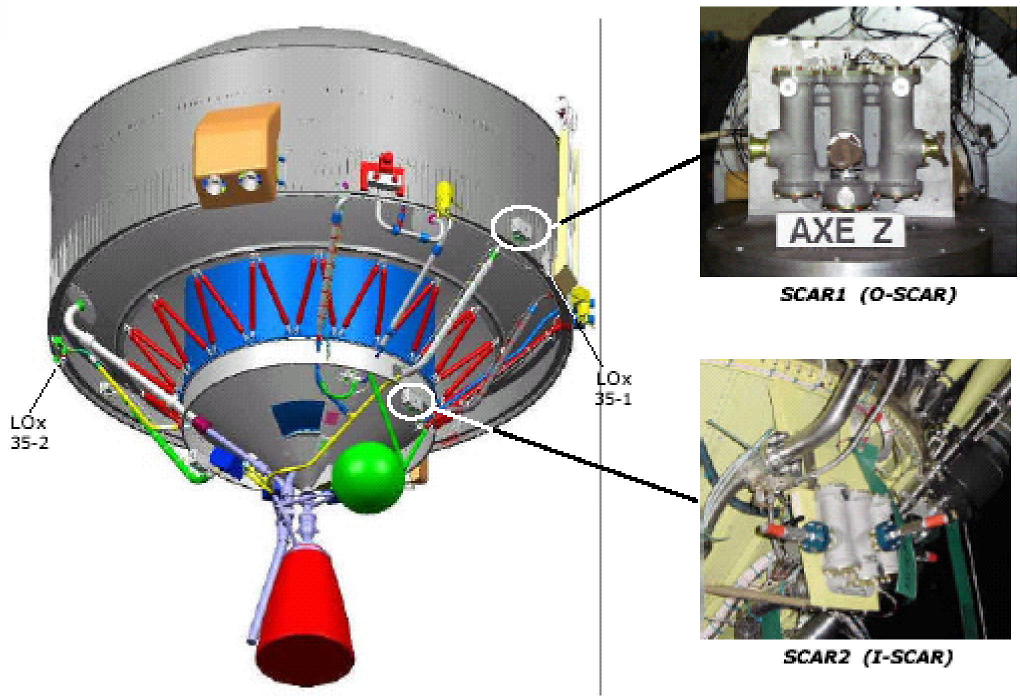
Type-A cryogenic upper stage:

The **ESC-A** 3rd stage has been developed for the ARIANE 5 ECA version of the ARIANE 5 Plus launcher, and is based on the **HM7B** engine previously used for the 3rd stage of the Ariane 4 launcher.

The ESC-A stage comprises:

- two tanks containing 14.7 tons propellant (LH_2 and LOX),
- **HM7B** engine delivering 6.5 tons thrust in vacuum for a burn time of about 925s. The HM7B nozzle is swivel-mounted (two axes) for attitude control.

To meet the needs of the mission, the **ESC-A** stage has **a single helium sphere** to cover the stage tank pressurisation and solenoid valve control requirements.



The ESC-A and the SCAR system

The **ESC-A** delivers the additional energy required to place the payloads into target orbit. This stage also provides a roll control function for the upper composite during the powered flight phase, and orients the payloads ready for separation during the ballistic phase using the **SCAR** (attitude and roll control system).

ESC-A thrust frame
© EADS ST

Ariane 5 ECA launcher in transit to launch pad ZL3 for the launch sequence rehearsal (RSL)
© Ds23230ESA/ARIANESPACE/Service optique CSG

Type C vehicle equipment bay:

The vehicle equipment bay (VEB) is a cylindrical carbon structure mounted on the **ESC-A** stage. The VEB contains part of the electrical equipment required for the mission (two OBCs, two new definition inertial guidance units, sequencing electronics, electrical power supplies, telemetry equipment, etc.).

The **upper composite** (ESC-A stage + VEB + 3936 cone) for launcher L546 was assembled for the eighth time at the Astrium ST site in Bremen, in order to meet needs resulting from the increase in production rates for the coming years.

Assembly of the upper composite at the Bremen site
© EADS Astrium

Nose fairing:

The ogival nose fairing protects the payloads 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 17m and a diameter of 5.4m.

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 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

The fairing has been coated with a new FAP (Fairing Acoustic Protection) product since flight 175-L534.

Fairing during integration

Launcher L545 fairing (in the BAF)

SYLDA 5 (ARIANE 5 dual-launch system):

This system provides for a second main payload inside one of the three fairing models. There are six different versions of this internal structure which has a diameter of 4.6m. SYLDA height varies between 4.6 and 6.4m (0.3m increments) for useful payload volumes between 50 and 65m^3.

A **SYLDA 5 'F'** with a **height of 4.9m** will be used for flight 188.

Sylda 5 No. 29-A for flight 183 during depreservation in the BAF in Kourou.
© ASTRIUM ST

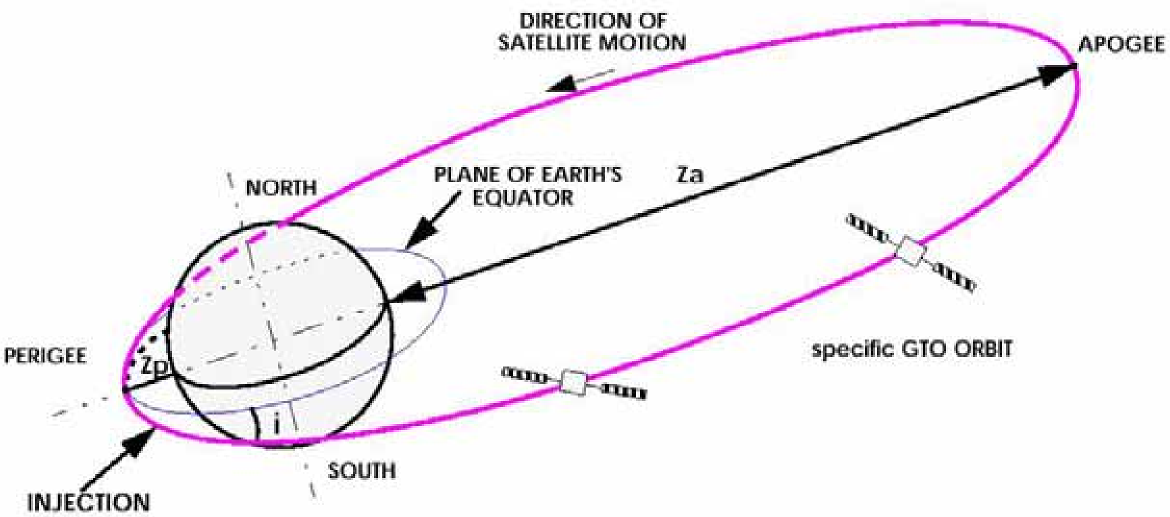
3. Mission V188

Payload mission

The main mission of flight 188 is to place the **HERSCHEL** and **PLANCK** scientific payloads into practically an escape orbit:

Apogee altitude (with an apogee radius	1,193,622 km 1,200,000 km)
Perigee altitude	270 km
Inclination	6.0°
Perigee argument	162°
Ascending node longitude	-108.0°(*)

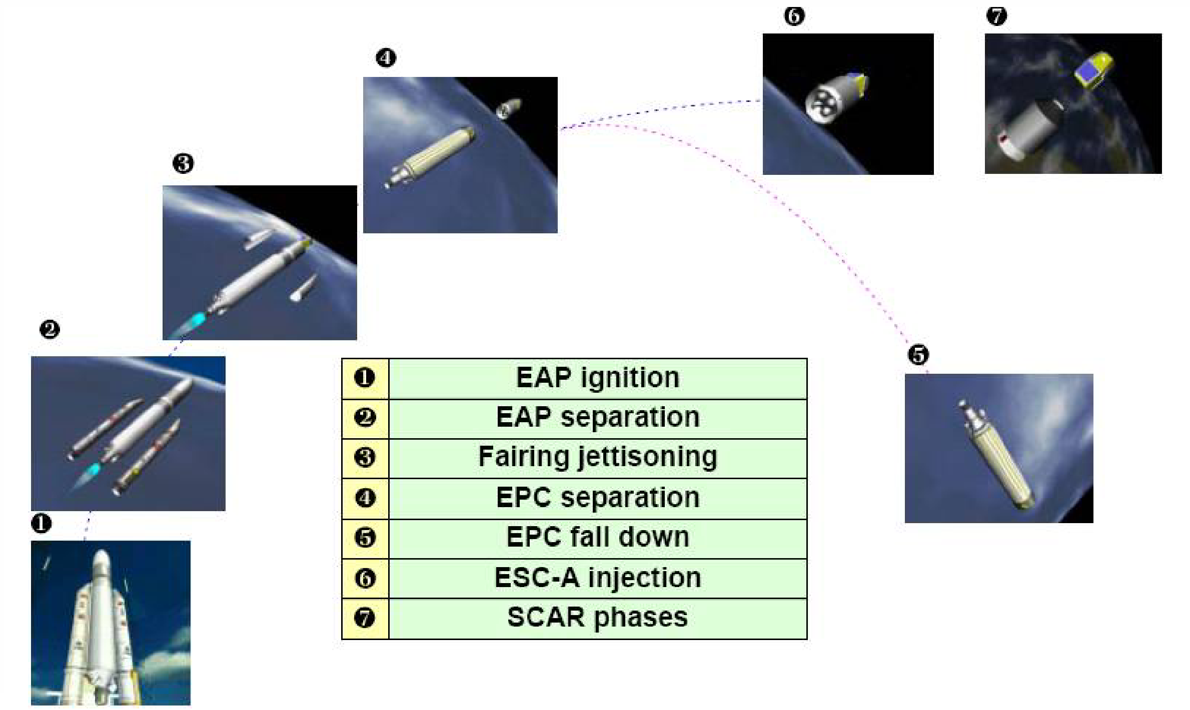
(*) in relation to a fixed axis, frozen at H_0 - 3s and passing through the ELA3 launch complex in Kourou.



The mass of **HERSCHEL** is **3,402 kg**, with **1,921 kg** for **PLANCK**.

Allowing for the adaptors and the **SYLDA 5** structure, total performance required from the launcher for the orbit described above is **6,001 kg**. Although total payload mass for this flight is substantially less than the maximum capacity of the A5ECA launcher (of the order of 9,500 kg for a standard GTO orbit inclined at 6°), the performance required from the launcher is very close to maximum performance level. This is due to the target orbit (practically an escape orbit to reach second Lagrange point L2).

Flight phases



❶	EAP ignition
❷	EAP separation
❸	Fairing jettisoning
❹	EPC separation
❺	EPC fall down
❻	ESC-A injection
❼	SCAR phases

Taking **H_0** as the basic time reference (1 s before the hydrogen valve of the EPC Vulcain engine combustion chamber opens), Vulcain ignition occurs at **H_0** + 2.7 s. Confirmation of nominal Vulcain operation authorizes ignition of the two solid propellant boosters (EAP) at **H_0** + 7.05 s, leading to launcher lift-off.

Lift-off mass is about 771 tons, and initial thrust 13,100 kN (of which 90% is delivered by the EAPs).

After a vertical ascent lasting 5s 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 **90**° 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:

- optimize trajectory and thus maximize 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**, 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** + 137.3s at an altitude of 67.3km and a relative velocity of 2,021 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 optimizes the trajectory by minimizing 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 upper (outer) payload. Separation of the fairing has been delayed for this mission in view of the insolation constraints for the upper payload, and will occur about 242.5 seconds after liftoff at an altitude of 146 km.

The **EPC powered flight** phase is aimed at a **predetermined orbit** established in relation to safety requirements, and the need to control the operation when the **EPC** falls back into the Atlantic Ocean.

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

Apogee altitude	266.9 km
Perigee altitude	-588.0 km
Inclination	5.7°
Perigee argument	-84.3 °
Ascending node longitude	-106.9 °

This is time reference **H_2**. It happens at **H_0**+534.7s.

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 depressurized (**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 angle of re-entry is **-3.20°**. The longitude of the point of impact is **8.4°W**.

The subsequent **ESC-A** powered **flight phase** lasts a little over 15 minutes. 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.

*This is time reference **H_3**. It happens at **H_0**+1,469.9s.*

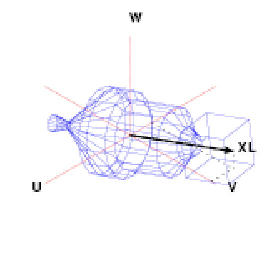
The purpose of the following ballistic phase is to ensure:

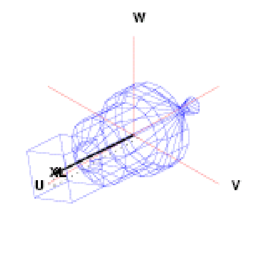
- Pointing of the upper composite in the direction required by **HERSCHEL** and **PLANCK** and then in that required for **SYLDA 5**,
- triple-axis stabilization of the launcher before separation of **HERSCHEL**,
- triple-axis stabilization of the launcher before separation of **SYLDA 5**,
- slow spin-up at 6°/s before separation of **PLANCK**,
- separation of **HERSCHEL**, **SYLDA 5** and **PLANCK**,
- final spin-up of the composite at 45°/s,
- passivation of the ESC-A stage pressurized LOX tank and LH_2 tank, preceded by a pre-passivation phase involving simultaneous opening of the eight SCAR nozzles.

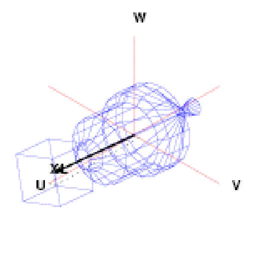
These operations contribute to short- and medium-term management of the mutual distancing of objects in orbit.

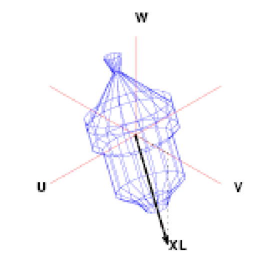
The ballistic phase for the mission comprises 17 elementary phases described hereafter. These include separation of **HERSCHEL** (phase 2), **SYLDA 5** separation (phase 4), and **PLANCK** separation (phase 8).

PHASE NUMBER 1 SPIN DOWN DURATION = 7.000 S	PHASE NUMBER 2 ORIENTATION DURATION = 105.000 S	PHASE NUMBER 3 SEPARATION DURATION = 10.000 S	PHASE NUMBER 4 ORIENTATION DURATION = 90.000 S

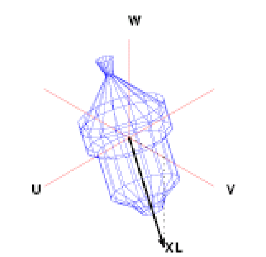


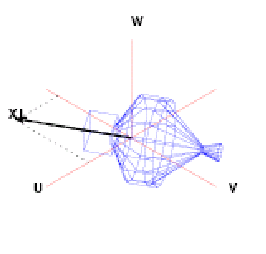


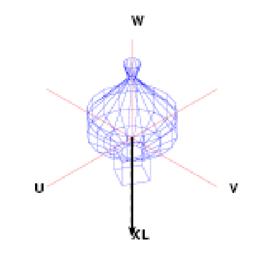


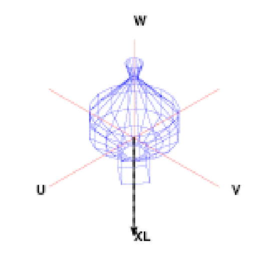


PHASE NUMBER 5 SEPARATION DURATION = 10.000 S	PHASE NUMBER 6 ORIENTATION DURATION = 95.000 S	PHASE NUMBER 7 ORIENTATION DURATION = 120.000 S	PHASE NUMBER 8 SLOW SPIN AT 0.9 ° /S DURATION = 10.000 S

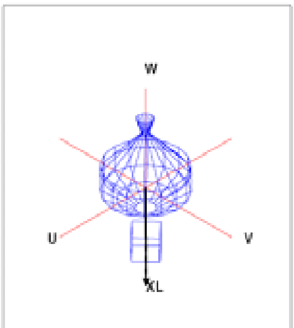


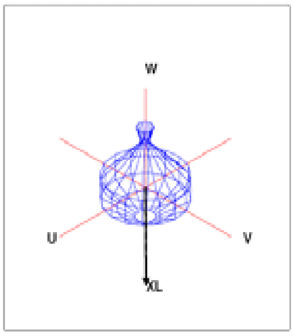


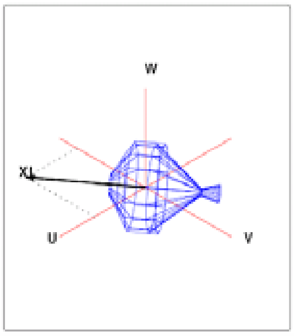


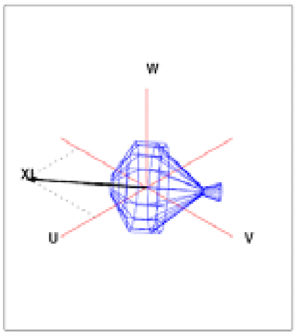


PHASE NUMBER 9 SEPARATION DURATION = 10.000 S	PHASE NUMBER 10 SPIN DOWN DURATION = 3.000 S	PHASE NUMBER 11 ORIENTATION DURATION = 90.000 S	PHASE NUMBER 12 SEPARATION DURATION = 10.000 S

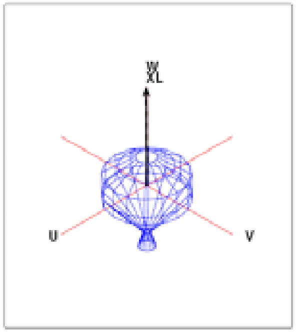


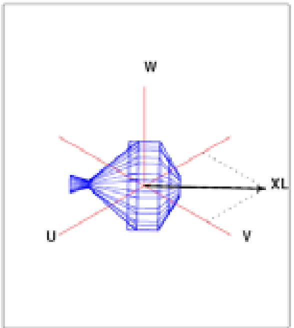


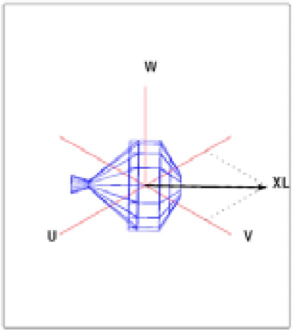


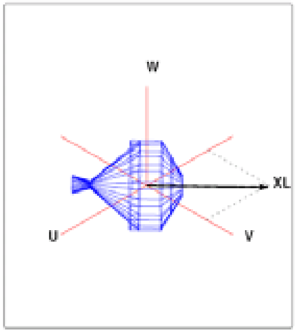


PHASE NUMBER 13 ORIENTATION DURATION = 85.000 S	PHASE NUMBER 14 ORIENTATION DURATION = 85.000 S	PHASE NUMBER 15 ORIENTATION DURATION = 87.000 S	PHASE NUMBER 16 ORIENTATION DURATION = 87.000 S

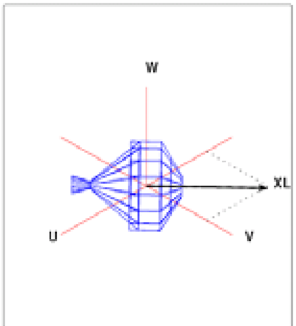


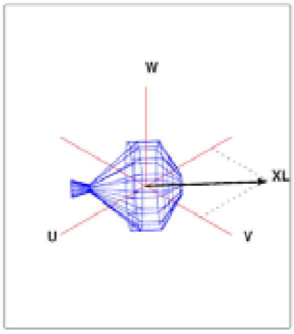


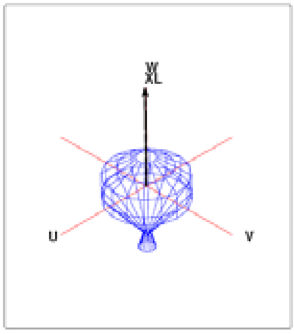


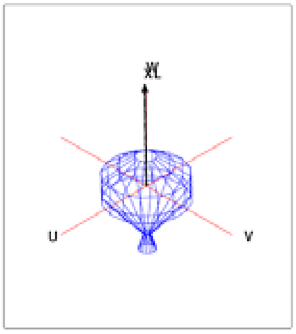


PHASE NUMBER 17 ORIENTATION DURATION = 87.000 S	PHASE NUMBER 18 ORIENTATION DURATION = 135.000 S	PHASE NUMBER 19 ORIENTATION DURATION = 85.000 S	PHASE NUMBER 20 SPIN UP 45.0 ° /S DURATION = 111.000 S

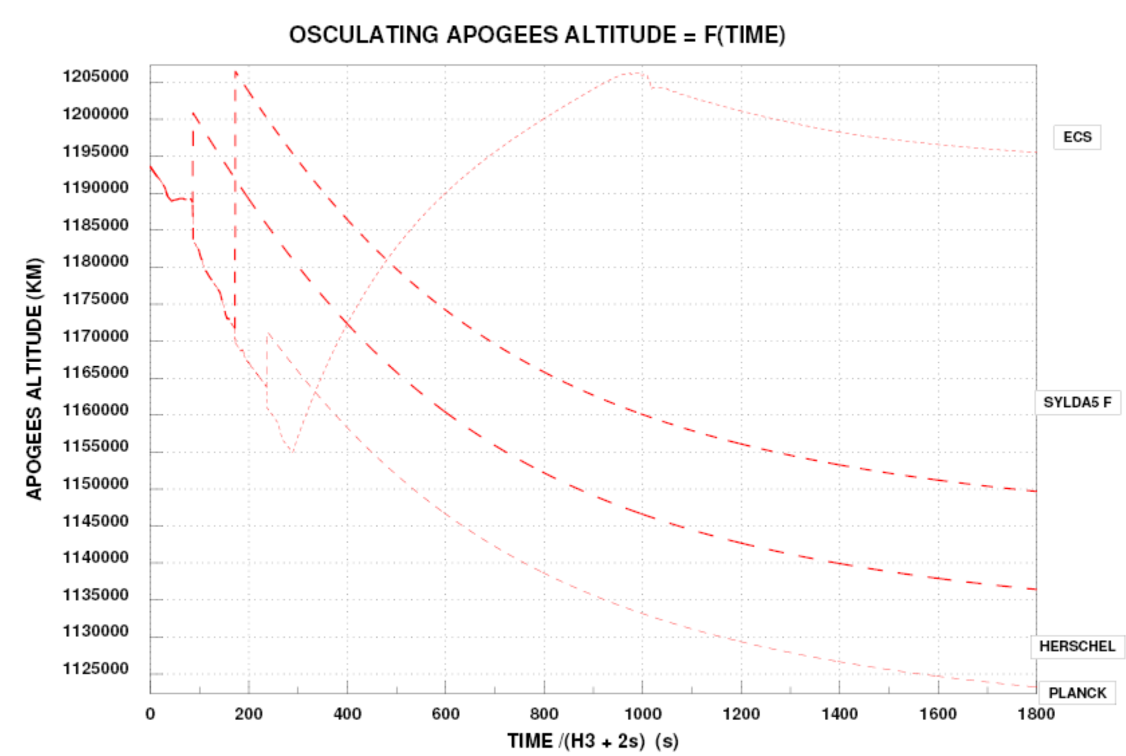






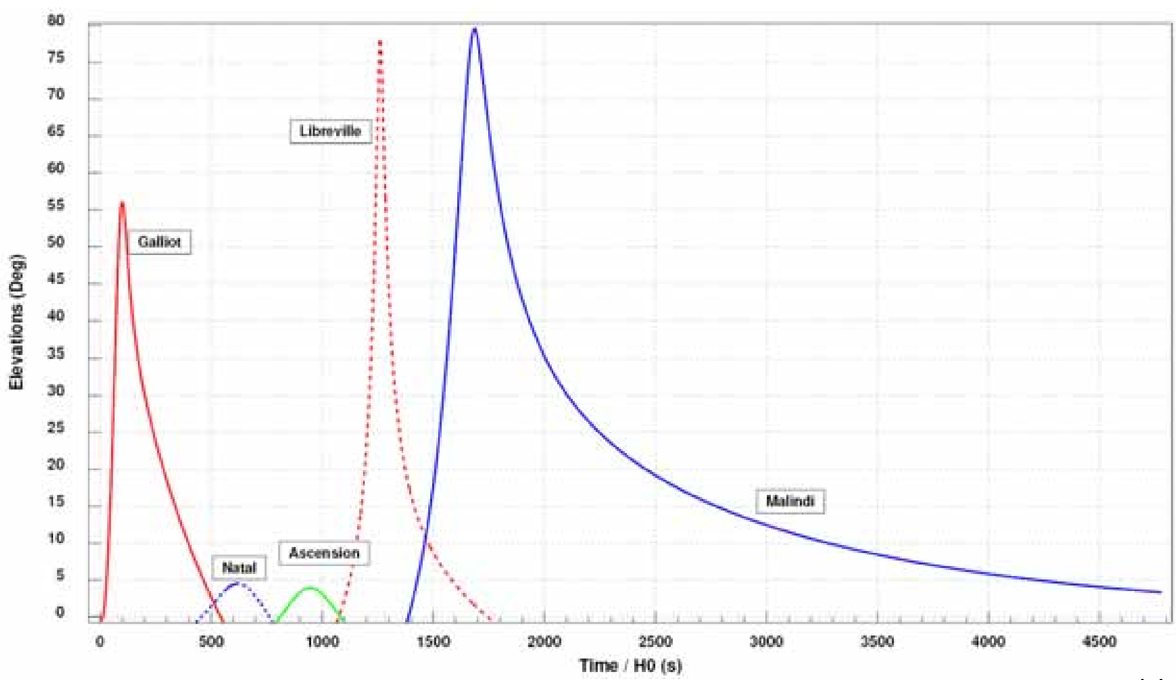


Staging of the various elements generated by the ballistic phase is described below.



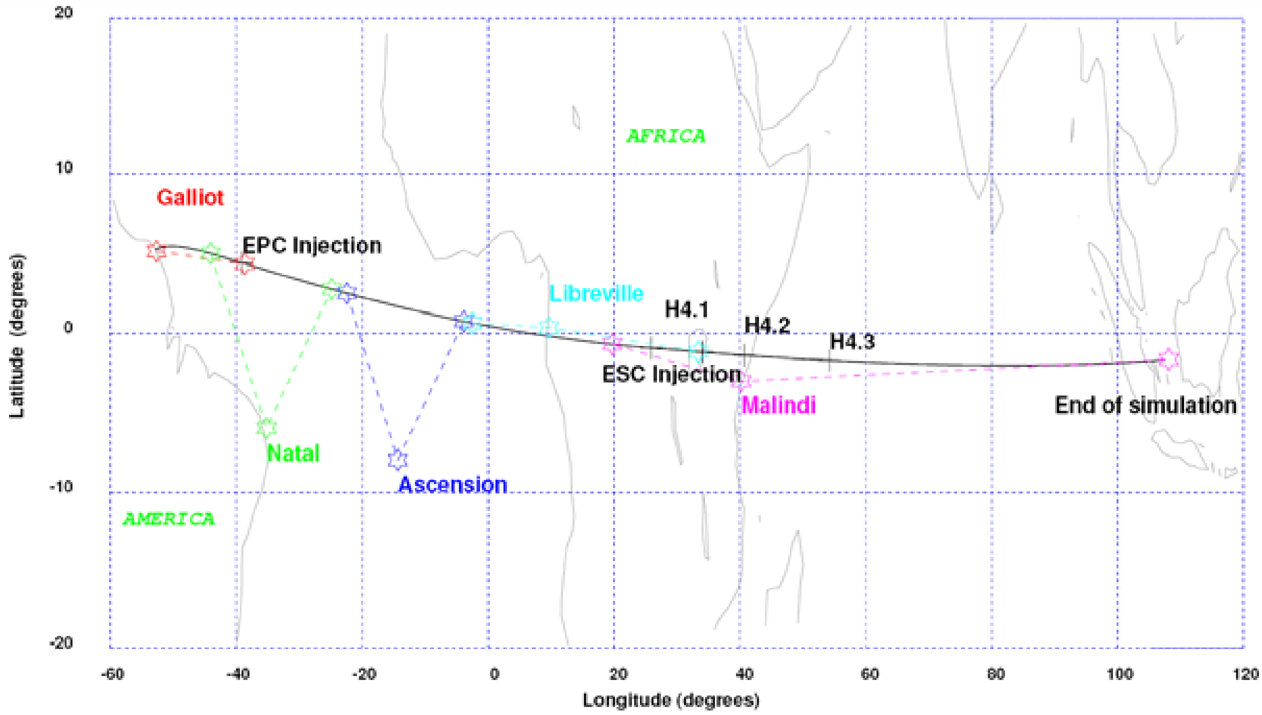
The launcher will be under **telemetry monitoring** by tracking stations in Kourou, Galliot, Natal, Ascension Island, Libreville and Malindi throughout the mission.

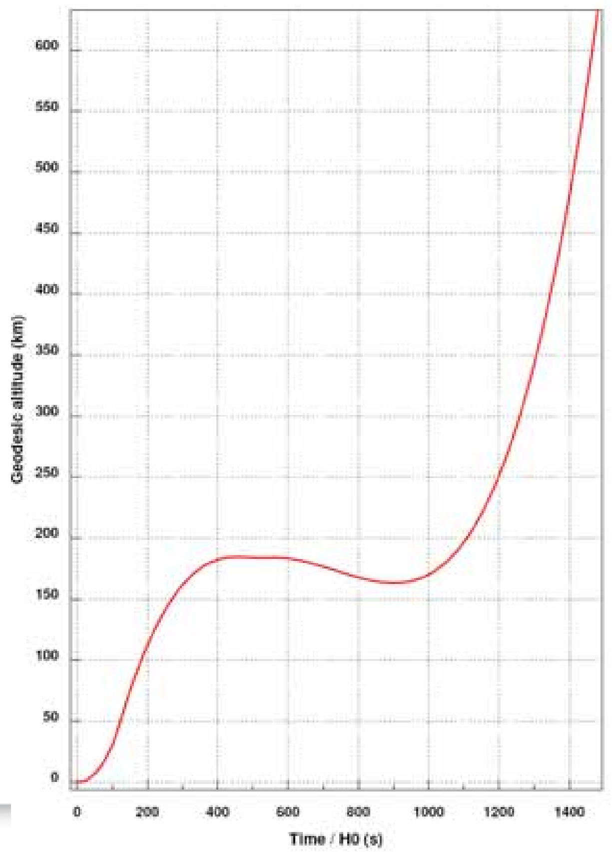
With the performance necessary for this mission, the trajectory should include one period of visibility loss between Natal and Ascension (approx. 65s) (between Ascension and Libreville, recovery is approx. 5s).

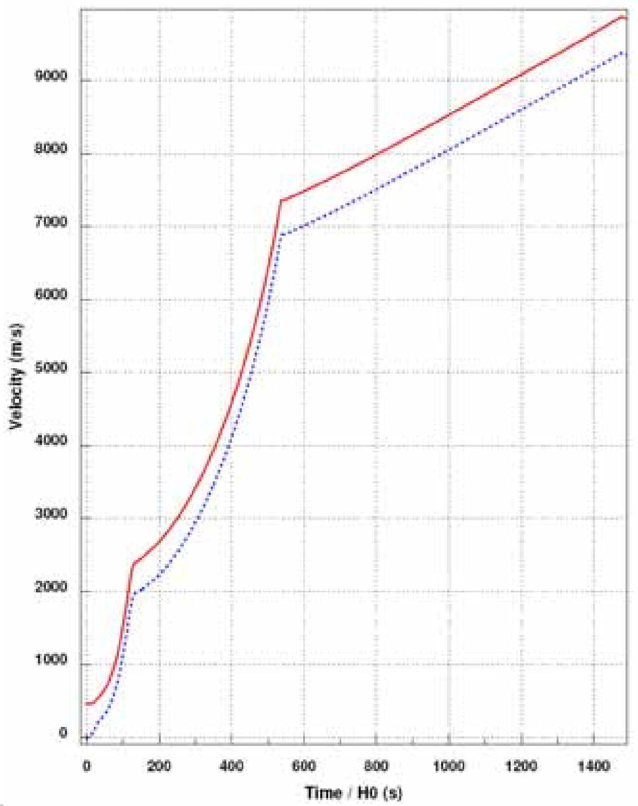


The following plates show:

- Situation of the main events of the flight,
- Evolution of launcher altitude during powered flight.





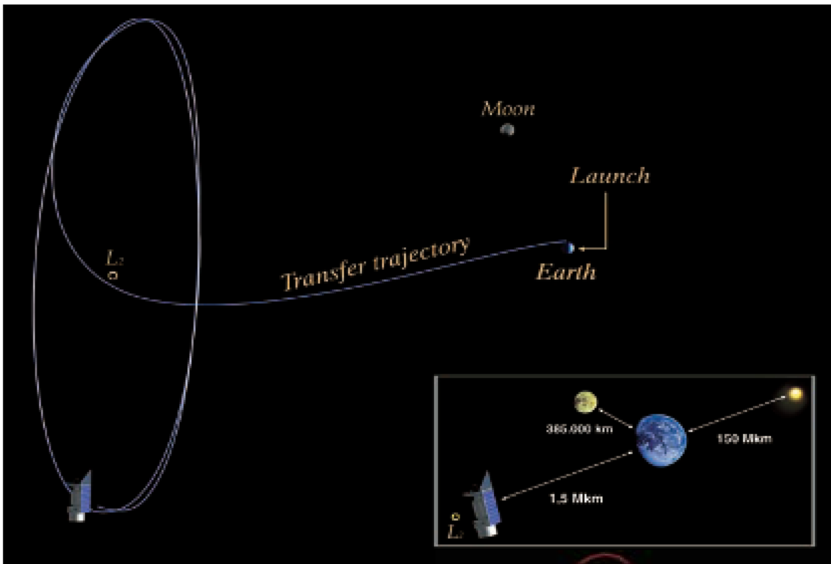


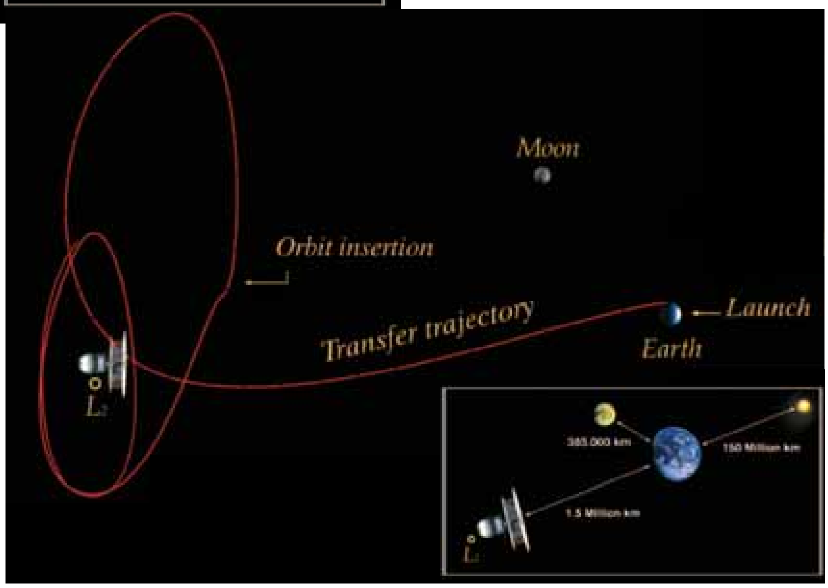
4. Payloads

HERSCHEL and PLANCK

The two payloads are both **ESA** scientific satellites built under the prime contractor responsibility of **Thales Alenia Space France** (Cannes).

After separation from the launcher, the two satellites will move into their operational orbits round the second Lagrange point (L2) about 1,500,000 km from the side of the Earth in shadow. This represents a little over four times the distance from Earth to the Moon. The satellites will take nearly 60 days to reach this virtual point in space, where they will be located in Lissajous orbits with an amplitude of 400,000 km round Lagrange point L2. Their distance from Earth will vary between 1.2 and 1.8 million km.



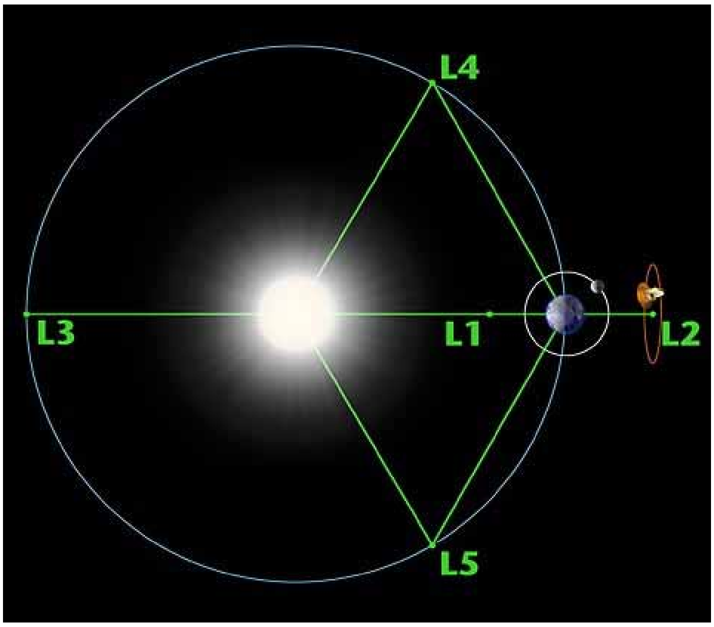


LAGRANGE points

The Lagrange points are points in space at which a body can remain fixed in relation to two other bodies.

Joseph-Louis Lagrange determined a five-point position for the Sun-Earth system, at which solar attraction and terrestrial attraction are precisely offset by the centrifugal force induced by Earth's movement round the Sun. A satellite placed in orbit in relation to one of these points rotates round the Sun at the same speed as Earth, and is consequently fixed in relation to the two stars.

By convention, the Lagrange points are denominated L1 to L5.



Of the five Lagrange points, only L4 and L5 are stable. This means that matter tends to accumulate at these points. The other points, such as L2, are consequently unstable and little perturbation is required for them to move out of position. It is for this reason that the two satellites will describe Lissajous orbits round L2 so as to minimise their fuel consumption.

The choice of point L2 is explained by the fact that the satellites will be protected from the Sun by Earth due to their alignment, thus providing excellent conditions for astronomic observation purposes. Furthermore, in the case of Herschel, the instruments carried by the satellite will not be perturbed by the strong infrared emission from Earth and the Moon, nor will its observations be perturbed by the Earth's radiation belts. As for Planck, this satellite will thus avoid emission from Earth, the Moon and the Sun, such as could otherwise perturb the CMB (Cosmic Microwave Background) radiation signal.

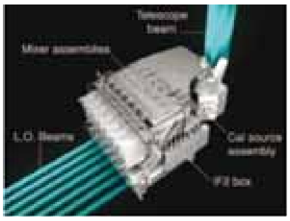
The HERSCHEL mission

This satellite is named after William Herschel who discovered and studied the thermal effects of infrared radiation.

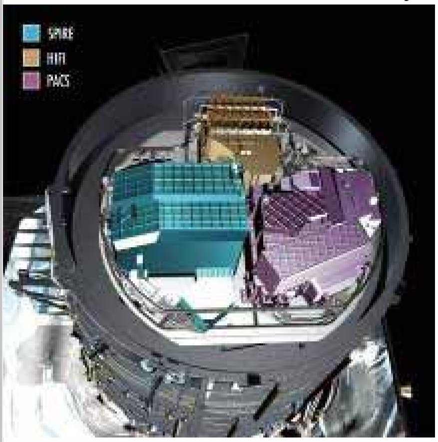
The main task of the Herschel spacecraft is to study the formation and evolution of galaxies and stars. For this purpose, the satellite will observe the cold and dusty zones of the universe, zones opaque for other telescopes. The Herschel telescope will also be used to observe gas and dust clouds in which stars and their surrounding disks are formed. Herschel will be the first spacecraft to cover the complete infrared range and the sub-millimetric wavelengths.

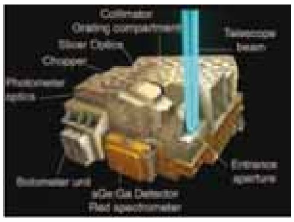
Herschel is a Cassegrain type telescope and is the largest mirror telescope ever to be placed into orbit. Its main mirror has a diameter of 3.5 m, almost one and a half time that of Hubble (2.4 m) for a mass of only 300 kg (it comprises twelve silicon carbide petals with a thickness of 3 mm, and was built by **ASTRIUM**). Its secondary mirror has a diameter of 30 cm. The Herschel spacecraft is 7.5 m long and has a lift-off mass of 3,402 kg. Once in its final orbit, it will be stabilised (triple-axis) and its orientation will depend on its observation programme.

Herschel carries the following instruments:

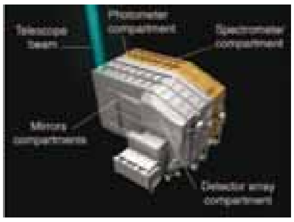


- the **HIFI** (Heterodyne Instrument for the Far Infrared) which will make it possible to observe a single point in the sky. This instrument incorporates seven heterodyne receivers and a very high spectral resolution spectrometer operating in the 157-610 μm band;





- the **PACS** (Photoconductor Array Camera and Spectrometer) is a blue and red focal plane photo-detector and wideband spectrometer covering the 60-120 μm and 120-210 μm bands;



- the **SPIRE** (Spectral and Photometric Imaging REciever) will be able to observe a vast region of the sky at the same time. **SPIRE** is an infrared camera coupled with a Fourier transform spectrometer comprising a set of bolometers operating in the 200-670 μm band.

These three instruments are housed in the cryostat and maintained at low temperature (< 1.7°K) by suprafluid helium (LHeII) in the HTT (Helium Two Tank). The operational lifetime of the cryostat depends directly on the LHeII supply autonomy of the satellite, for which the minimum anticipated is 3 years.

Herschel's superfluid helium tank, where the helium is kept at its boiling temperature (1.65K or −271.5°C). The helium cools the focal plane unit of the scientific instruments and the three thermal shields. The liquid boils and produces gas that slowly flows from the tank into pipes around the payload, cooling it to between 1.7K (−271.4°C) and 4K (−269°C).

The gas continues into the rings of the shields, cooling them down to 30K (−241°C), 50K (−221°C) and 60K (−211°C), respectively.

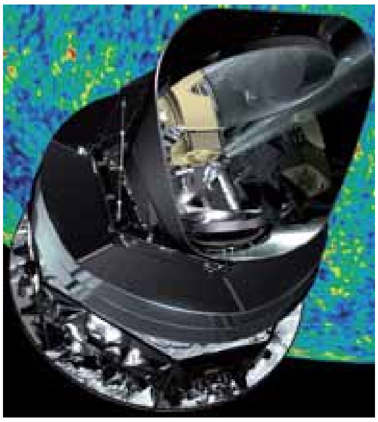
The cryostat vacuum vessel containing the superfluid helium tank. The gas is ejected into space. The cryostat vacuum vessel is cooled down to about 70K (−203°C) by radiating heat into space.

Typical application:

The Andromeda galaxy, situated at 2 .5 millions light years from Earth, is one of the closest to our own galaxy. Andromeda represents a good example of the possibilities for space exploration in the IR domain, and is regarded as a typical spiral galaxy.

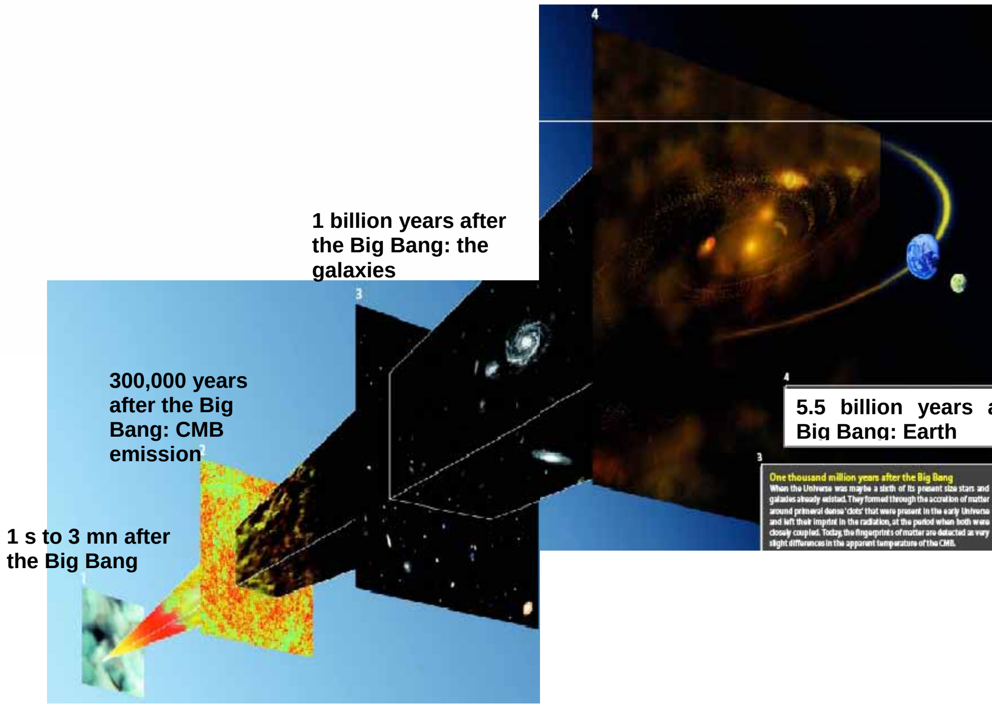
Observation in the IR domain using **ESA** resources demonstrates that the galaxy comprises a number of concentric dust rings at a temperature of close to 10/12°K, substantially colder than earlier predictions.

Conventional telescopes cannot detect these phenomena, and the Andromeda rings are still largely terra incognita. Only observations made by Herschel will enable us to obtain comprehensive knowledge of the constitution of this type of galaxy.

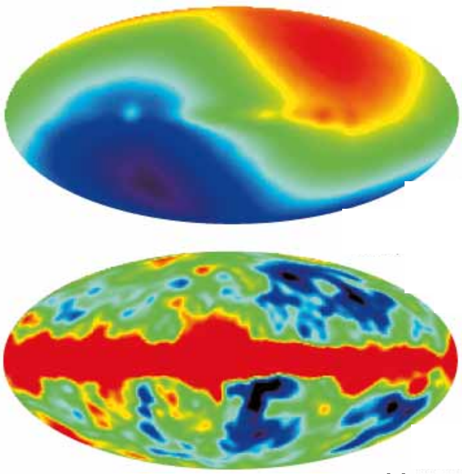


The PLANCK mission

The Planck satellite has been designed to analyse and measure, with unequalled precision, the very low temperature variations, or “anisotropies”, of the of the first light which filled the Universe after the Big Bang, namely Cosmic Microwave Background (CMB) radiation. Planck will cover the whole sky with an angular resolution of 5 minutes of arc, improving by a factor of about 15 on the information delivered by its predecessor WMAP. With the data collected by Planck, the scientists hope to obtain a better understanding of the origin, evolution and geometry of the Universe, and the nature of black energy and the minute matter density fluctuations at the origin of the galaxies.



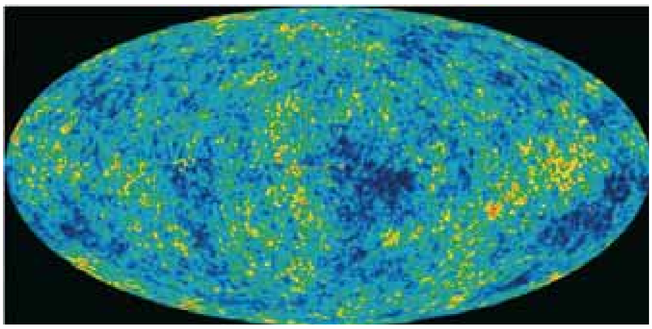
Planck is taking over from the COBE and WMAP satellites (launched by NASA in 1992 and 2003 respectively) and will provide very substantially enhanced measurement precision.



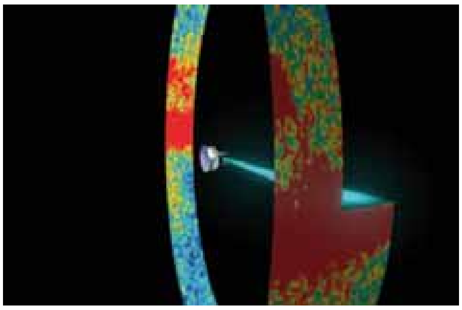
Sky maps as seen by COBE: the first image presents the temperature of the sky: we observe the impact of movement of the Sun (dipole form) and the Milky Way (weak horizontal smudge).

With these two effects eliminated, the second diagram presents a wideband associated with the residual emission of the galaxy, and a background filled with hot and cold points due largely to mixture of the CMB with the measurement noise induced by the instrument.

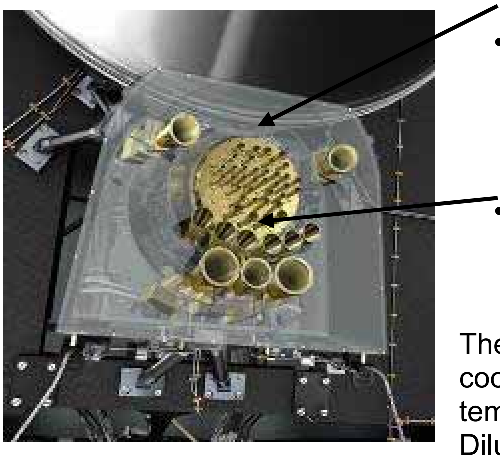
Sky map as seen by WMAP: this image presents a marked enhancement of the clarity and acuity of the sky map resulting from WMAP resolution. It shows minuscule CMB temperature irregularities.



The rotational speed of the satellite, separated under slow spin, will stabilise at 1 rotation per minute, making it possible to scan the entire sky in 6 months. Planck will acquire data covering four to five times the complete Universe in the space of 21 months.



The 1.5 m-diameter Planck telescope will focus radiation on two instruments:



- The **HFI** (High Frequency Instrument) comprises 50 bolometers and will be used to convert radiation (from a wavelength of 1 cm to 1/3 mm) into heat. The focal plane of this instrument operates at a temperature of 0.1°K;

- The **LFI** (Low Frequency Instrument) comprises a number of radio receivers operating at a temperature of -253°C.

The two instruments will be kept permanently chilled by a cooling system operating in the cascade mode (passive system to 50°K, Sorption Cooler to 18°K, 4°K Cooler to 4°K and Dilution Cooler to 0.1°K).

5. Launch campaign

Ariane 5 ESC-A flight thrust frame at EADS-ST Les Mureaux, before departure for Astrium in Bremen
© EADS ST photo: Studio Bernot

The Ariane 5 main cryogenic stage (EPC) in the integration dock at Les Mureaux, France, in course of preparation for tilt and containerization
© EADS ST photo: Studio Bernot

The main cryogenic stage loading on board the "Toucan" in the port of Le Havre for shipment to French Guiana
© EADS ST photo: JL

Principal phases of the flight 187 launch campaign:

Arrival of **HERSCHEL** in French Guiana	January 29, 09
EPC depreservation and erection in the launcher integration building (BIL)	February 5, 09
Transfer of Solid Booster Stages (EAP)	February 5 & 6, 09
Mating of the EAPs with the EPC	February 9, 09
Depreservation and erection of the Upper Composite	February 11 & 14, 09
V187: Success of the HOTBIRD™ 10/NSS-9/SPIRALE mission on launcher L545	February 12, 09
Assembly of the ARF on the ESC-A	February 16, 09
Arrival of **PLANCK** in French Guiana	February 18, 09
Launcher Synthesis Control	March 2, 09
Launcher acceptance by Arianespace	March 6, 09
Transfer from BIL to BAF	March 9, 09
Launcher mothballing	March 10, 09
Launcher recovery	April 16, 09
Assembly of HERSCHEL on its adaptor HERSCHEL fuelling with hydrazine Cryostat fuelling with LHe Transfer to the BAF Assembly on the SYLDA 5	March 27, 09 April 9, 09 Bet. April 10 & 28, 09 April 29, 09 April 30, 09
Assembly of PLANCK on its adaptor PLANCK fuelling with hydrazine Transfer to the BAF S/C integration on the launcher SYLDA integration on the launcher	April 11, 09 April 15 & 16, 09 April 22, 09 April 23, 09 April 27, 09
Launch Rehearsal	May 7, 09
Flight Readiness Review (Part I)	May 9, 09
Final preparation of HERSCHEL Fairing integration on the launcher	May 10, 09
Flight Readiness Review (Part II) Arming of the launcher	May 12, 09
Launcher transfer from the BAF to the Pad (ZL3) Fuelling of the EPC helium sphere	May 13, 09
Final countdown	May 14, 09

Kourou: depreservation and erection of the EPC in the BIL
© ESA/ARIANESPACE/Service optique CSG

Kourou: transfer of the launcher L545 from the Launcher Integration Building (BIL) to the Final Assembly Building
© ESA/ARIANESPACE/Service optique CSG

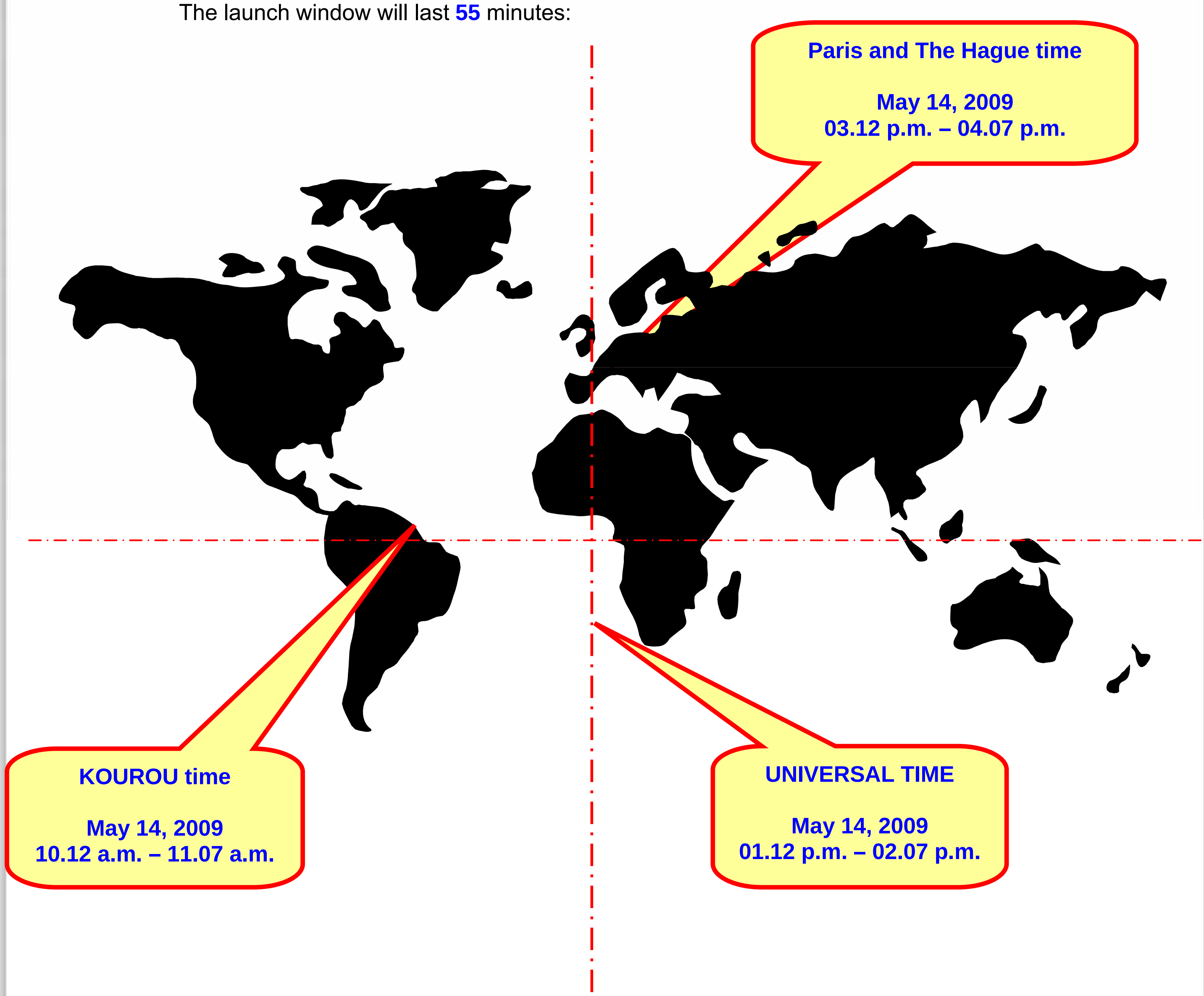
Kourou: erection of the Upper Composite in the Launcher Integration Building (BIL)
© ESA/ARIANESPACE/Service optique CSG

Kourou: transfer from the Final Assembly Building (BAF) to the pad for the Launch Sequence Rehearsal (RSL)
© ESA/ARIANESPACE/Service optique CSG

6. Launch window

The window for a launch on **May 14, 2009**, with H_0 at **01.12 p.m. (UT)** is at **02.07 p.m. (UT).**

The launch window will last **55** minutes:



The launch window for this mission is dictated principally by satellite-related constraints (associated with the manoeuvring capabilities of the satellites, and an absence-of-insolation constraint for Herschel).

The window will vary as follows in the event of a launch postponement:

- 15 May between 01.12 p.m. (TU) and 02.08 p.m. (56 minutes),
- 16 May between 01.13 p.m. (TU) and 02.08 p.m. (55 minutes),
- 17 May between 01.14 p.m. (TU) and 02.08 p.m. (54 minutes),
- 18 May between 01.14 p.m. (TU) and 02.08 p.m. (54 minutes).

7. Final countdown

The final countdown includes all operations for preparation of the launcher, satellites and launch base. Correct execution of these operations authorizes 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 synchronized sequence managed by the Ariane ground checkout computers, starting at H_0 - 7 min. In some cases, a pre-synchronized sequence may be necessary to optimize fuelling of the main cryogenic stage (*). If a countdown hold pushes time H_0 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.

H0 - 7 hours 30	**Checkout** of electrical systems. **Flushing** and configuration of the **EPC** and **Vulcain** engine for fuelling and chill-down
H0 - 6 hours	**Final preparation of the launch pad:** closure of doors, removal of safety barriers, configuration of the fluid circuits for fuelling. **Loading of the flight program** **Testing of radio links** between the launcher and BLA **Alignment of inertial guidance units**
H0 - 5 hours	**Evacuation of personnel from the launch pad** **Fuelling of the EPC** in four phases: pressurization of the ground tanks (30 minutes) chill-down of the ground lines (30 minutes) fuelling of the stage tanks (2 hours) topping up (up to synchronized sequence)
H0 - 5 hours	**Pressurization of the attitude control and command systems:** (GAT for the EAPs and GAM for the EPC)
H0 - 4 hours	**Fuelling of the ESC-A** stage in four phases: pressurization of the ground tanks (30 minutes) chill-down of the ground lines (30 minutes) fuelling of the stage tanks (1 hour) topping up (up to synchronized sequence)
H0 - 3 hours	**Chill-down of the Vulcain engine**
H0 - 30 minutes	**Preparation of the synchronized sequence**
H0 - 7 minutes	**Beginning of the synchronized sequence (*)**

(*) The standard synchronised sequence will start at T_0 - 7 minutes, incorporating all final launcher operations leading to lift-off. By comparison, the stretched synchronised sequence for flight 173 commenced at T_0 - 12 minutes, to cater for top-up LOX fuelling of the EPC stage to meet mission performance requirements.

Synchronized 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 synchronized 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 synchronized 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 synchronized sequence is no longer dependent on CGS 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 Termination of topping up (LOX and LH_2) LOX and LH_2 topped up to flight value Launch pad safety flood valves opened	**H_0 - 6 min 30s** Arming of pyrotechnic line safety barriers
H_0 - 6 min: Isolation of the ESC-A helium sphere	
H_0 - 4 min Flight pressurization of EPC tanks Isolation of tanks and start of EPC ground/OB interface umbilical circuit flushing Termination of ESC-A LOX topping up ESC-A LOX transition to flight pressure	
H_0 - 3 min 40: termination of ESC-A LH2 topping up	**H_0 - 3 min 30 :** Calculation of ground H_0 and verification that the second OBC has switched to the observer mode
H_0 - 3 min10: ESC-A LH_2 transition to flight pressure	
H_0 - 2 min: Vulcain bleeder valves opened Engine ground chill-down valve closed	**H_0 - 3 min** H_0 loaded in the 2 OBCs H_0 loaded in OBCs checked against ground H_0
	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 - 1min 5s Termination of ESC-A tank pressurization from the ground, and start of ESC-A valve plate seal-tightness checkout	**H_0 - 1 min 50s** Pre-deflection of the HM7B nozzle
	H_0 - 1min 5s Launcher electrical power supply switched from ground to OB
H_0 - 30s Verification of ground/OB umbilical circuit flushing EPC flue flood valves opened	**H_0 - 37s** Start-up of ignition sequence automatic control system Start-up of OB measurement recorders Arming of pyrotechnic line electric safety barriers
H_0 - 16.5 s Pressurization of POGO corrector system Ventilation of fairing POP and VEB POE connectors and EPC shut down	**H_0 - 22s** Activation of launcher lower stage attitude control systems Authorization for switchover to OBC control
H_0 - 12 s Flood valves opening command	

IRREVERSIBLE SEQUENCE

H_0 - 6s

Arming and **ignition** of AMEFs to burn hydrogen run-off during chill-down of the combustion chamber on Vulcain ignition
Valve plate and cryogenic arm retraction commands

H_0 - 5.5s

Ground information communication bus control switched to OBC

IGNITION SEQUENCE

H_0 - 3s

Checkout of computer status
Switchover of inertial guidance systems to flight mode
Helium pressurization activated
LOX and LH_2 pressures monitored
Navigation, guidance and attitude control functions activated

H_0 - 2.5s

Verification of **HM7B** nozzle deflection

H_0 - 1.4s

Engine flushing valve closed

H_0 - 0.2s

Verification of acquisition of the “cryogenic arms retracted” report by the **OBC** at the latest moment

$H_0 \rightarrow H_0 + 6.65s$

Vulcain engine ignition and verification of its correct operation
(H_0+1s corresponds to opening of the hydrogen chamber valve)

H_0 + 6.9s

End of Vulcain engine checkout

H_0 + 7,05s

Ignition of the **EAPs**

8. Flight sequence

time /H_0 (s)	time/H_0 (mn)	event	altitude (km)	mass (kg)	Vreal (m/s)
- - - -		**EAP-EPC powered flight**			- - -
7.31	0 ' 07 "	Lift-off	---	771.1	0
12.41	0 ' 12 "	Start of tilt manoeuvre	0.09	744.3	37.2
17.05	0 ' 17 "	Start of roll manoeuvre	0.35	719.0	78.6
32.05	0 ' 32 "	End of roll manoeuvre	2.6	639.7	224.5
46.5	0 ' 47 "	Transsonic (Mach = 1)	6.4	581.4	323.4
64.5	1 ' 05 "	Pdyn max.	12.7	509.1	497.6
110.3	1 ' 50 "	Transition to γ_{max} (42.54 m/s^2)	41.1	303.4	1,596.1
137.3	2 ' 17 "	Transition to γ = 6.22 m/s² H_1	67.3	249.9	2,020.9
138.1	**2 ' 18 "**	**EAP separation**	**68.0**	**175.9**	**2,022.3**
- - - -		**EPC powered flight**			- - - -
242.5	4 ' 02 "	Fairing jettisoned	146.0	138.9	2,540.4
315	*5 ' 15 "*	*Intermediate point*	*181.7*	*116.8*	*3,101.3*
408	*6 ' 48 "*	*Acquisition Natal*	*214.8*	*84.5*	*4,340.1*
470	*7 ' 50 "*	*Culmination*	*221.5*	*65.0*	*5,422.0*
534.7	8 ' 55 "	EPC burnout (H_2)	214.3	44.4	7,031.7
540.7	**9 ' 01 "**	**EPC separation**	**212.8**	**25.1**	**7,062.0**
- - - -		**ESC-A powered flight**			- - - -
544.9	9 ' 05 "	ESC-A ignition	211.7	25.1	7,066.0
640	*10 ' 40 "*	*Intermediate point*	*186.2*	*23.6*	*7,355.9*
740	*12 ' 20 "*	*Lost Natal*	*168.0*	*22.3*	*7,628.9*
806	*13 ' 26 "*	*Acquisition Ascension*	*158.9*	*21.2*	*7,862.4*
860	*14 ' 20 "*	*Resource (minimum altitude)*	*157.2*	*20.5*	*8,004.1*
1,071	*17 ' 51"*	*Acquisition Libreville*	*208.5*	*17.4*	*8,687.2*
1,075	*17 ' 55 "*	*Lost Ascension*	*210.7*	*17.3*	*8,703.4*
1,200	*20 ' 00 "*	*Intermediate point*	*316.2*	*15.4*	*9,096.1*
1,330	*22 ' 10 "*	*Acquisition Malindi*	*521.9*	*13.4*	*9,520.8*
1,470	24 ' 30 "	**ESC-A burnout ($H_{3\text{-}1}$)**	847.6	11.3	9,968

time /H_0 (s)	time/H_0 (mn)		event	altitude (km
- - - -			"Ballistic" phase	- - -
1,472	24 ' 32 "	Phase 1	Adjustment manoeuvres at start of SCAR phase	854
1,558	**25 ' 58 "**		**HERSCHEL separation ($H_{4.1}$)**	**1,133**
1,568	26 ' 08 "	Phase 3	Start of SYLDA orientation	1,167
1,644	27 ' 24 "		**SYLDA separation ($H_{4.2}$)**	1,449
1,654	27 ' 34 "	Phases 5	Start of PLANCK orientation	1,488
1,677	27 ' 57 "	Phases 6	Slow spin-up at 5°/s for PLANCK (CA 5)	1,578
1,705	28 ' 25"	Phases 7	Slow spin-up at 6°/s for PLANCK (CA 1)	1,693
1,708	**28 ' 28 "**		**PLANCK separation ($H_{4.3}$)**	**1,710**
1,718	28' 38 "	Phase 9	Composite despin	1,751
1,730	28 ' 50 "	Phase 10 to 15	ESC-A orientation for the final spin-up	1,802
2,487	41 ' 27 "	Phases 16	Start of spin-up at 45°/s	5,604
2,586	43 ' 06 "	Phase 17	Start of ESC-A pre-passivation	6,140
2,614	43 ' 34 "		Oxygen tank passivation (breakdown S34)	6,289
2,887	48 ' 07 "		ESC-A passivation (breakdown S37)	7,771

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

9. EADS ASTRIUM and the ARIANE programmes

Astrium Space Transportation, a business unit of **EADS Astrium,** is the European specialist for access to space and manned space activities. It develops and produces Ariane launchers, the Columbus laboratory and the ATV cargo carrier for the International Space Station, atmospheric re-entry vehicles, missile systems for France's deterrent force, propulsion systems and space equipment.

EADS Astrium, a wholly owned subsidiary of **EADS**, is dedicated to providing civil and defence space systems. In 2008, **EADS Astrium** had a turnover of €4.3 billion and 15,000 employees in France, Germany, the United Kingdom, Spain and the Netherlands. Its three main areas of activity are **Astrium Space Transportation** for launchers and orbital infrastructure, and **Astrium Satellites** for spacecraft and ground segment, and its wholly owned subsidiary Astrium Services for the development and delivery of satellites in orbit.

EADS is a global leader in aerospace, defence and related services. In 2008, **EADS** generated revenues of €43.3 billion and employed a workforce of more than 118, 000.

EADS Astrium has acquired extensive expertise, unrivaled in Europe, as industrial architect or prime contractor for large-scale strategic and space programs. This position is based on the company's ability to direct and coordinate the wealth of expertise required to design and develop complex projects.

In line with the ESA resolution concerning restructuring of the Ariane launcher system, involving a redistribution of responsibilities between the various players involved in design, development and manufacture, Ariane program activities in the industrial domain are now structured round a single prime contractor (see **European Space Agency** Council Meeting at Ministerial level of May 27, 2003)

As from the current ARIANE 5 production batch (**PA** batch), **Astrium Space Transportation** is consequently **sole prime contractor for the Ariane 5 system**. In this context, the company is responsible for supplying Arianespace with complete, tested launchers, and for managing all contracts necessary for launcher production. **Astrium ST** also supplies all component elements for ARIANE 5, including the stages built in its Les Mureaux (France), Bremen (Germany) and Kourou (French Guiana) facilities, the Vehicle Equipment Bay, the flight program and numerous sub-assemblies.

EADS Astrium is now the sole point of contact for the **European Space Agency** for future launcher development, acting as sole prime contractor in this domain also.

EADS Astrium 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 programs: design, qualification and development of flight programs, each specific to a particular mission,
- customer assistance: the company plays a major role in Ariane launch campaigns, providing support for Arianespace throughout launch operations,
- mission analysis and flight data analysis after each launch.

EADS Astrium is prime contractor for all Ariane 5 launcher stages - the main cryogenic stage (EPC), solid propellant boosters (EAP) and the various versions of the upper stage.

The EPC is integrated in the company's vast Les Mureaux complex near Paris. This site is located close to Cryospace, an EADS SPACE Transportation/AIR LIQUIDE joint venture which manufactures the main stage propellant tanks. Also nearby is the functional simulation facility where **Astrium** developed the launcher's electrical system and software, as well as its guidance-attitude control and navigation system.

To ensure maximum safety, the solid propellant boosters are manufactured in French Guiana. **Astrium** integrates the booster stages in dedicated buildings at the Guiana Space Center (CSG) 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 that a major part of the launcher has been constructed in French Guiana. A complete Ariane 5 "assembly line" and launch system was built up in French Guiana between 1988 and 1996, including not only production facilities for the solid propellant boosters, but also assembly buildings for launcher elements shipped out from Europe and all payload preparation facilities.

The different versions of the Ariane 5 upper stage are manufactured at the **Astrium** Bremen site in North Germany. Up to five upper stages can now be assembled simultaneously. The company's other German sites at Ottobrunn near Munich, and Lampoldshausen, supply the combustion chambers for the Ariane 5 Vulcain main engine, and the Aestus motor for the basic versions of the upper stage.

EADS Astrium is also responsible for the SYLDA 5 (**SY**stème de **L**ancement **D**ouble **Ariane 5**) built in its Les Mureaux (France).

EPC Integration Site in Les Mureaux

Site internet EADS Astrium : www.astrium.eads.net

Site internet ARIANESPACE : www.arianespace.com