Satellites
Space Transportation
Services

KOUROU

July 2013

ARIANE 5

Data relating to Flight 214

ARIANE 5 PRIME CONTRACTORSHIP AND INTEGRATOR

ALPHASAT

INSAT-3D

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ASTRIUM
AN EADS COMPANY

Flight 214 Ariane 5
Satellites: ALPHASAT – INSAT-3D

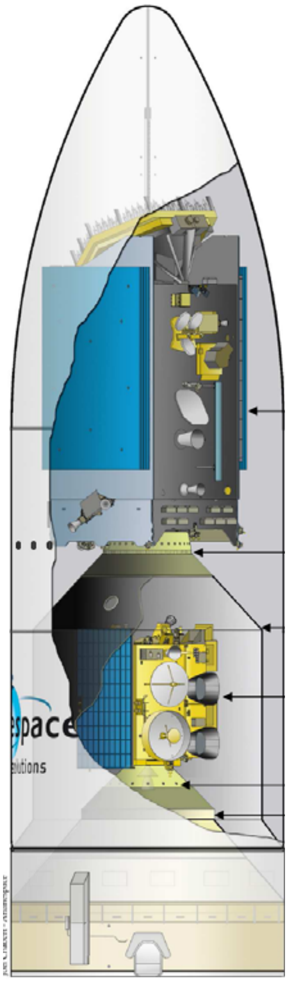
Content

1. Introduction

Flight 214 is the 70th **Ariane 5 launch** and the third in 2013.
It follows on from a series of **55** consecutive successful **Ariane 5** launches. 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 214 is a commercial mission for Ariane 5. The **L569** launcher is the thirteenth in the A5ECA family to be delivered by **ASTRIUM ST** 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 and covers the period from 2010 to 2016. L569 is consequently the forty-fourth 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 "D"** system and a long pattern fairing (total height: 17 m), the launcher is the communications satellite **ALPHASAT** in the upper position and the meteorological satellite **INSAT-3D** in the lower position.



Installed inside the long pattern fairing built by:	**RUAG Aerospace AG**
ALPHASAT built by:	**ASTRIUM**
Strapped to a type **PAS 1666S** adaptor built by:	**RUAG Aerospace AB**
Located inside the **SYLDA 5 D** built by:	**ASTRIUM ST**
INSAT-3D built by:	**I.S.R.O.**
Strapped to a type **PAS 937S** adaptor built by:	**RUAG Aerospace AB**
Placed on a **MFD-D** shock absorber built by:	**EADS-CASA**

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 L569

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 **EAP (P240)** solid propellant strap-on boosters secured on either side of the EPC

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
© 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 authorising lift-off.

The main stage burns continuously for about **533 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 **169 km** for this mission, the stage separates from the upper composite and falls back into the Atlantic Ocean.

Type-C 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 **135 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*).

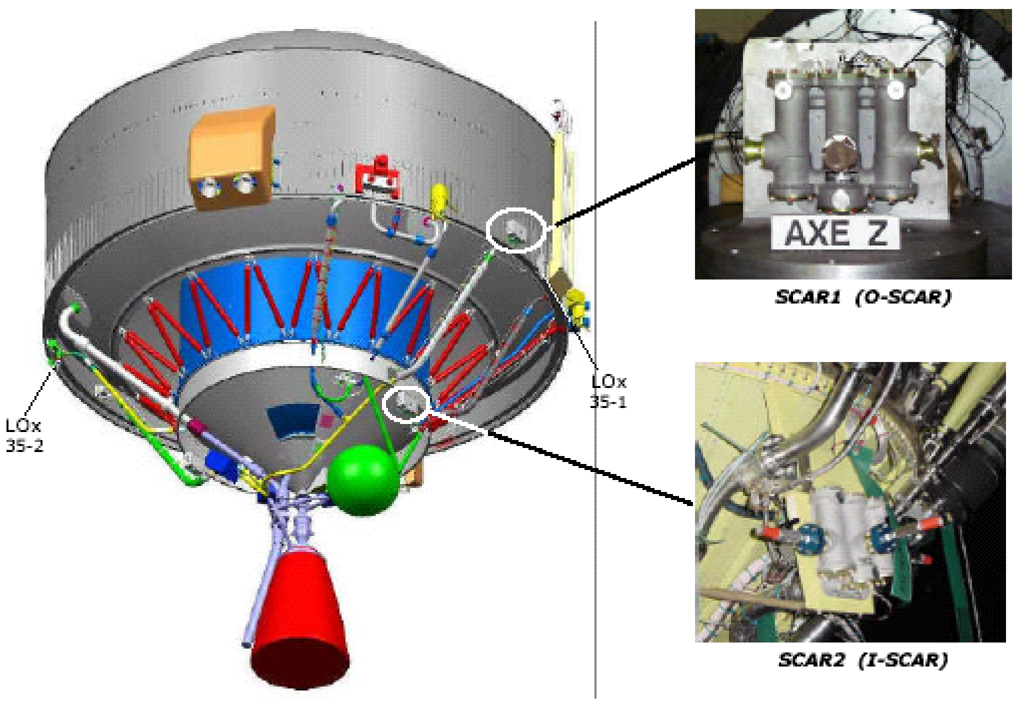
Type-A cryogenic upper stage:

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 **957 s**. 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

The C-Fibre Placement type 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 inertial guidance units, sequencing electronics, electrical power supplies, telemetry equipment, etc.). For the sixteenth time, the VEB cylinder and cone have been produced using a new process involving depositing carbon fibres on a mould before baking of the structure.

The **upper composite** (ESC-A stage + VEB + 3936 cone) for launcher L569 was assembled for the twenty-ninth 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:

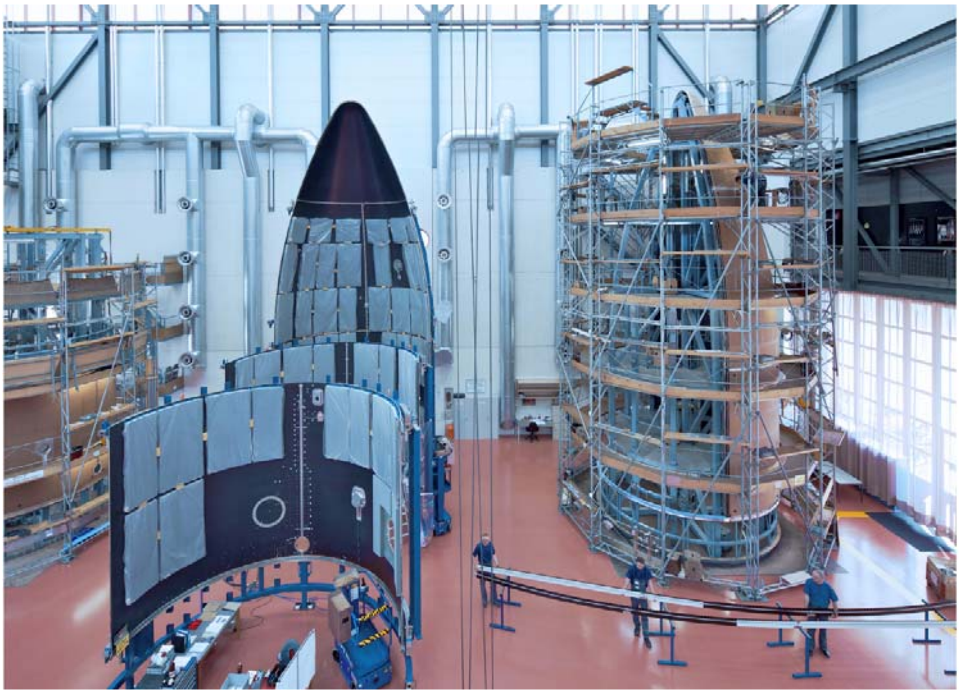
The ogival nose fairing protects the payloads during the atmospheric flight phase (acoustic protection on lift-off and during transonic flight, aerothermodynamic flux).

A long pattern fairing is used for this mission. It has a height of 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 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 lighter FAP (Fairing Acoustic Protection) product since flight 175-L534.



Fairing production line

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 4.6 m. SYLDA height varies between 4.9 and 6.4 m (0.3 m increments) for useful payload volumes between 50 and 65 m^3.

For this mission, a **SYLDA 5 'D'** with a **height of 5.5 m** will be used for the first time. It enables the carriage of a payload in the lower position, **INSAT-3D**. For the fifth time on this flight, the structure was manufactured using a new "co-curing" method, enabling the industrial process to be rationalised.

Sylda 5 No. 56-D for launcher L569 at Les Mureaux

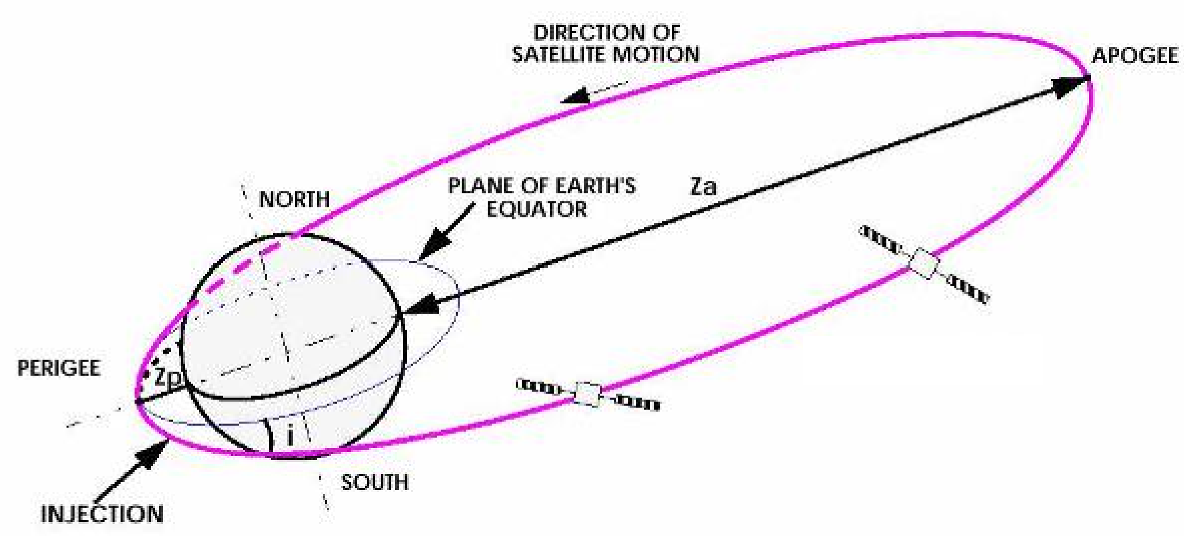
3. Mission V214

Payload mission

The main mission of Flight 214 is to place the **ALPHASAT** and **INSAT-3D** commercial payloads into a low-inclined standard GTO orbit:

Apogee altitude	35786 km
Perigee altitude	248.1 km
Inclination	3.5°
Perigee argument	178°
Ascending node longitude	-122.975°(*)

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



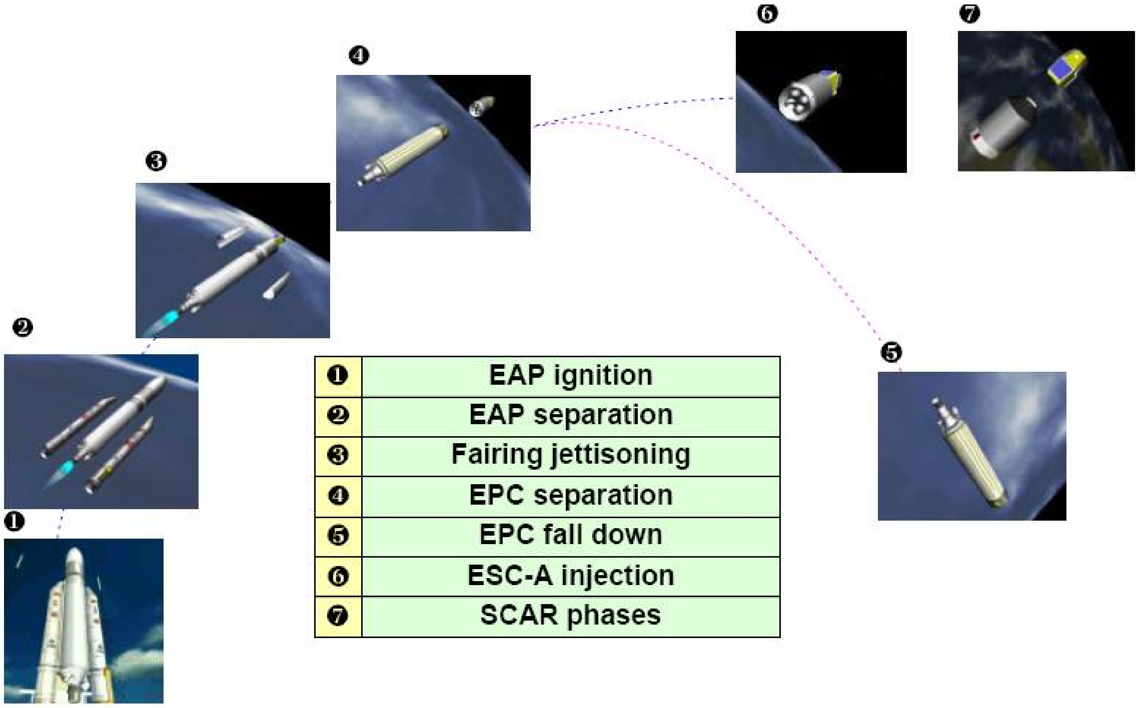
The mass of **ALPHASAT** is **6649 kg**, with **2061 kg** for **INSAT-3D**. Allowing for the adaptors and the **SYLDA 5** structure, total performance required from the launcher for the orbit described above is **9674.1 kg**.

It should be remembered that the maximum performance offered by the Ariane 5 ESC-A launcher exceeds 10300 kg (performance recorded by ARIANE 5 ECA L568-V212, on February 7, 2013) for a standard orbit inclined at 6°.

Part of the performance margin is used to reduce the inclination of the target orbit.

This also demonstrates the adaptability of the launcher in terms of payload mass.

Flight 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 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 775 tons, and initial thrust 13,000 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 **93**° 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**, 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 + 142 s*** *at an altitude of* ***66.7 km*** *and a relative velocity of* ***2013m/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. For this mission, separation of the payload will occur about **198 s** after lift-off at an altitude of **107.2 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	168.9 km
Perigee altitude	-1051.1 km
Inclination	6.038°
Perigee argument	-42.53°
Ascending node longitude	-121.53°

This is time reference **H_2**. It happens at **H_0 + 533.7 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 angle of re-entry is **-2.50°**. The longitude of the point of impact is **5.74°W**.

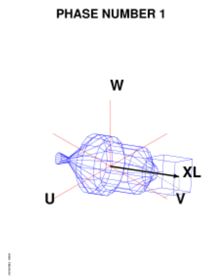
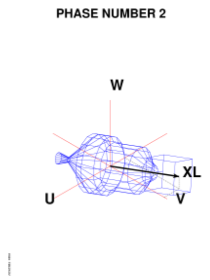
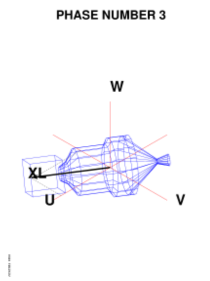
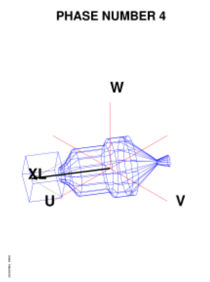
The subsequent **ESC-A** powered **flight phase** lasts about 16 minutes. This phase is terminated by a command signal from the OBC, when the computer estimates, from data calculated by the inertial guidance unit, that the **target orbit** has been acquired.

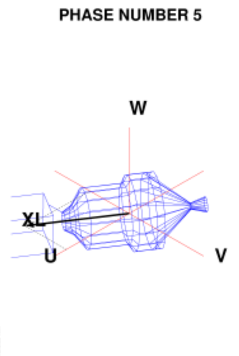
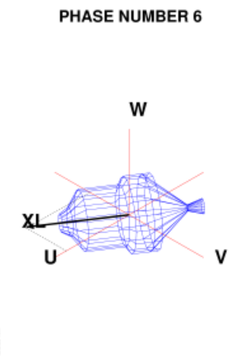
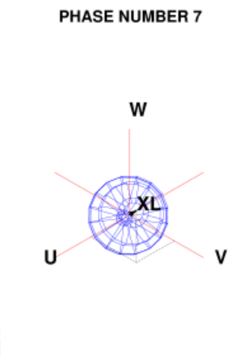
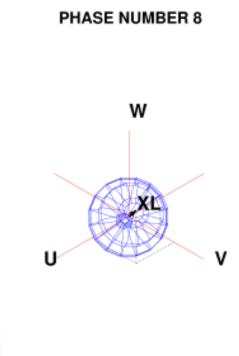
This is time reference ***H_3***. *It happens at* ***H_0 + 1501.3 s.***

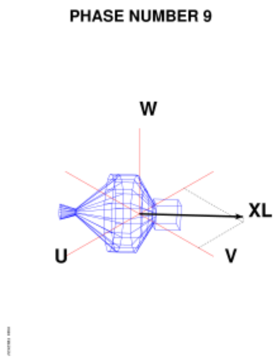
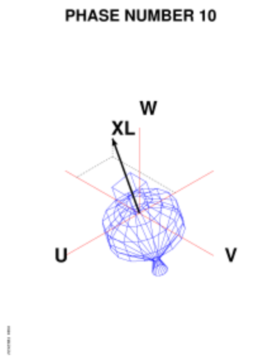
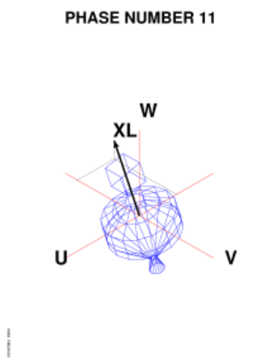
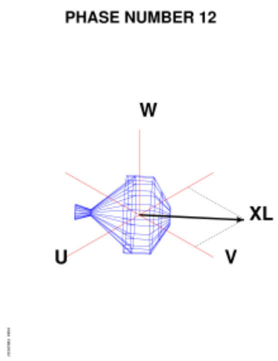
The purpose of the following ballistic phase is to ensure:

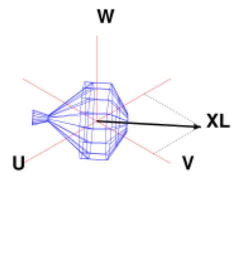
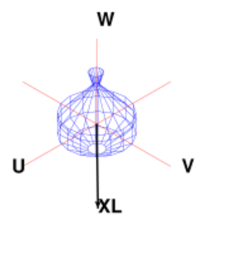
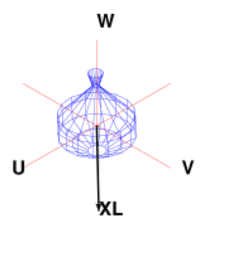
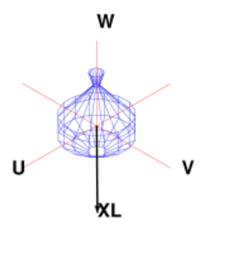
- Pointing of the upper composite in the direction required by **ALPHASAT** and **INSAT-3D** and then in that required for **SYLDA 5**,
- Launcher transverse spin-up before separation of **ALPHASAT**,
- Triple-axis stabilisation of the launcher before separation of **SYLDA 5** and **INSAT-3D**,
- Separation of **ALPHASAT, SYLDA 5** and **INSAT-3D**,
- Final spin-up of the composite at 45°/s,
- Passivation of the ESC-A stage pressurised 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 21 elementary phases described hereafter. These include separation of **ALPHASAT** (phase 5), **SYLDA 5** separation (phase 8), and **INSAT-3D** separation (phase 11).

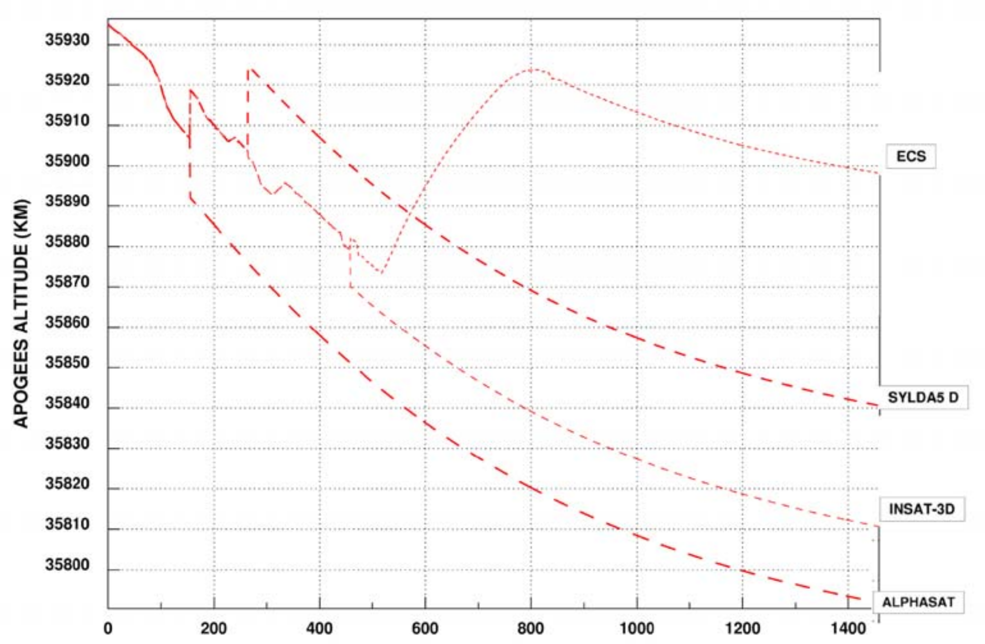
Phase n° 1 Transverse velocity control (minimizing the transverse angular rate) Duration: 0.57600 s LOX valves are closed.	
Phase n° 2 Despin Duration:0.57600 s LOX valves are closed.	
Phase n° 3 Tilting aiming at the following orientation: U_{beg} = 0.8643 / U_{end}= 0.5047 V_{beg} = -0.5030 / V_{end}= -0.8633 W_{beg} = -0.0005 / W_{end}= -0.0012 Duration: 131.0 s From the begining of this manoeuvre, the LOX valves are opened between 35.0 to 120.0s	
Phase n° 4 Slow spin up to 2.50000 °/s Duration: 20.0 s LOX valves are closed.	

Phase n° 5 Transverse angular velocity control Stand-by of 10s for separation LOX valves are closed.	
Phase n° 6 Despin Duration:3.0 s LOX valves are closed.	
Phase n° 7 Tilting aiming at the following orientation: U = 0.5046 V = 0.6012 W = 0.6197 Duration: 95.0 s LOX valves are closed.	
Phase n° 8 Transverse angular velocity control Stand-by of 10s for separation LOX valves are closed.	

<u>Phase n° 9</u> Tilting aiming at the following orientation: U = -0.6428 V = 0.7660 W = 0.0000 Duration: 60.0 s From the begining of this manoeuvre, the LOX valves are opened between 35.0 to the end	
<u>Phase n° 10</u> Tilting aiming at the following orientation: U_{beg} = -0.4921 / U_{end}= -0.8384 V_{beg} = -0.8401 / V_{end}= -0.4840 W_{beg} = 0.2283 / W_{end}= 0.2506 Duration: 122.0 s LOX valves are closed.	
<u>Phase n° 11</u> Transverse angular velocity control Stand-by of 10s for separation LOX valves are closed.	
<u>Phase n° 12</u> Tilting aiming at the following orientation: U = -0.6428 V = 0.7660 W = 0.0000 Duration: 90.0 s From the begining of this manoeuvre, the LOX valves are opened between 50.0 to the end	

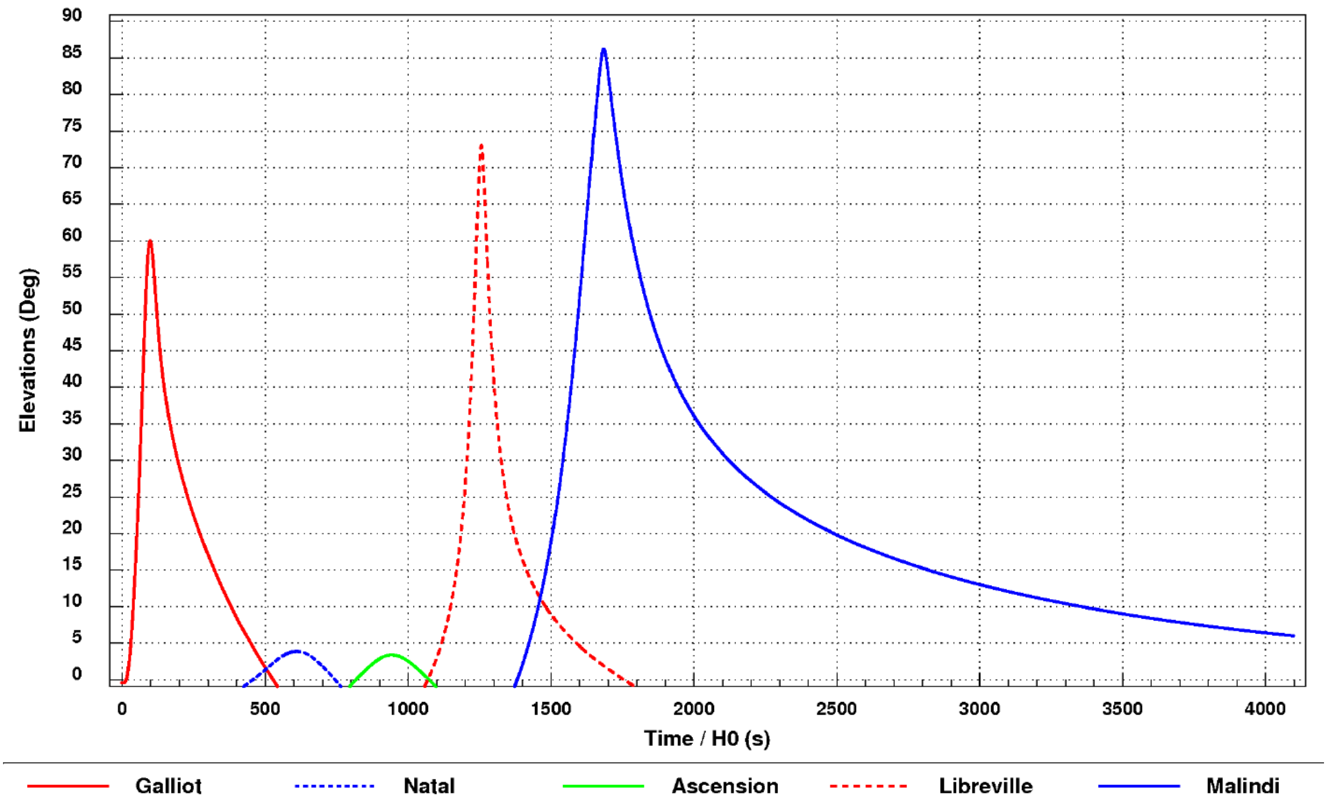
Phase n° 13 Tilting aiming at the following orientation: U = -0.6428 V = 0.7660 W = 0.0000 Duration: 164.0 s From the begining of this manoeuvre, the LOX valves are opened between 0. to the end	PHASE NUMBER 13 
Phase n° 14 Tilting aiming at the following orientation: U = 0.0000 V = 0.0000 W = -1.0000 Duration: 120.0 s From the begining of this manoeuvre, the LOX valves are opened between 0. to the end	PHASE NUMBER 14 
Phase n° 15 Spin up to 45.0 °/s Duration: 70.0 s From the begining of this manoeuvre, the LOX valves are opened between 0. to the end	PHASE NUMBER 15 
Phase n° 16 Pre-passivation phase during which the roll LH2 thrusters are kept open, to reduce pressure inside the LH2 tank, before the end of the sequence. The SCAR algorithm is switched off s after INSAT-3D separation ($H_{4.3}$), which also ends this manoeuvre. From the begining of this manoeuvre, the LOX valves are opened between 0. to the end	PHASE NUMBER 16 

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



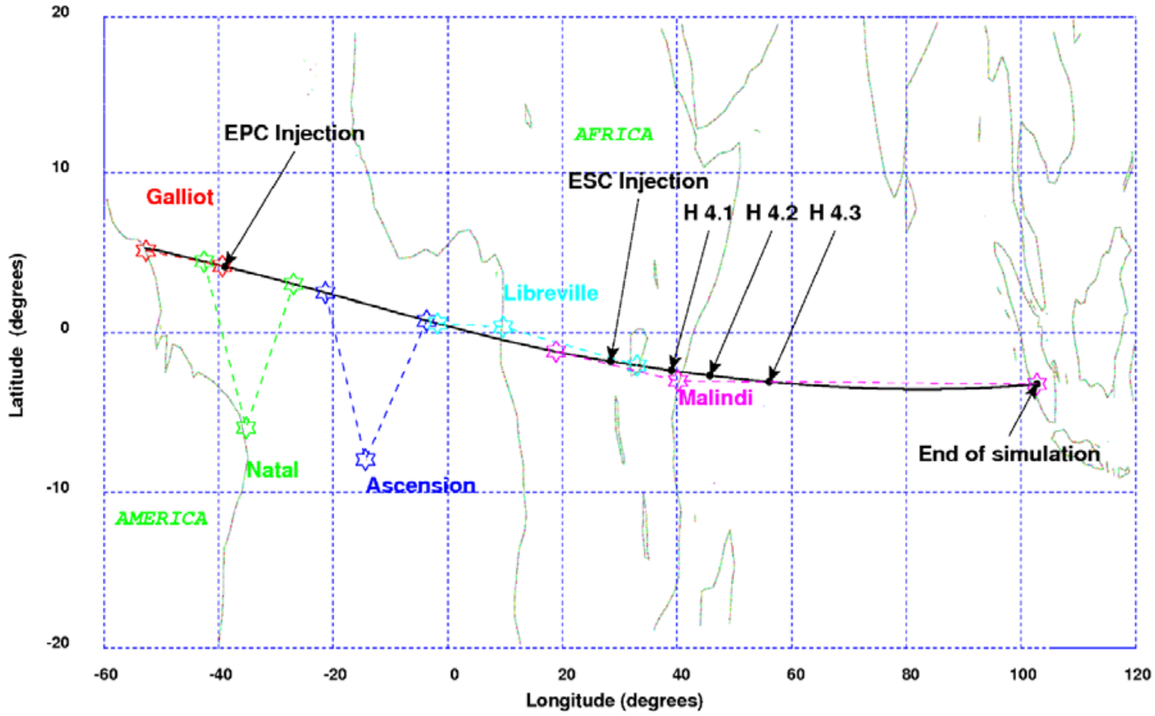
The launcher will be under **telemetry monitoring** by tracking stations in Kourou, Galliot, Natal, Ascension Island, Libreville and Malindi throughout the mission.

With the performance necessary for this mission, the trajectory includes two periods of visibility loss: between Natal and Ascension (~**85** s.) and between Ascension and Libreville (~**26** s.):

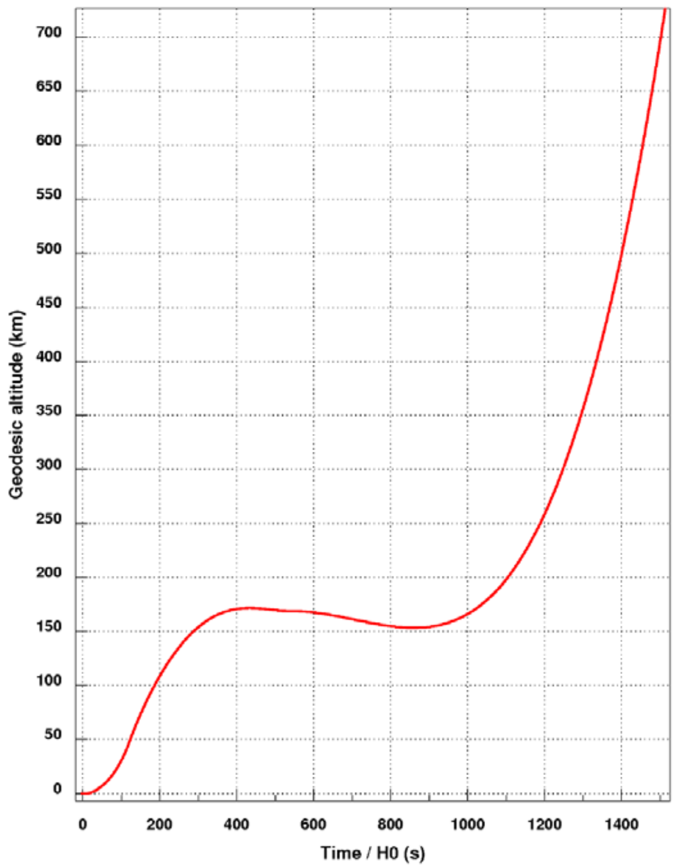


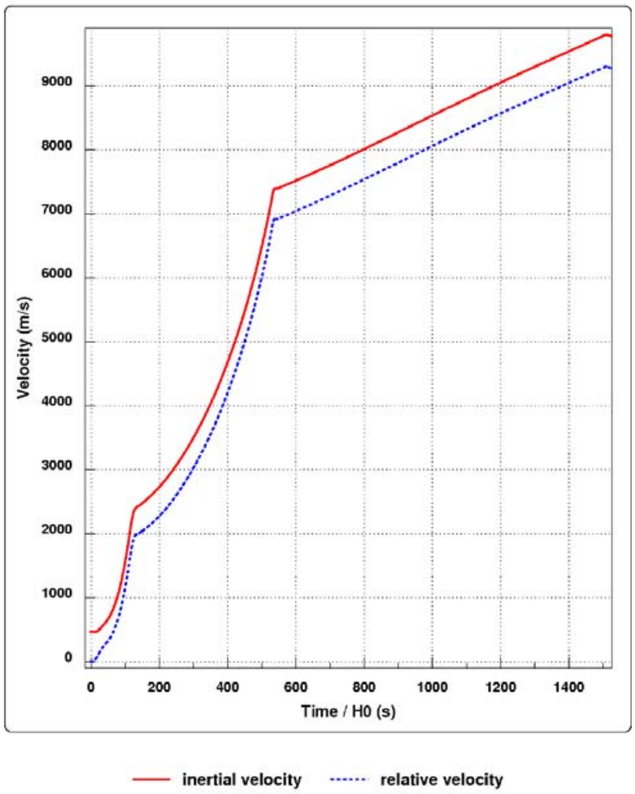
The following plates show:

- Situation of the main events of the flight,



- Evolution of launcher altitude during powered flight.

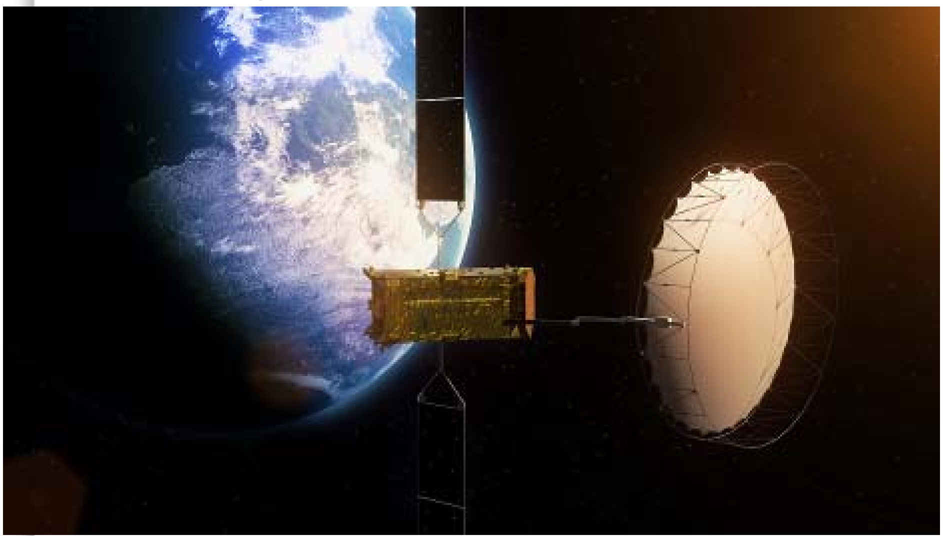




4. Payloads

INMARSAT

INMARSAT (***IN**ternational **MAR**itime **SAT**ellite organization*) is a British telecommunications company. **INMARSAT** was originally an international organisation founded in 1979, with the aim of establishing satellite communications for the entire maritime community. It was privatised in April 1999.



ALPHASAT in orbit
[Artist's impression]
© ASTRIUM - ESA

INMARSAT today operates 37 ground stations and a three-generation fleet of 11 satellites, providing telephony, data, telex and fax functions. The latest generation, comprising 3 **INMARSAT IV** satellites launched between 2005 and 2008, should be operational until 2023.

On its **BGAN** (**B**roadband **G**lobal **A**rea **N**etwork) **INMARSAT** is currently developing a wide range of broadband applications intended for the mobile terminals of terrestrial, aeronautical and maritime users.

The **INMARSAT V** generation should be launched in about 2014.

ALPHASAT

ALPHASAT is the first satellite to use the high capacity of the new **ALPHABUS** platform. **ALPHABUS** is the most powerful platform on the market and is Europe's response to increased demand for large communication payloads, able to provide better and faster services for direct TV broadcasting, digital radio broadcasting, access to broadband and to mobiles. The **ALPHASAT** programme is resolutely European and is a real benchmark in terms of cooperation: the satellite was designed and built under a public-private partnership (PPP) between **INMARSAT** and **ESA**, through an industrial contract concluded between **INMARSAT** and Astrium. Many partners from across Europe contributed to the programme, supported by **ESA** and the national space agencies.

ALPHABUS was co-developed by the main partner, **ASTRIUM** and **Thales Alenia Space (TAS)**, with a vast team of industrial collaborators present throughout Europe.

The satellite

Designed and built by **ASTRIUM**, **ALPHASAT** embodies three outstanding achievements in one single programme. Not only does it comprise in excess of 200 spot beams, with digital beam forming capability, but it marks the first flight of Europe's new high capacity satellite platform **ALPHABUS** and is also equipped with four technology demonstrator hosted payloads for the European Space Agency (**ESA**).

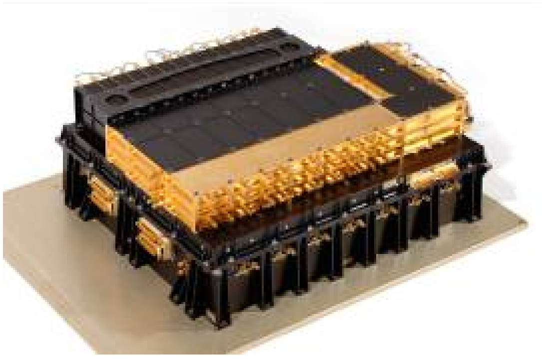
Indeed, it is the number of spot beams and the digital beam forming capability which denote Alphasat's high level of technological refinement. The payload makes best use of the limited spectrum available in L-band to efficiently manage numerous communications with maximum flexibility in both frequency and beam power allocation according to users' throughput requirements. The eight integrated processors (IP), developed by Astrium, are the key elements of this payload.

The new, high capacity **ALPHABUS** platform being flown for the first time on **ALPHASAT** is the most powerful platform on the market. It is capable of conducting missions with a satellite launch mass of up to **8800 kg**, a payload power of up to **22 kW** and a payload mass up to **2000 kg**.

The **ASTRIUM**-built **ALPHASAT** satellite and payload incorporate an impressive number of innovations developed here in Europe.

ASTRIUM's eight advanced digital integrated processors are a core element of the leading-edge geomobile L-band communications payload, allowing allocation of capacity with an unprecedented flexibility through digital channelization and beamforming.

The Integrated Processor (IP) developed for the **ALPHASAT** mobile mission is the latest evolution of Astrium's Digital Signal Processors product line. It is based on **ASTRIUM** Next Generation Processor modular technology, which can be applied for other applications such as broadband and military missions.

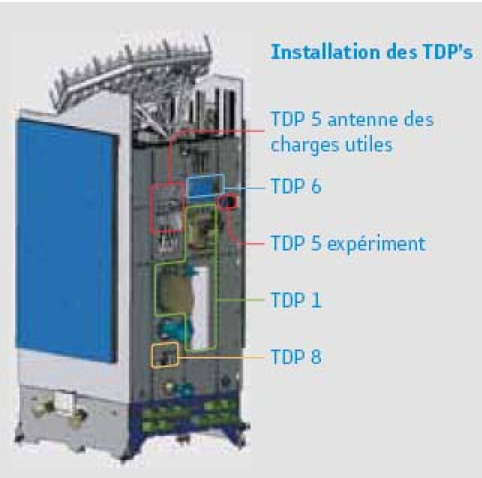


The primary function of **ALPHASAT**'s IPs is the routing and combining of channels to the desired beam. They are the key elements for the generation of spot beams and associated channel gain. This provides **ALPHASAT** with maximum flexibility in both frequency and power allocation to beams to meet traffic demands.

The eight large processors weigh around 250kg and use the latest electronics technology to work in parallel on board **ALPHASAT**, providing Alphasat with a processing capacity which is unprecedented on board a commercial satellite: it can perform more than 10 trillion calculations per second.

These new technologies will enable **ALPHASAT** to manage communications across Europe, Africa and the Middle East with ease and deliver extra capacity – Alphasat is capable of handling over 750 L-band channels with enhanced quality, which is especially beneficial for satellite telephone users. As a result of more efficient utilization of the spectrum, the satellite will guarantee communications in areas with no terrestrial infrastructure, in particular in crises and humanitarian emergencies. This will enable governmental authorities to maintain contact with scattered populations, and secure voice-data transmission of crucial importance for sectors such as the press, marine transport, and the oil and gas industry, to name but a few.

Technological demonstration payloads

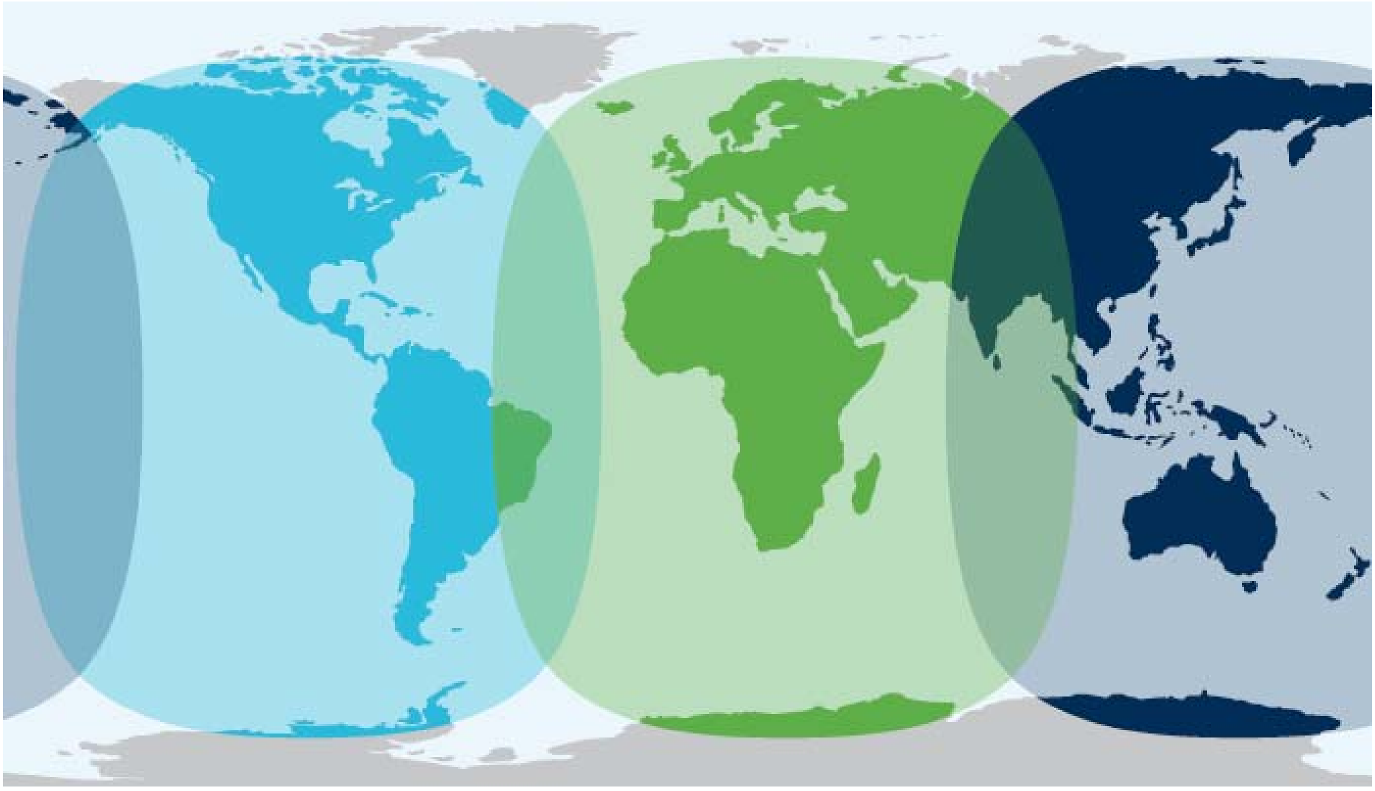


ESA decided to choose four **T**echnological **D**emonstration **P**ayloads, carried on **ALPHASAT**, after a number of studies and a series of preliminary installation activities:

- A sophisticated laser telecommunications terminal, for demonstrating GEO/LEO telecommunication links at 1064 nm (TDP 1)
- A Q/V band telecommunications experiment designed to assess the compatibility of this frequency band with future commercial applications (TDP 5)
- A advanced technology star-tracker equipped with active pixel sensors (TDP 6)
- An environment sensor for monitoring the GEO radiation environment and its effects on the electronic components and the sensors (TDP 8)

ALPHASAT is the 8th **INMARSAT** satellite entrusted to Arianespace and has the following main characteristics:

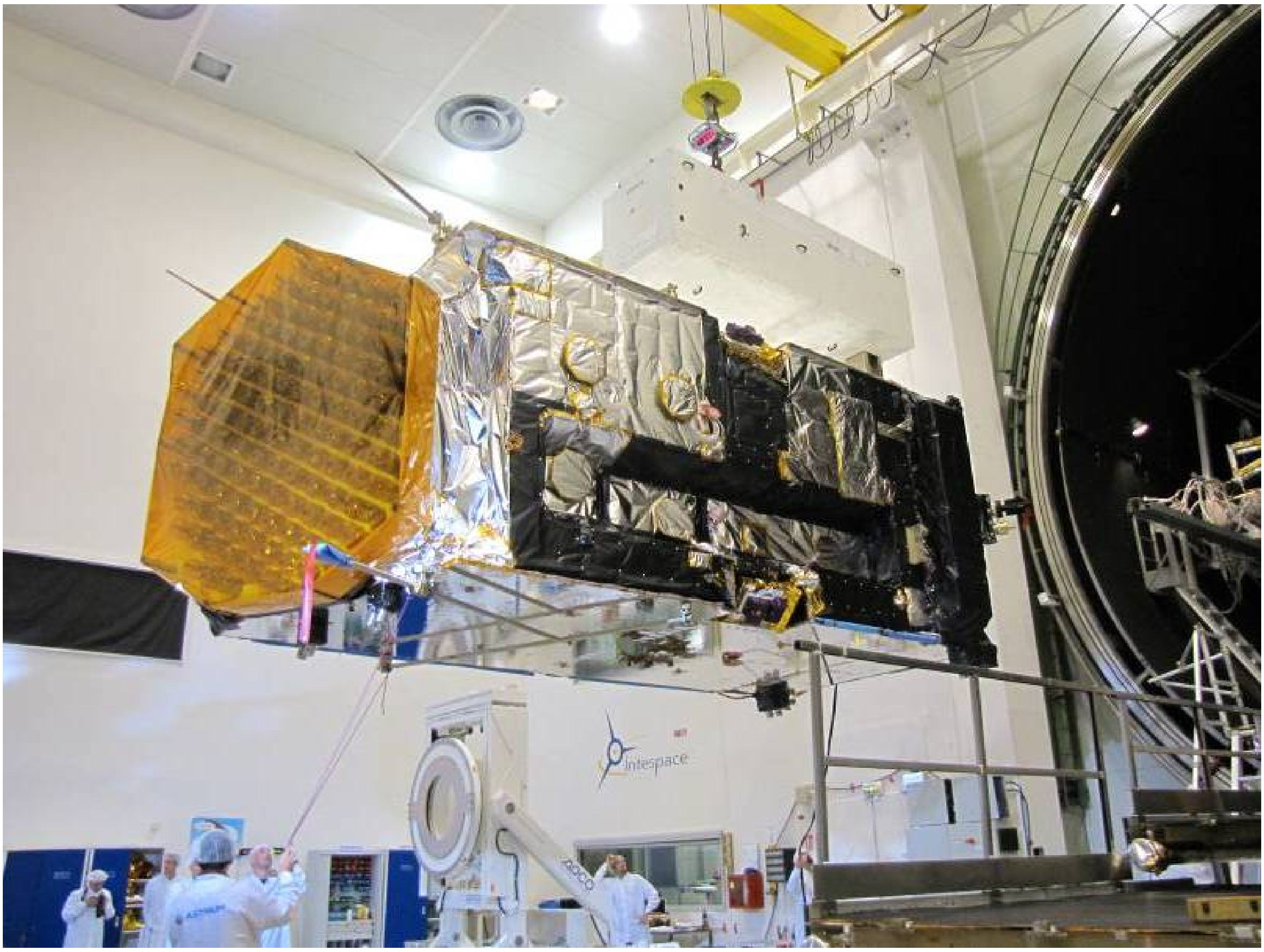
* Dimensions	• 7.15 x 4.30 x 3.10 m • In-orbit span 40 m
* Mass	• Lift-off 6648.7 kg
* Power	• Payload power: > 12 kW • 1 Li-Ion battery
* Propulsion	• Biliquid propellant tanks (MMH & NTO) • Apogee kick motor 400 N and 10 N nozzles for orbit control
* Stabilisation	• Transverse spin-up at separation • Triple-axis stabilisation in orbit
* Transmission capacity	• L & C band mobile communications • 750 L-band channels • 400 Narrow spots
* Orbit Position	• 25° East
* Coverage	• Europe, Africa and Middle East / Asia
Expected lifetime exceeds 15 years	



Global coverage of the INMARSAT IV network inmarsat

ASTRIUM
AN EADS COMPANY

ALPHASAT
after anechoic chamber testing



ALPHASAT
entering the vacuum chamber
.© ASTRIUM

INSAT-3D

I.S.R.O.

Indian Space program began with the objective to develop an independent space technology and its application to various national tasks. Accordingly, **I.S.R.O.** (**I**ndian **S**pace **R**esearch **O**rganisation) has successfully operationalized:

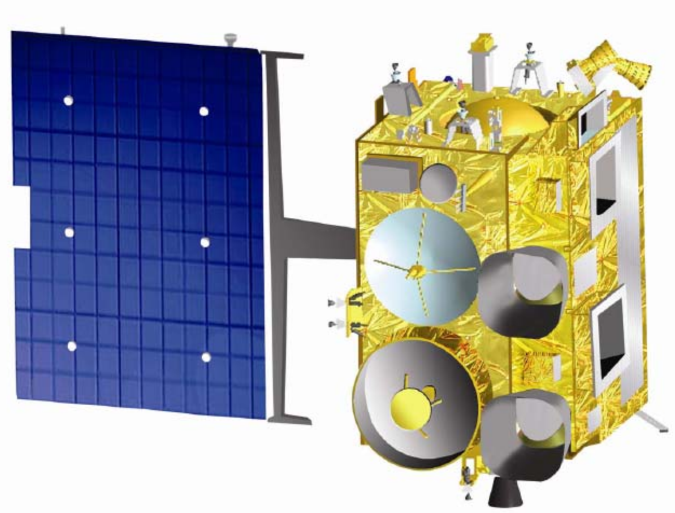
- Two major satellite systems namely:
  - **INSAT** (**I**ndian **N**ational **SAT**ellites) for communication services
  - **IRS** (**I**ndian **R**emote **S**ensing) satellites for management of natural resources

- Two launcher families:
  - **PSLV** (**P**olar **S**atellite **L**aunch **V**ehicle) for launching IRS type of satellites
  - **GSLV** (**G**eostationary **S**atellite **L**aunch **V**ehicle) for launching INSAT type of satellites

I.S.R.O. currently has a constellation of 9 communication satellites, 1 navigation satellite, 1 meteorological satellite, 11 Earth observation satellites and 1 scientific satellite.

So far **I.S.R.O.** has completed a number of projects (66 spacecraft and 38 launches, carrying 35 foreign payloads). ISRO has also launched 4 student satellites and 35 foreign satellites.

INSAT-3D



INSAT-3D
(Artist's impression)
.© I.S.R.O.

INSAT-3D is a very high-tech meteorological satellite designed, built and integrated by **I.S.R.O.** and intended eventually to replace the **KALPANA-1** and **INSAT-3A** satellites, launched 10 years ago on an Ariane 5 (L514, V160 with **GALAXY XII**).

Equipped with 6 "Imager" channels and 19 "Sounder" channels, it will provide a range of ground, sea, cloud, wind and atmospheric data, plus data on the energy exchanges between these various environments.

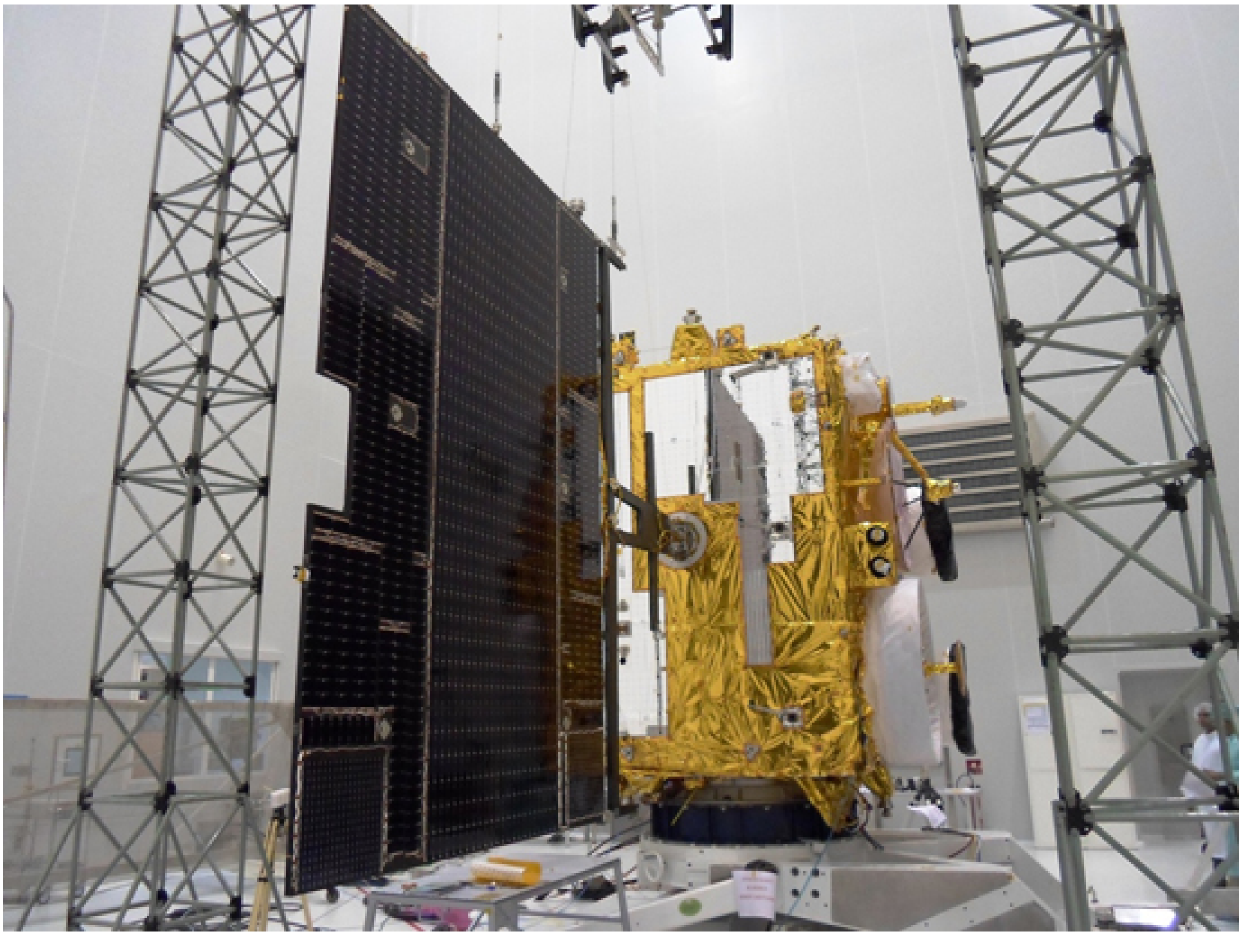
The satellite is also equipped with repeaters for data transmission and a natural disaster search and rescue payload.

भारत INDIA

इन्सैट-3डी INSAT-3D

INSAT-3D, based on the **I-2K bus** platform, is the 16th satellite entrusted by **I.S.R.O.** to **Arianespace**, and its main characteristics are as follows:

* Dimensions	• 2.40 x 1.65 x 1.55 m
* Mass	• Lift-off 2061 kg
* Power	• Payload power: > 1200 W • 2 Ni-Cd batteries
* Propulsion	• Biliquid propellant tanks (MMH & MON3)
* Stabilisation	• Transverse spin-up at separation • Triple-axis stabilisation in orbit
* Transmission capacity	• 6 imagers • 19 sounders • **D**ata **R**elay **T**ransponder & **S**atellite-**A**ided **S**earch and **R**escue
* Orbit Position	• 82° East
* Coverage	• Indian subcontinent
Expected lifetime exceeds 7 years	



INSAT-3D in Kourou
during solar panel deployment testing
.© I.S.R.O.

भारत INDIA

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इन्सैट-3डी

INSAT-3D

INSAT-3D
during tests in Bangalore
.© I.S.R.O.

INSAT-3D on its PAS 937S

5. Launch campaign

ESC-A undergoing integration at ASTRIUM Bremen
© EADS ST

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 214 launch campaign:

EPC depreservation and erection in the launcher integration building (BIL)	April 24 & 25, 2013
Transfer of Solid Booster Stages (EAP)	April 25 & 26, 2013
Mating of the EAPs with the EPC	April 26, 2013
Depreservation and erection of the Upper Composite	May 13, 2013
Launcher Synthesis Control	May 28, 2013
Launcher acceptance by Arianespace	June 3, 2013
VA213 - L592: Success of the **ATV # 4 Albert EINSTEIN** mission	June 5, 2013
Arrival of **INSAT-3D** in Kourou	June 11, 2013
Arrival of **ALPHASAT** in Kourou	June 18, 2013
Transfer from BIL to BAF	June 26, 2013
ALPHASAT fuelling Assembly on its adaptor Transfer to the BAF Integration on the SYLDA	July 5 to 8, 2013 July 11, 2013 July 11, 2013 July 12, 2013
INSAT-3D fuelling Assembly on its adaptor Transfer to the BAF Integration on the launcher	July 5 to 9, 2013 July 12, 2013 July 15, 2013 July 16, 2013
Integration of the fairing on the SYLDA	July 15, 2013
Integration of the composite (**ALPHASAT** + PAS 1666S + SYLDA + fairing) on the launcher	July 17 & 18, 2013
General rehearsal	July 19, 2013
Arming of the launcher Flight Readiness Review	July 22 & 23, 2013 July 23, 2013
Launcher transfer from the BAF to the Pad (ZL3) Fuelling of the EPC helium sphere	July 24, 2013
Final countdown	July 25, 2013

Kourou: transfer of the launcher from the Launcher Integration Building (BIL) to the Final Assembly Building (BAF)

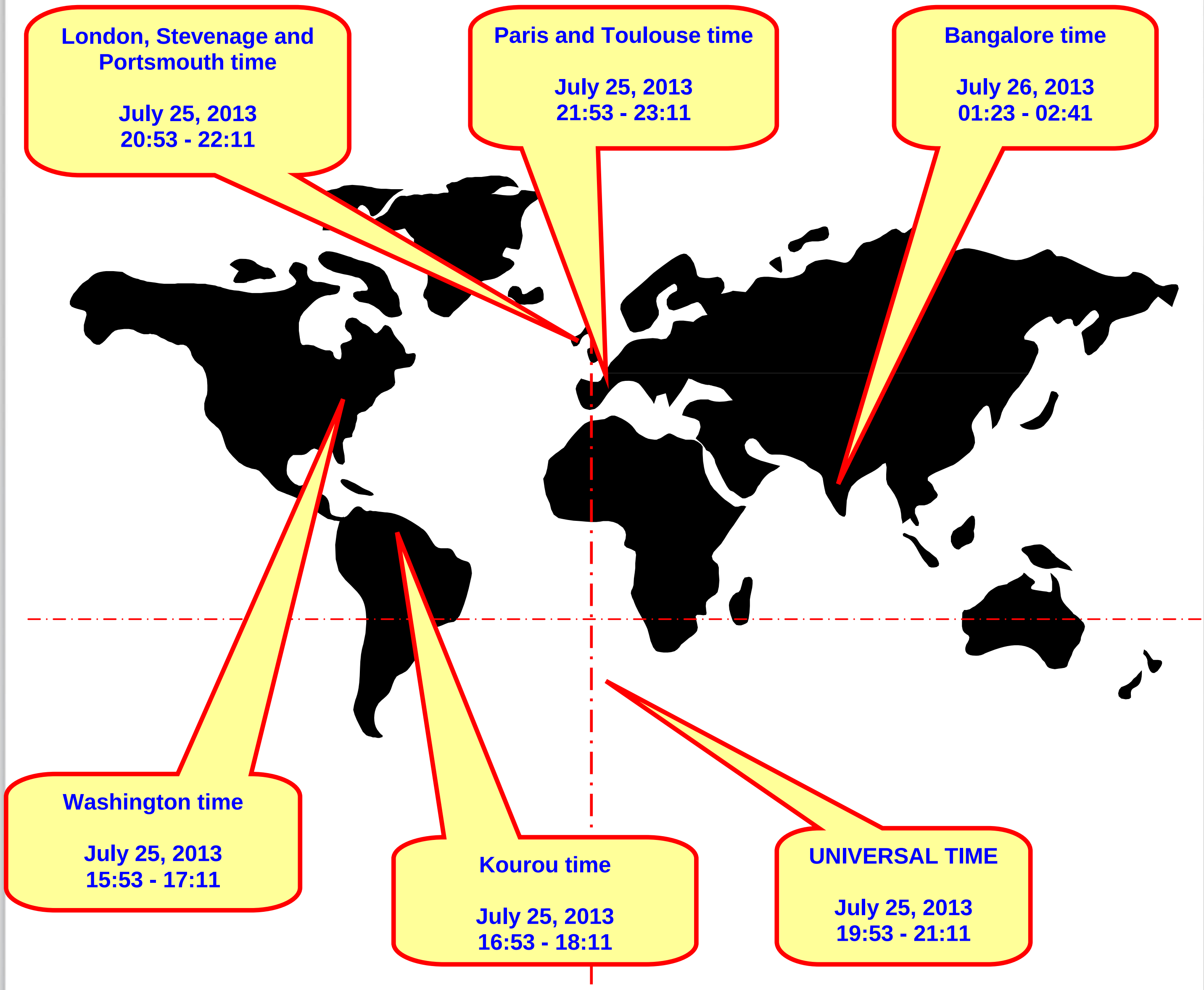
Kourou: erection of the Upper Composite in the Launcher Integration Building (BIL)
© ESA/ARIANESPACE/Service optique CSG

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 **July 25, 2013** is with **H_0** at **19:53 (UT).** The closing of the window is at **21:11 (UT).**

The launch window will last **1 hour and 18 minutes**:



The launch window for this mission is dictated principally by launcher and payloads constraints.

In the event of a launch postponement, the window remains unchanged July on 26, 27 and 28. As of July 29, it changes as follows:
- from 19:55 to 21:11, from July 29 to August 1st,
- from 19:55 to 21:10, from August 2nd,
- from 19:57 to 21:10, from August 3rd to 7.

7. 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 H_0 - 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 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.

H_0 - 7 hours 30	**Checkout** of electrical systems. **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. **Loading of the flight program** **Testing of radio links** between the launcher and BLA **Alignment of inertial guidance units**
H_0 - 5 hours	**Evacuation of personnel from the launch pad** **Fuelling of the EPC** in four phases: pressurisation 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 synchronised sequence)
H_0 - 5 hours	**Pressurisation of the attitude control and command systems:** (GAT for the EAPs and GAM for the EPC)
H_0 - 4 hours	**Fuelling of the ESC-A** stage in four phases: pressurisation 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 synchronised sequence)
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 (*)**

(*) The standard synchronised sequence will start at H_0 - 7 minutes, incorporating all final launcher operations leading to lift-off. By comparison, the stretched synchronised sequence for flight 173 commenced at H_0 - 12 minutes, to cater for top-up LOX fuelling of the EPC stage to meet mission performance requirements.

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 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 pressurisation 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 40s: termination of ESC-A LH2 topping up	**H_0 - 3 min 30s:** Calculation of ground H_0 and verification that the second OBC has switched to the observer mode
H_0 - 3 min 10s: ESC-A LH_2 transition to flight pressure	**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 - 2 min: Vulcain 2 bleeder valves opened Engine ground chill-down valve closed	**H_0 - 1 min 50s** Pre-deflection of the HM7B nozzle
H_0 - 1 min 5s Termination of ESC-A tank pressurisation from the ground, and start of ESC-A valve plate seal-tightness checkout	**H_0 - 1 min 5s** Launcher electrical power supply switched from ground to OB
	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 - 30s Verification of ground/OB umbilical circuit flushing EPC flue flood valves opened	**H_0 - 22s** Activation of launcher lower stage attitude control systems Authorisation for switchover to OBC control
H_0 - 16.5 s Pressurisation of POGO corrector system Ventilation of fairing POP and VEB POE connectors and EPC shut down	
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 pressurisation 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 (t)	Vreal (m/s)
- - - -		**EAP-EPC powered flight**			- - -
7.30	0 ' 07 ''	Lift-off	---	774.1	0
12.62	0 ' 13 ''	Start of tilt manoeuvre	0.09	746.4	36.6
17.05	0 ' 17 ''	Start of roll manoeuvre	0.33	722.4	73.9
22.6	0 ' 23 ''	*End of tilt manoeuvre*	0.90	694.0	124.1
32.05	0 ' 32 ''	End of roll manoeuvre	2.45	644.0	211.6
49.0	0 ' 49 ''	Transsonic (Mach = 1)	6.73	576.9	321.4
68.6	1 ' 09 ''	Speed at Pdyn max	13.6	497.8	522.0
112.3	1 ' 52 ''	Transition to γ_{max} (41.49 m/s^2)	39.9	306.8	1570
142.1	2 ' 22 ''	Transition to γ = 6.22 m/s² H_1	66.7	251.7	2013
142.9	**2 ' 23 ''**	**EAP separation**	**67.4**	**177.0**	**2014**
- - - -		**EPC powered flight**			- - - -
197.5	3 ' 18 ''	Fairing jettisoned	107.2	156.8	2263
335	*5 ' 35 ''*	*Intermediate point*	*162.6*	*112.5*	*3388*
465	*7 ' 45 ''*	*Acquisition Natal*	*171.1*	*70.2*	*5282*
533.7	8 ' 54 ''	EPC burnout (H_2) *Lost Galliot*	168.9	47.7	6891
539.7	**9 ' 00 ''**	**EPC separation**	**168.9**	**28.9**	**6917**
- - - -		**ESC-A powered flight**			- - - -
543.7	9 ' 04 ''	ESC-A ignition	168.9	28.9	6919
725	*12 ' 05 ''*	*Lost Natal*	*159.5*	*26.4*	*7346*
815	*13 ' 35 ''*	*Acquisition Ascension*	*154.3*	*25.1*	*7576*
860	*14 ' 20 ''*	*Minimum altitude*	*153.5*	*24.4*	*7694*
1070	*17 ' 50 ''*	*Lost Ascension*	*185.8*	*21.3*	*8243*
1100	*18 ' 20 ''*	*Acquisition Libreville*	*198.0*	*20.9*	*8319*
1235	*20 ' 35 ''*	*Intermediate point*	*288.1*	*18.9*	*8655*
1370	*22 ' 50 ''*	*Acquisition Malindi*	*451.0*	*16.9*	*8976*
1501	25 ' 01 ''	**ESC-A burnout (H_{3-1})**	701.5	14.7	9313

time /H_0 (s)	time/H_0 (mn)		event	altitude (km)
- - - -			"Ballistic" phase	- - -
1506	25 ' 06 "	Phase 3	Start of **ALPHASAT** orientation	712
1638	27 ' 18 "	Phase 4	Start of **ALPHASAT s**low spin-up	1055
1659	**27 ' 39 "**		**ALPHASAT separation ($H_{4.1}$)**	**1116**
1668	27 ' 48 "	Phase 6	Upper composite despin	1145
1673	27 ' 53 "	Phases 7	SYLDA staging to orientation phases	1157
1768	**29 ' 28 "**		**SYLDA 5 separation ($H_{4.2}$)**	**1460**
1778	29 ' 38 "	Phase 9 & 10	Start of **INSAT-3D** orientation	1493
1961	**32 ' 41 "**		**INSAT-3D separation ($H_{4.3}$)**	**2151**
1971	32 ' 51 "	Phase 12	Staging phases orientation	2190
2061	34 ' 21 "	Phase 13	ESC-A staging phases	2542
2226	37 ' 06 "	Phase 14	ESC-A orientation for the final spin-up	3208
2346	39 ' 06 "	Phase 15	Start of spin-up at 45°/s	3712
2413	40 ' 13 "	Phase 20	Oxygen tank passivation (breakdown S34)	3997
2688	44 ' 48 "		ESC-A passivation (breakdown S37)	5167

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

Launcher L592 take-off, ATV# 4 mission, June 5, 2013

9. ASTRIUM and the ARIANE programmes

Astrium Space Transportation, a Division of **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 is a global leader in aerospace, defence and related services. In 2011, the Group generated revenues of € 49.1 billion and employed a workforce of about 133,000.

Astrium is the number one company in Europe for space technologies and a wholly owned subsidiary of **EADS**, dedicated to providing civil and defence space systems and services. In 2011, Astrium had a turnover of €5 billion and more than 18,000 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, **Astrium Satellites** for spacecraft and ground segment, and **Astrium Services** for comprehensive end-to-end solutions covering secure and commercial satcoms and networks, high security satellite communications equipment, bespoke geo-information and navigation services worldwide.

Astrium has acquired extensive expertise, unrivalled 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.

Further to the failure of launcher L517 in December 2002, the ministerial level conference organised by the **European Space Agency** on May 27, 2003 decided to appoint an industrial prime contractor to manage firstly Ariane 5 production activities and, secondly, development activities. Over and beyond the management requirement to master the chain of responsibilities for the entire Ariane 5 design and production cycle, the set economic target was to significantly reduce costs with respect to the modes of functioning in effect at the time.
The PA production batch contract was signed in 2004 with these objectives, and **Astrium ST**, through an innovative industrial approach in the Ariane launchers' European environment and by adapting the management processes, successfully led launcher production as from the launching of unit L527 on March 11, 2006. The launch rate increased from 4 to 7 launchers per year while controlling costs and improving the quality of the product delivered to **Arianespace**.

The PB production batch contract was drawn up on the basis of this new management reference, while making maximum use of the experience acquired with the PA batch.

Astrium ST 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 **Astrium** developed the launcher's electrical system and software, and its guidance-attitude control and navigation system.


Bordeaux 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 (SYstème de Lancement Double Ariane 5), a carrier structure allowing dual satellite launches, which is integrated on the Les Mureaux site and adapted to the particularities of the customers' payloads,

- o the flight program tested at Les Mureaux, the data of which result from the mission analysis process also conducted by **Astrium ST**.

Astrium ST 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.

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 data analysis after each launch.

ASTRIUM web site : www.astrium.eads.net

ARIANESPACE web site : www.arianespace.com