Satellites
Space Transportation
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KOUROU

May 2012

ARIANE 5

Data relating to Flight 206 by Pierre LEROUX

ARIANE 5 PRIME CONTRACTORSHIP AND INTEGRATOR

JCSAT-13

SKY Perfect JSAT Corporation

Hope for Japan

VINASAT-2

VNPT

VINASAT-2

100th/101st Lockheed Martin Commercial GEO Satellite

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ASTRIUM
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Flight 206 Ariane 5
Satellites: JCSAT-13 – VINASAT-2

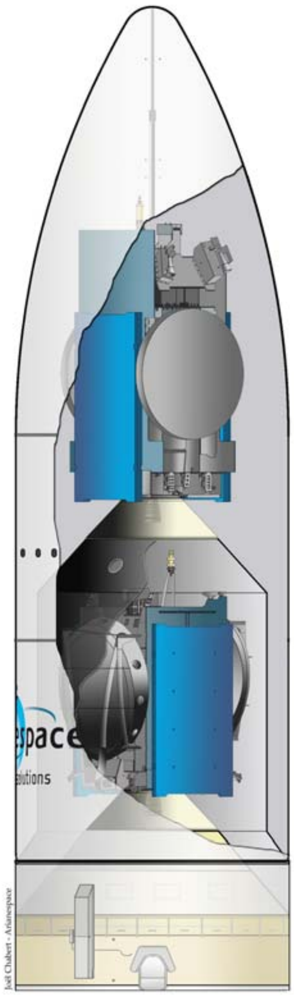
Content

1. Introduction

Flight 206 is the 62nd **Ariane 5 launch** and the second in 2012. 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 206 is a commercial mission for Ariane 5. The L562 launcher is the sixth 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. L562 is consequently the thirty-sixth 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 "A"** system and a long pattern fairing (total height: 17 m), the launcher is the communications satellites **JCSAT-13** in the upper position and **VINASAT-2** in the lower position.



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

JCSAT-13 built by: **Lockheed Martin**

Strapped to a type **PAS 1194C** adaptor built by: **EADS-CASA**

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

VINASAT-2 built by: **Lockheed Martin**

Strapped to a type **PAS 1194C** adaptor 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 L562

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 **534 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 **201 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 Σ = 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 **138 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*).

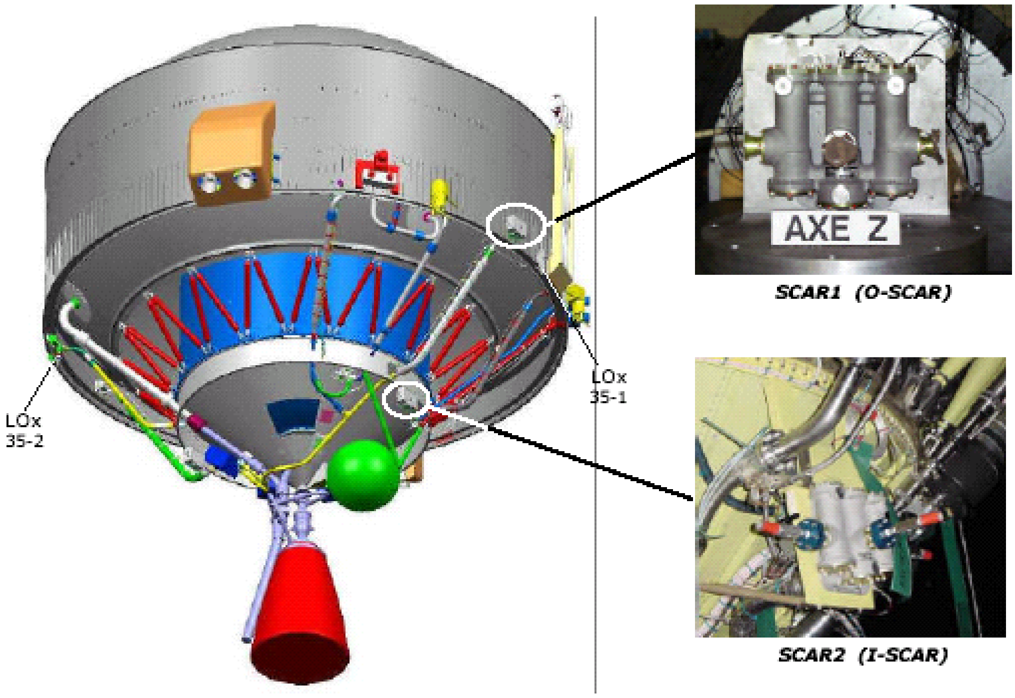
Type-A cryogenic upper stage:

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 **955 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 ninth 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 L562 was assembled for the twenty-second 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.

The 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 'A'** with a **height of 6.4 m** will be used. It enables the carriage of a payload in the lower position, **VINASAT-2**. For the first time on this flight, the structure was manufactured using a new "co-curing" method, enabling the industrial process to be rationalised.

Sylda 5 No. 49-A for launcher L562 at Les Mureaux
© ASTRIUM ST

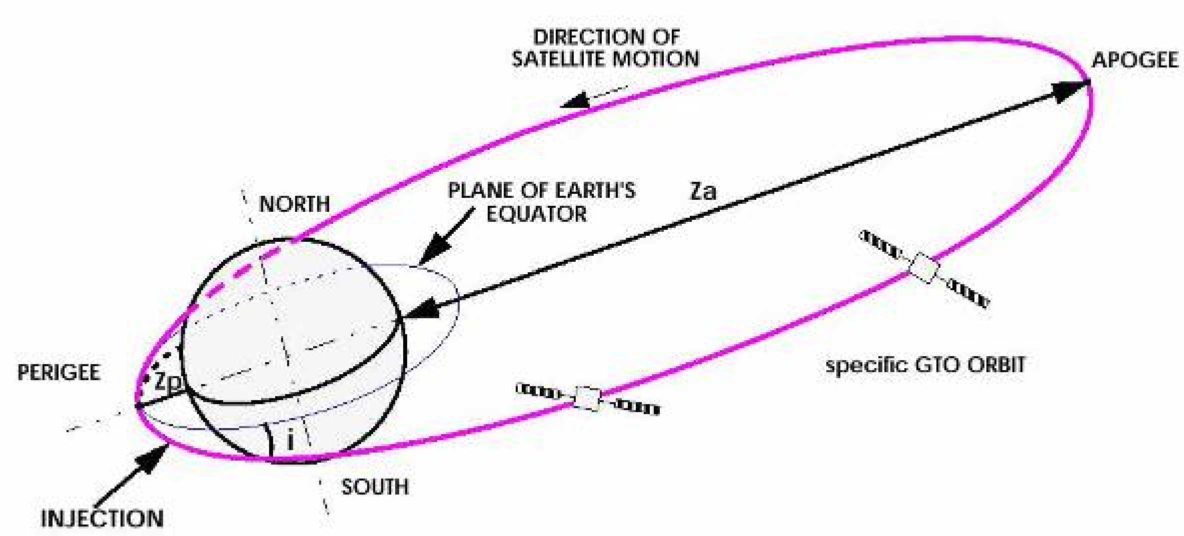
3. Mission V206

Payload mission

The main mission of Flight 206 is to place the **JCSAT-13** and **VINASAT-2** commercial payloads into nearly standard GTO orbit:

Apogee altitude	35,756 km
Perigee altitude	250 km
Inclination	2.0°
Perigee argument	178°
Ascending node longitude	-122.89°(*)

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



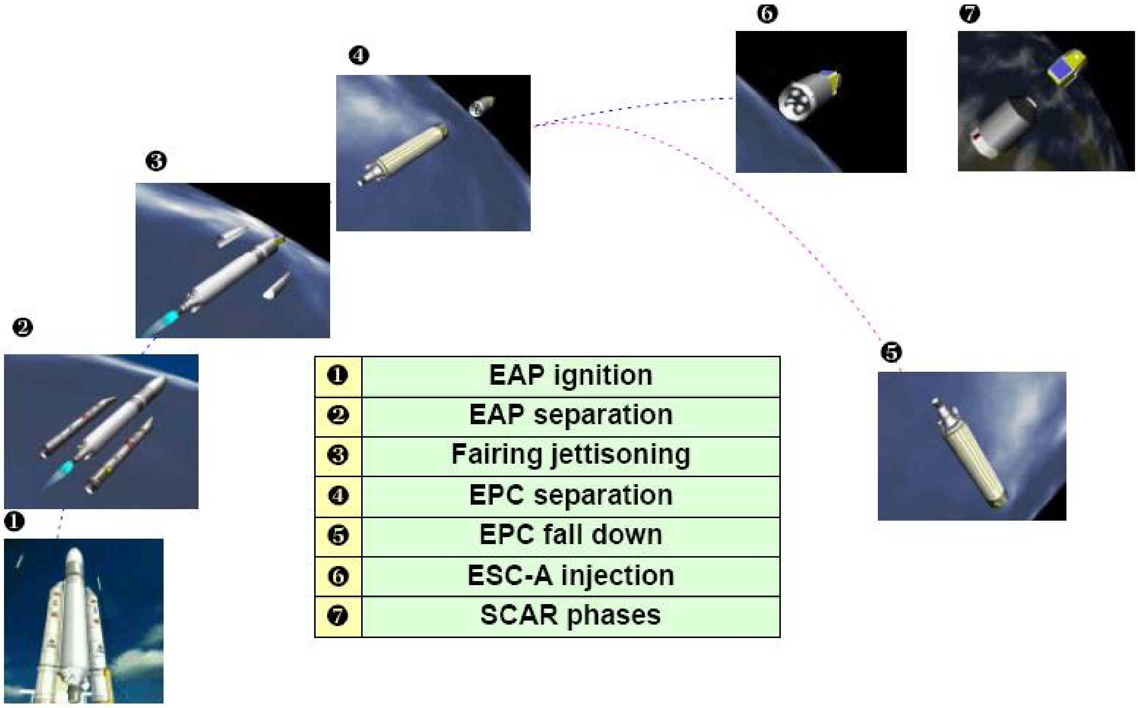
The mass of **JCSAT-13** is **4,528 kg**, with **2,964 kg** for **VINASAT-2**.

Allowing for the adaptors and the **SYLDA 5** structure, total performance required from the launcher for the orbit described above is **8,300 kg**.

It should be remembered that the maximum performance offered by the Ariane 5 ESC-A launcher is about 10,000 kg (performance achieved with the latest launch V201 on 22nd April, with launcher L558) for a standard orbit inclined at 6°.

This also demonstrates the launcher's adaptability in terms of payload mass. Part of the performance margin is used to reduce the inclination of the target orbit.

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 authorises ignition of the two solid propellant boosters (EAP) at **H_0** + 7.05 s, leading to launcher lift-off.

Lift-off mass is about 773 tons, and initial thrust 13,000 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 **82**° 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 + 144 s*** *at an altitude of* ***70 km*** *and a relative velocity of* ***2,001 m/s****.*

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

The **fairing** is jettisoned during the EPC flight phase as soon as aerothermodynamic flux levels are sufficiently low not to impact the payload. For this mission, separation of the payload will occur about **191 s** after lift-off at an altitude of **107 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	201.0 km
Perigee altitude	-1,146.0 km
Inclination	7.31°
Perigee argument	-40.6°
Ascending node longitude	-123.7°

This is time reference **H_2**. It happens at **H_0 + 533.8 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 **-3.36°**. The longitude of the point of impact is **4.1°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.

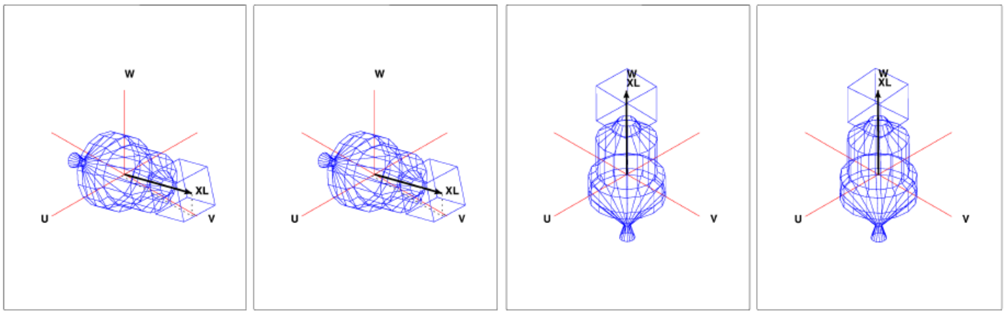
This is time reference ***H_3****. It happens at* ***H_0 + 1,499.0 s****.*

The purpose of the following ballistic phase is to ensure:

- Pointing of the upper composite in the direction required by **JCSAT-13** and **VINASAT-2** and then in that required for **SYLDA 5**,
- Composite slow spin-up before separation of **JCSAT-13**,
- Triple-axis stabilisation before separation of **SYLDA 5**,
- Composite slow spin-up before separation of **VINASAT-2,**
- Separation of **JCSAT-13**, **SYLDA 5** and **VINASAT-2**,
- 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.

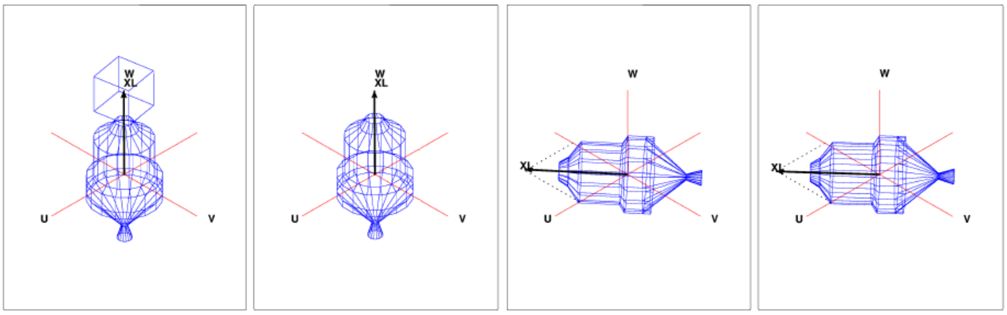
The ballistic phase for the mission comprises 22 elementary phases described hereafter. These include separation of **JCSAT-13** (phase 5), **SYLDA 5** separation (phase 11), and **VINASAT-2** separation (phase 14).

PHASE NUMBER 1	PHASE NUMBER 2	PHASE NUMBER 3	PHASE NUMBER 4
TRANS. VELOCITY CONTROL	SPIN DOWN	ORIENTATION	SLOW SPIN TO 0.6 ° /S
DURATION = 2.000 S	DURATION = 0.576 S	DURATION = 80.000 S	DURATION = 10.000 S



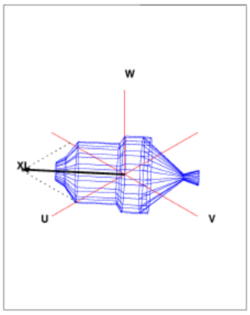
LOX CLOSED	LOX CLOSED	LOX CLOSED DURING 50. S THEN OPENED DURING 25. S THEN CLOSED AGAIN	LOX CLOSED

PHASE NUMBER 5	PHASE NUMBER 6	PHASE NUMBER 7	PHASE NUMBER 8
SEPARATION	SPIN DOWN	ORIENTATION	ORIENTATION
DURATION = 10.000 S	DURATION = 3.000 S	DURATION = 80.000 S	DURATION = 160.000 S



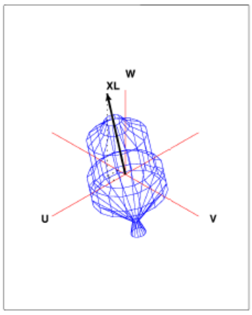
LOX CLOSED	LOX CLOSED	LOX CLOSED DURING 50. S AND OPENED AFTER	LOX OPENED

PHASE NUMBER 9
ORIENTATION
DURATION = 160.000 S



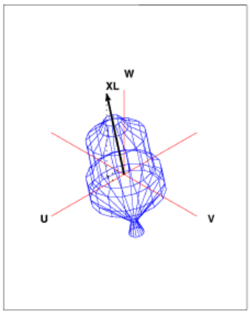
LOX OPENED

PHASE NUMBER 10
ORIENTATION
DURATION = 90.000 S



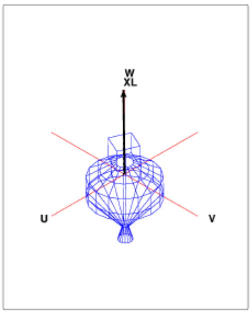
LOX CLOSED

PHASE NUMBER 11
SEPARATION
DURATION = 10.000 S



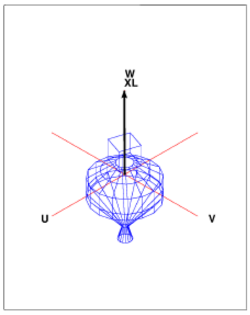
LOX CLOSED

PHASE NUMBER 12
ORIENTATION
DURATION = 40.000 S



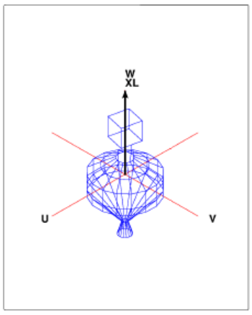
LOX CLOSED

PHASE NUMBER 13
SLOW SPIN TO 0.6 ° /S
DURATION = 10.000 S



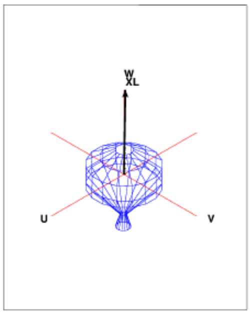
LOX CLOSED

PHASE NUMBER 14
SEPARATION
DURATION = 10.000 S



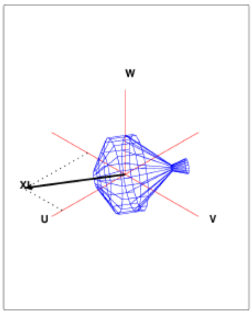
LOX CLOSED

PHASE NUMBER 15
SPIN DOWN
DURATION = 3.000 S



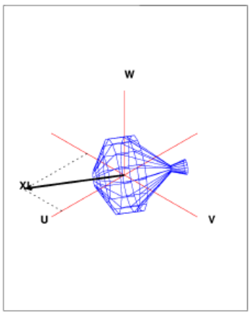
LOX CLOSED

PHASE NUMBER 16
ORIENTATION
DURATION = 70.000 S



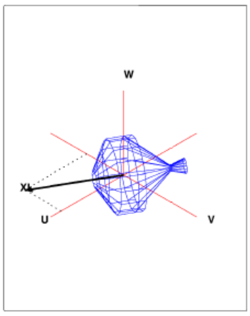
LOX CLOSED DURING 30. S
AND OPENED AFTER

PHASE NUMBER 17
ORIENTATION
DURATION = 120.000 S



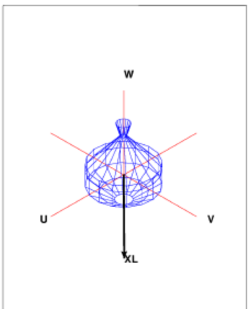
LOX OPENED

PHASE NUMBER 18
ORIENTATION
DURATION = 120.000 S



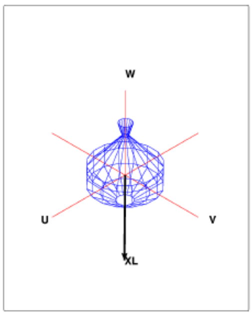
LOX OPENED

PHASE NUMBER 19
ORIENTATION
DURATION = 70.000 S



LOX OPENED

PHASE NUMBER 20
SPIN UP TO 45.0 ° /S
WITH NUTATION CONTROL
DURATION = 110.000 S

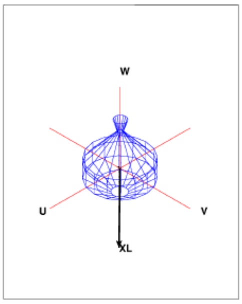


LOX CLOSED

PHASE NUMBER 21

LH2 PRE-PASSIVATION

DURATION = 244.000 S

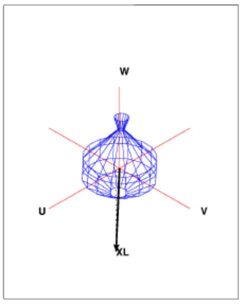


LOX OPENED

PHASE NUMBER 22

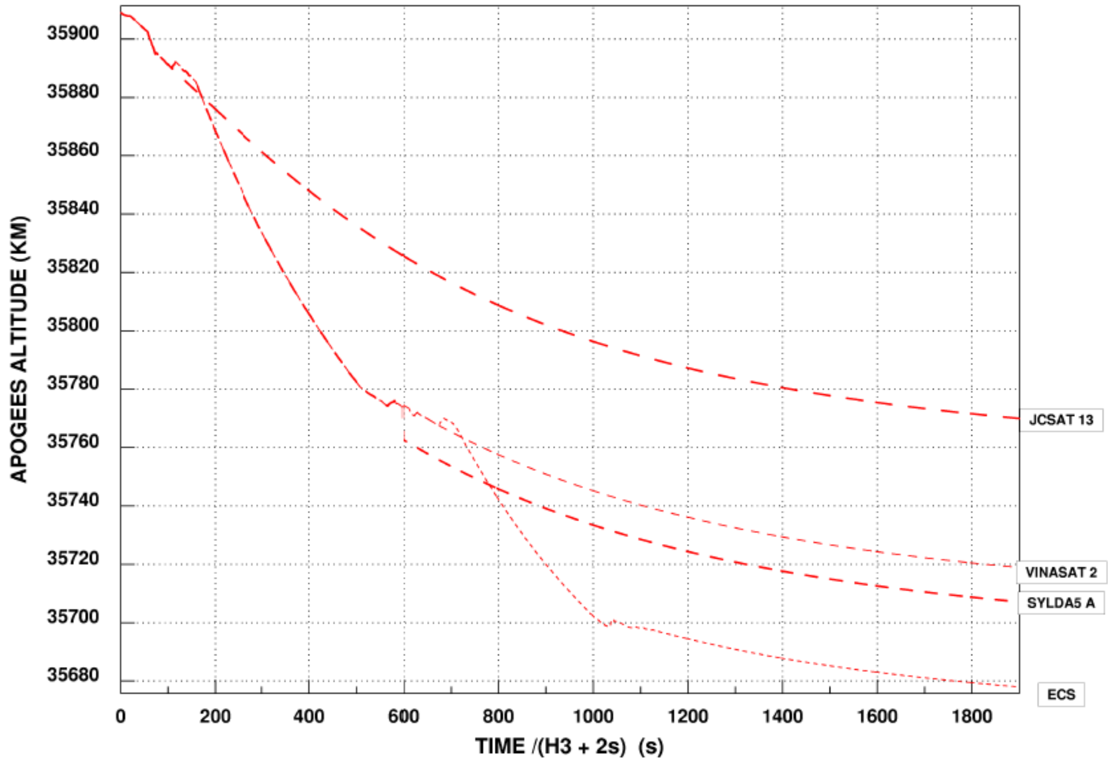
STAND BY

DURATION = 2.400 S



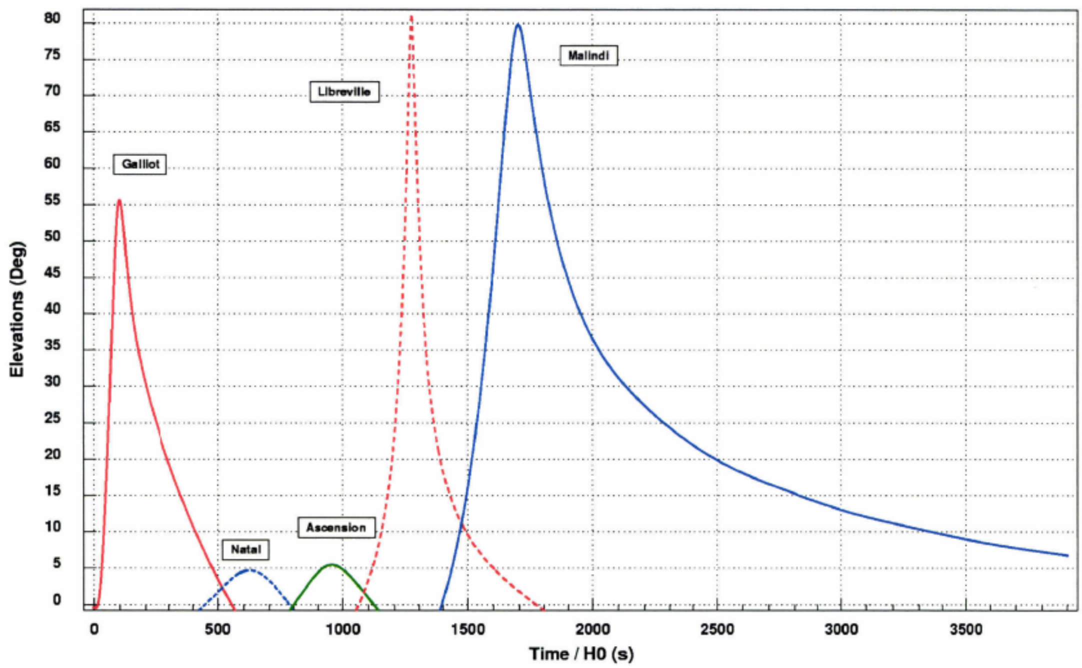
LOX OPENED

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



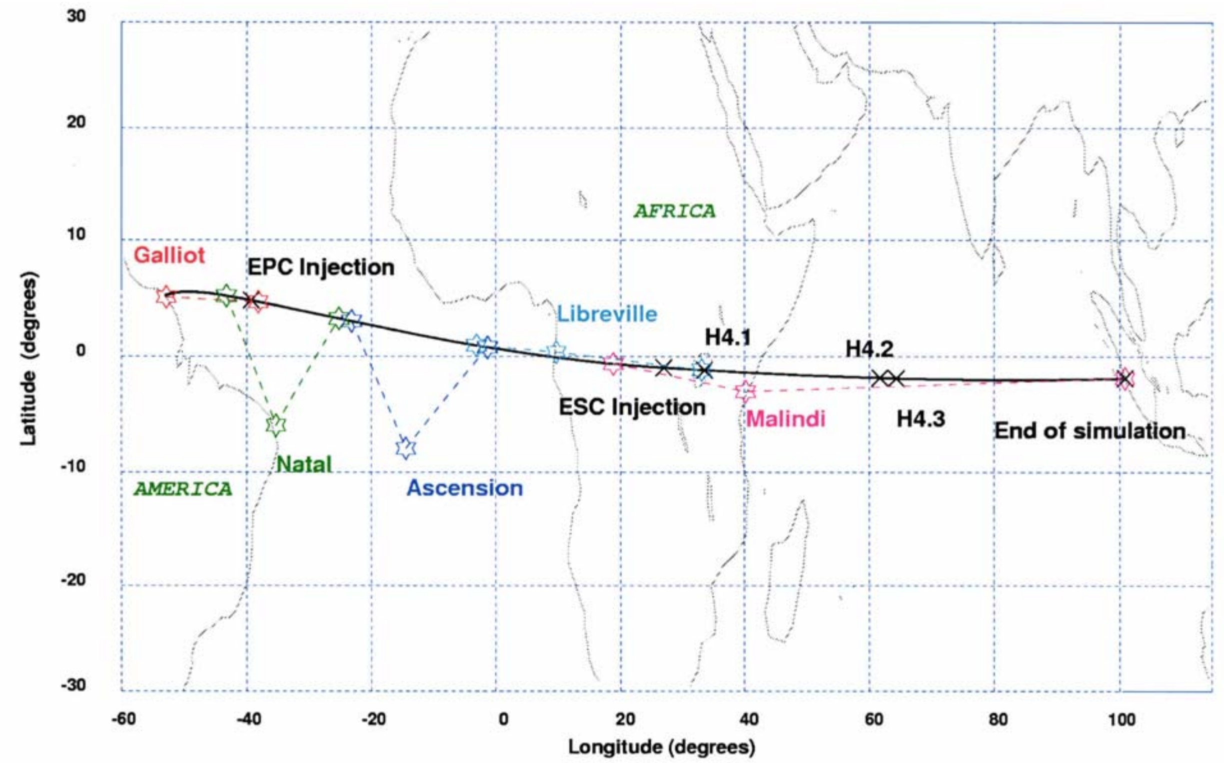
The launcher will be under **telemetry monitoring** by tracking stations in Kourou, Galliot, Natal, Ascension Island, Libreville and Malindi throughout the mission.

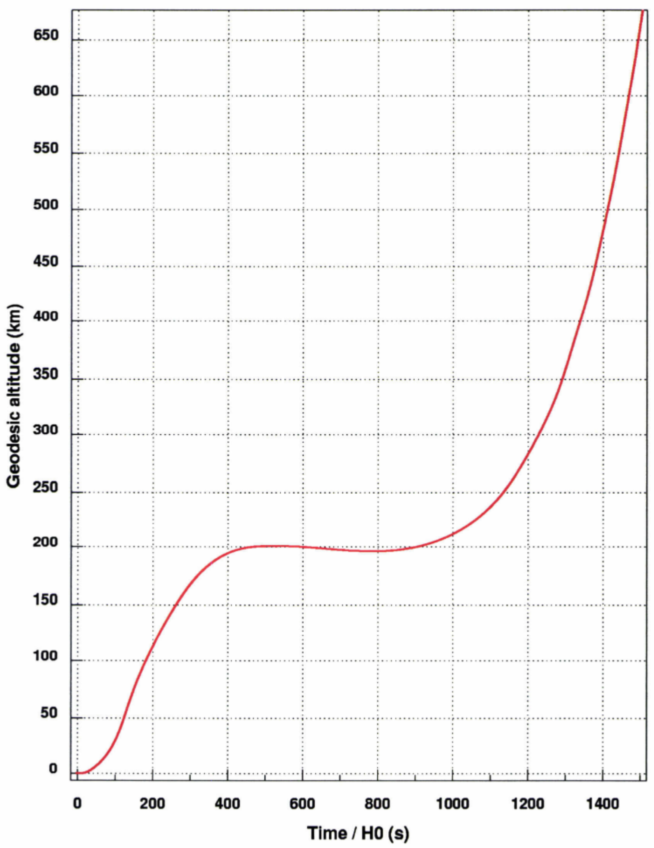
With the performance necessary for this mission, the trajectory includes one period of visibility loss: between Natal and Ascension (**~30 s.**):

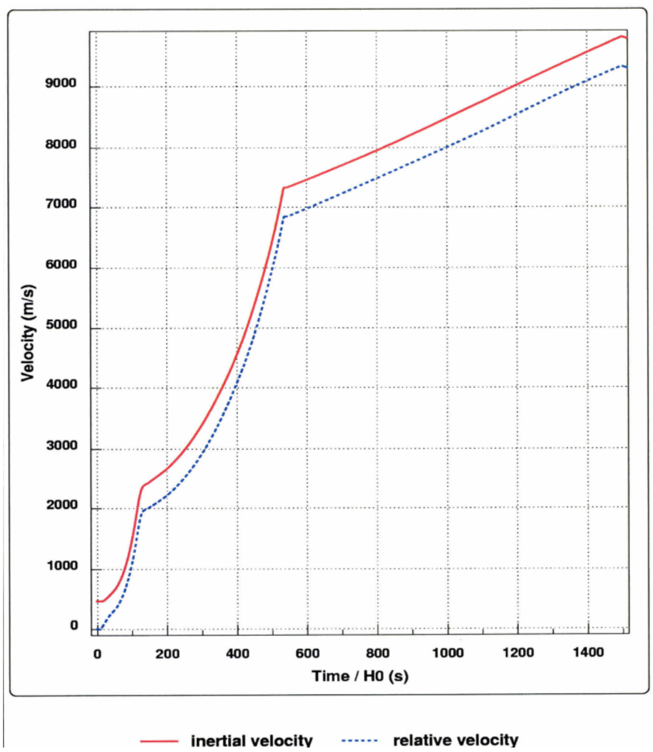


The following plates show:

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







4. Payloads

This launch is an important event for **Lockheed Martin Commercial Space System** because the two satellites carried on this flight are the 100th and 101st commercial geostationary communications satellites built by this firm. To date, 41 satellites designed by **Lockheed Martin** have already been carried by Ariane launchers.

JCSAT-13

This is the 27th Japanese operator satellite entrusted to an Ariane launcher since the JCSAT-1 in 1989. **JCSAT-13** is being launched on behalf of the **SKY Perfect JSAT Corporation** operator and is optimised to provide direct TV links from its geostationary orbit to the entire Japanese archipelago, replacing the JCSAT-4A satellite. It will also provide satellite services to South-East Asia. The satellite will be positioned at a longitude of 124° East. This launch is for the same operator as **JCSAT-110R**, launched in August 2011 on flight VA203.

JCSAT-13 – Artist's impression

The satellite

JCSAT-13 was built by **Lockheed Martin Commercial Space System** around an A2100 AX platform. The satellite's mass will be 4,528 kg.

Initial satellite manoeuvres will be monitored from the **A2100 Spacecraft Operation Center (ASOC)** based in Newton, Pennsylvania. The ASOC is responsible for the final orbital transfer operations, deployment of the various satellite elements, payload initialisation and in-orbit testing.

The main characteristics of the satellite are recalled in the following table:

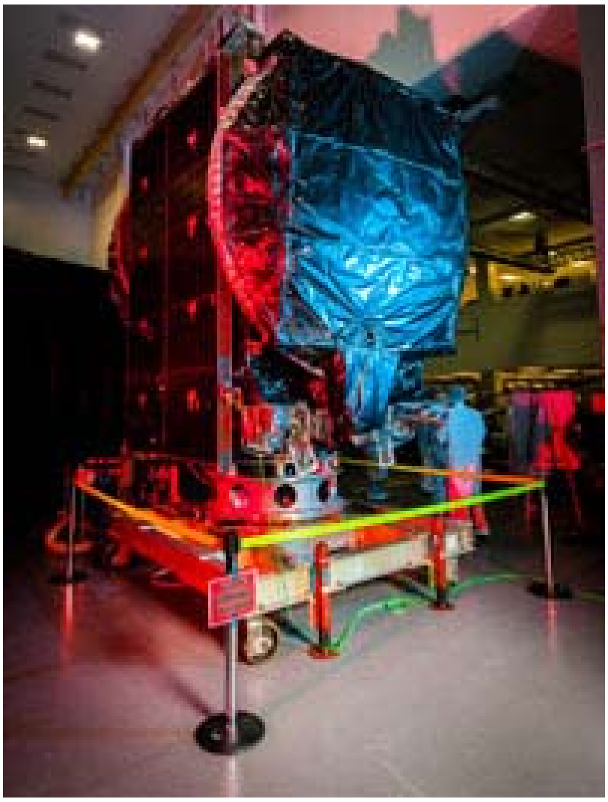
* Dimensions	• 6.00 x 3.30 x 2.60 m • In-orbit span 27,00 m
* Mass	• Lift-off 4,528 kg
* Power	• Payload power: 11.9 Kw (EOL) • Ni-H batteries
* Propulsion	• Biliquid propellant tanks (NTO & N2H4)
* Stabilisation	• 0.6°/second spin on separation and transfer • Triple-axis stabilisation in orbit
* Transmission capacity	• 44 Ku-band transponders • 4 deployable antennas
* Orbit position	• 124° East
* Coverage	Japan, Asia et Oceania
Expected lifetime exceeds 15 years	

Transfer of JCSAT-13 to S5 before fuelling.

VINASAT-2

VINASAT-2 in orbit (Artist's impression)
© Lockheed Martin Commercial Space Systems

VINASAT-2 is the second Vietnamese telecommunications satellite to be launched by an Ariane 5 after **VINASAT-1** in April 2008. **VINASAT-2** is being launched on behalf of the **Vietnam Post and Telecommunication Groups** which will thus be able to enhance its range of Telecommunications services.



VINASAT-2
© Lockheed Martin Commercial Space System

The satellite

VINASAT-2 is built by **Lockheed Martin Commercial Space System** around an A2100 A platform. The satellite's mass will be 2,964 kg.

As with **JCSAT-13**, initial satellite manoeuvres will be monitored from the **A2100 Spacecraft Operation Center (ASOC)** based in Newton, Pennsylvania. The ASOC is responsible for the final orbital transfer operations, deployment of the various satellite elements, payload initialisation and in-orbit testing.

The main characteristics of the satellite are recalled in the following table:

* Dimensions	• 4.40 x 1.90 x 1.80 m • In-orbit span 18.90 m
* Mass	• Lift-off 2,964 kg
* Power	• Payload power: 7.6 Kw (EOL) • Ni-H batteries
* Propulsion	• Biliquid propellant tanks (MON3 & N2H4)
* Stabilisation	• 0.6°/second spin on separation and transfer • Triple-axis stabilisation in orbit
* Transmission capacity	• 24 Ku-band transponders • 2 deployable antennas
* Orbit position	• 131.8° East
* Coverage	Vietnam and neighbour countries
Expected lifetime exceeds 15 years	

Transfer of VINASAT-2 from S1B to S5
© CNES - Arianespace

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 206 launch campaign:

EPC depreservation and erection in the launcher integration building (BIL)	February 6, 2012
Transfer of Solid Booster Stages (EAP)	February 6 & 7, 2012
Mating of the EAPs with the EPC	February 7, 2012
Depreservation and erection of the Upper Composite	February 10, 2012
Launcher Synthesis Control	March 5, 2012
Success of the VA205 – L553 ATV#3 Edoardo Amaldi mission	**March 23, 2012**
Arrival of **VINASAT-2** in Kourou	**April 11, 2012**
Arrival of **JCSAT-13** in Kourou	**April 11, 2012**
Launcher acceptance by Arianespace	March 14, 2012
Transfer from BIL to BAF	April 11, 2012
JCSAT-13 fuelling Assembly on its adaptor Transfer to the BAF Integration on the SYLDA	April 24 to 26, 2012 April 28, 2012 April 30, 2012 May 2, 2012
VINASAT-2 fuelling Assembly on its adaptor Transfer to the BAF Integration on the launcher	April 25 to 27, 2012 May 2, 2012 May 3, 2012 May 4, 2012
Integration of the fairing on the SYLDA	May 3, 2012
Integration of the composite (**JCSAT-13** + PAS 1194C + SYLDA + fairing) on the launcher	May 5, 2012
General rehearsal	May 9, 2012
Flight Readiness Review Arming of the launcher	May 12, 2012
Launcher transfer from the BAF to the Pad (ZL3) Fuelling of the EPC helium sphere	May 14, 2012
Final countdown	May 15, 2012

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

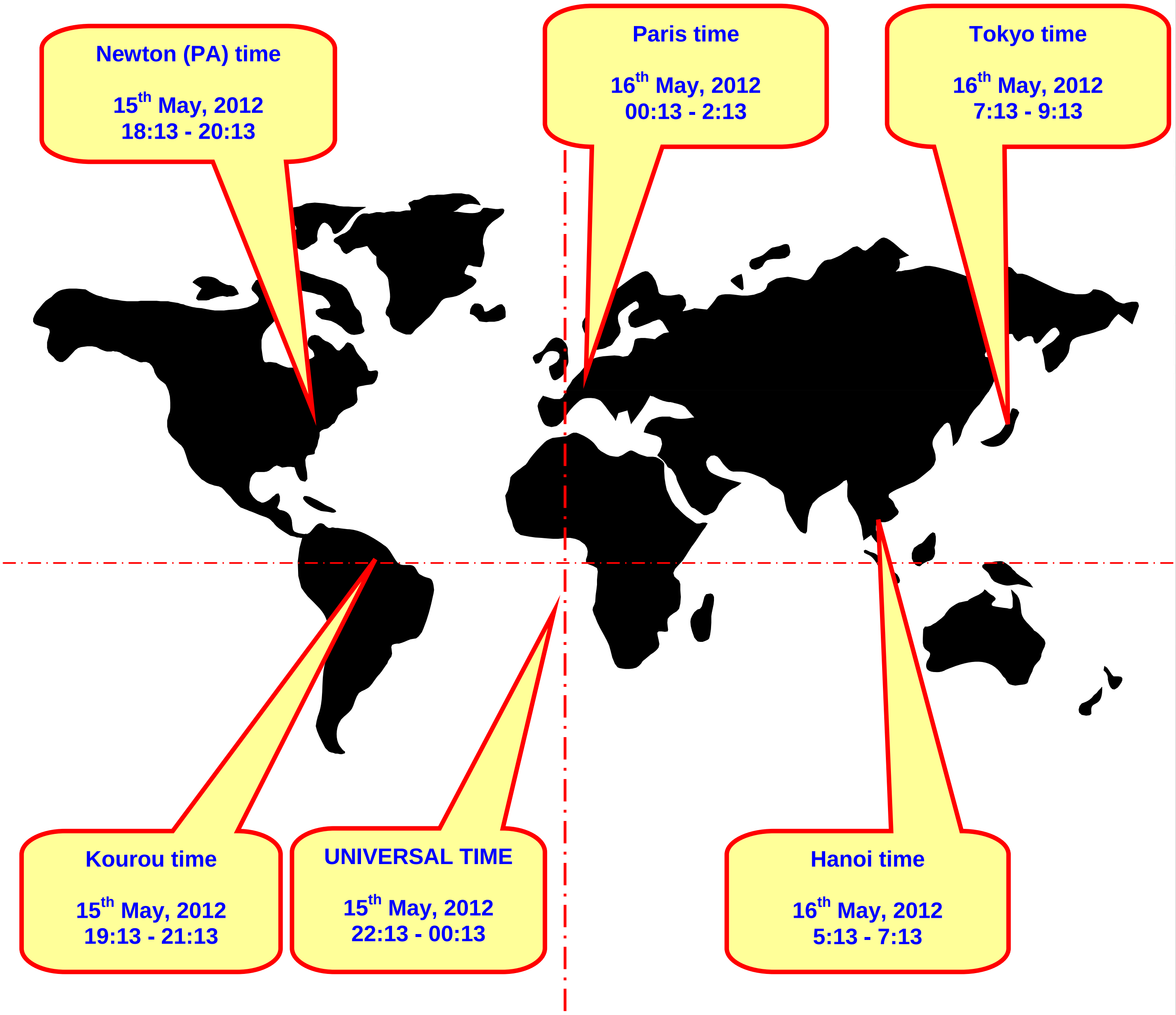
Kourou: erection of the Upper Composite in the Launcher Integration Building (BIL)

Kourou: transfer from the Final Assembly Building (BAF) to the pad for the Launch Sequence Rehearsal (RSL)

6. Launch window

The window for a launch on **15th May, 2012** is with **H_0** at **22:13 (UT).** The closing of the window is at **00:13 (UT).**

The launch window will last **120** minutes:



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

If the launch is postponed, the opening of the launch window will be brought forward by 2 minutes, while closure of the window remains unchanged until 29th May.

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	---	773.2	0
12.62	0 ’ 13 ”	Start of tilt manoeuvre	0.09	745.9	36.4
17.05	0 ’ 17 ”	Start of roll manoeuvre	0.32	722.4	72.8
32.05	0 ’ 32 ”	End of roll manoeuvre	2.43	644.1	209.1
49.8	0 ’ 50 ”	Transsonic (Mach = 1)	6.92	574.2	322.3
68.4	1 ’ 08 ”	Speed at Pdyn max	13.35	500,3	504.9
113.4	1 ’ 53 ”	Transition to γ_{max} (41.96 m/s^2)	41.1	304.9	1565
144.3	2 ’ 24 ”	Transition to γ = 6.15 m/s² H_1	70.2	249.8	2001
145.1	**2 ’ 25 ”**	**EAP separation**	**70.9**	**249.5**	**2003**
- - - -		**EPC powered flight**			- - - -
191.0	3 ’ 11 ”	Fairing jettisoned	107.4	160.1	2181
321.0	*5 ’ 21 ”*	*Intermediate point*	*175.3*	*115.6*	*3132*
464.3	*7 ’ 44 ”*	*Acquisition Natal*	*200.3*	*69.1*	*5163*
533.8	8 ’ 54 ”	EPC burnout (H_2)	201.1	46.5	6824
539.8	**8 ’ 59 ”**	**EPC separation**	**201.1**	**27.6**	**6851**
- - - -		**ESC-A powered flight**			- - - -
543.7	9 ’ 04 ”	ESC-A ignition	201.1	27.6	6853
559.7	*9 ’ 20 ”*	*Lost Galliot*	*201.0*	*27.4*	*6886*
768.5	*12 ’ 49 ”*	*Lost Natal*	*196.3*	*24.3*	*7394*
784.5	*13 ’ 05 ”*	*Minimum altitude*	*196.3*	*24.1*	*7436*
799.0	*13 ’ 19 ”*	*Acquisition Ascension*	*196.3*	*23.9*	*7473*
1096.1	*18 ’ 16 ”*	*Acquisition Libreville*	*236.8*	*19.5*	*8258*
1119.8	*18 ’ 40 ”*	*Lost Ascension*	*245.0*	*19.2*	*8321*
1256.0	*20 ’ 56 ”*	*Intermediate point*	*321.3*	*17.1*	*8697*
1393.6	*23 ’ 13 ”*	*Acquisition Malindi*	*473.4*	*15.1*	*9070*
1499.0	24 ’ 59 ”	**ESC-A burnout (H_{3-1})**	665.5	13.5	9341

time /H_0 (s)	time/H_0 (mn)	event		altitude (km)
- - - -		"Ballistic" phase		- - -
1504	25 ' 04 "	Phase 3	Start of **JCSAT-13** orientation	677
2150	35 ' 50 "	Phase 4	**JCSAT-13** slow spin-up	2837
1595	**26 ' 35 "**	**JCSAT-13 separation ($H_{4.1}$)**		**898**
1608	26 ' 48 "	Phases 11 to 14 SYLDA staging to orientation phases		934
2100	**35 ' 00 "**	**SYLDA separation ($H_{4.2}$)**		**2635**
2110	35 ' 10 "	Phase 19	Start of **VINASAT-2** orientation	2674
2150	35 ' 50 "	Phase 20	**VINASAT-2** slow spin-up	2837
2161	**36 ' 01 "**	**VINASAT-2 separation ($H_{4.3}$)**		**2777**
2174	36 ' 14 "	Phase 26	Orientation to staging phases	2935
2244	37 ' 24 "	Phases 27 - 28	ESC-A staging phases	3224
2431	40 ' 31 "	Phase 29	ESC-A orientation for the final spin-up	3931
2555	42 ' 35 "	Phase 30	Start of spin-up at 45°/s	4539
2706	45 ' 06 "		Oxygen tank passivation (breakdown S34)	5186
2912	48 ' 32 "		ESC-A passivation (breakdown S37)	6057

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

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 2010, the Group – comprising **Airbus, Astrium, Cassidian and Eurocopter** – generated revenues of € 45.8 billion and employed a workforce of about 122,000.

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 2010, Astrium had a turnover of €5 billion and more than 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, **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 takeoff, 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