Satellites
Space Transportation
Services

KOUROU

April 2008

ARIANE 5

Data relating to Flight 182 by Sébastien ROUCHON

ARIANE 5 PRIME CONTRACTORSHIP AND INTEGRATOR

STAR ONE C2

VINASAT-1

All the space you need

Flight 182
Ariane 5 – Satellites: STAR ONE C2 & VINASAT-1

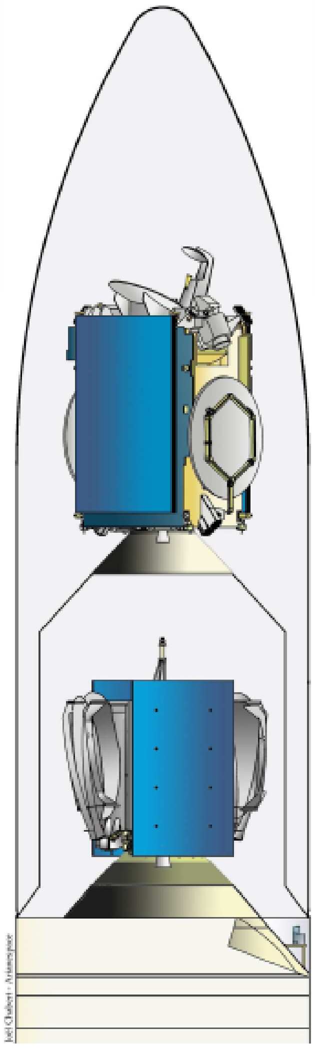
Content

1. Introduction

Flight 182 is the 38th Ariane 5 launch and the second in 2008. 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.

This will be the 34th commercial mission for Ariane 5. Launcher 539, the 34th production phase Ariane 5, is the twelfth of the 30 **PA** contract launchers, for which **ASTRIUM** is production prime contractor. 539 is consequently the thirteenth 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” (6.4m high) system and a long pattern fairing (total height: 17m), the launcher is carrying a Brazilian telecommunications satellite, **STAR ONE C2** in the upper position, and a Vietnamese one, **VINASAT-1** in the lower position.



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

STAR ONE C2 built by: **THALES ALENIA SPACE**

Strapped to a type **PAS1194 VS** adaptor built by: **SAAB SPACE**

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

VINASAT-1 built by: **LOCKHEED MARTIN CSS**

Strapped to a type **PAS1194 VS** adaptor built by: **SAAB SPACE**

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 L539

Description

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

- **ESC-A** cryogenic upper stage,
- **Vehicle Equipment Bay**
- **3936 cone**,
- **SYLDA 5** payload carrier structure,
- **Fairing**

The lower composite incorporates:

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

Type C main cryogenic stage:

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

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

Liquid helium sub-system capacity
© ASTRIUM ST

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

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

The main stage burns continuously for about 540s, 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 208km for this mission, the stage separates from the upper composite and falls back into the Atlantic Ocean.

Type B solid propellant strap-on boosters:

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

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

Equipment displayed at Paris Air Show 2001

The boosters (EAP) are ignited 6.05s after the Vulcain engine, i.e. 7.05s from H_0. Booster thrust varies in time (approx. 600 tons on lift-off or over 90% of total thrust, with a maximum of 650 tons in flight. EAP burn time is about 140s, after which the boosters are separated from the EPC by cutting the pyrotechnic anchor bolts, and fall back into the ocean.

Compared with the Ariane 5 “generic” version of the booster stage, the main changes include the elimination of one GAT cylinder, overloading of segment S1 to increase thrust on lift-off, and the use of a reduced mass nozzle.

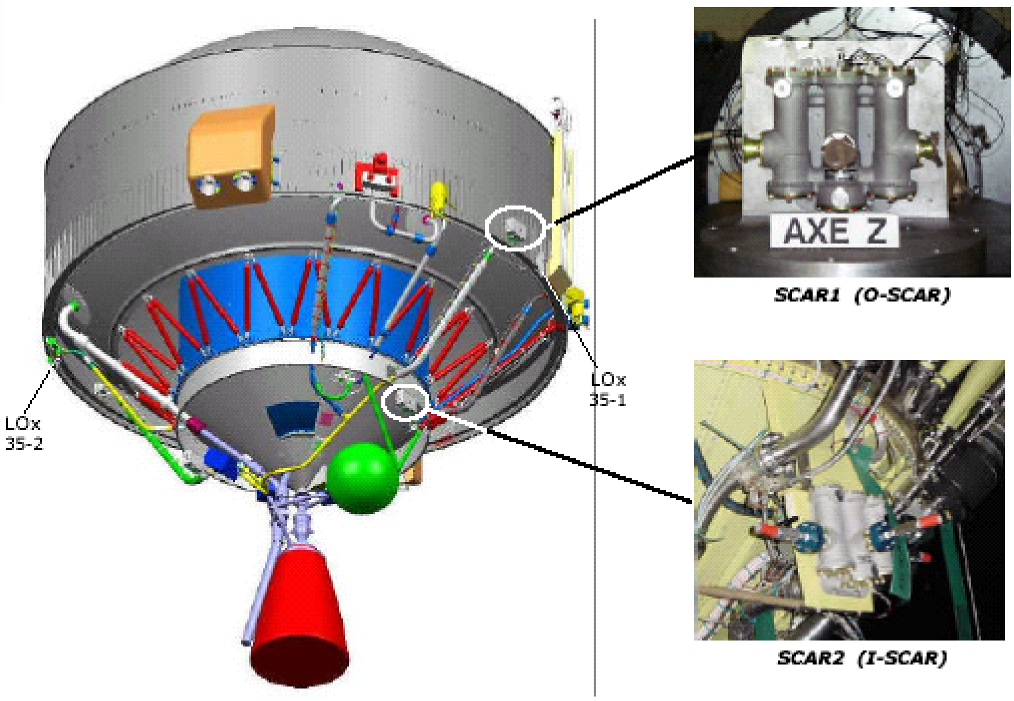
Type-A cryogenic upper stage:

The **ESC-A** 3rd stage has been developed for the Ariane 5 ECA version, 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 940s. The HM7B nozzle is swivel-mounted (two axes) for attitude control.

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



The ESC-A and the SCAR system

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

ESC-A thrust frame
© EADS ST

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

Type C vehicle equipment bay:

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

The **upper composite** (ESC-A stage + VEB + 3936 cone) for launcher L539 was assembled for the 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
© K. BAINTINGER

Nose fairing:

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

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

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

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

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

Fairing during integration

Flight 175 fairing

SYLDA 5 (Ariane 5 dual-launch system):

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

A **SYLDA A** with a **height of 6.4 m** will be used for flight 182.

SYLDA 5 No. 28-A for flight 182
© ASTRIUM ST

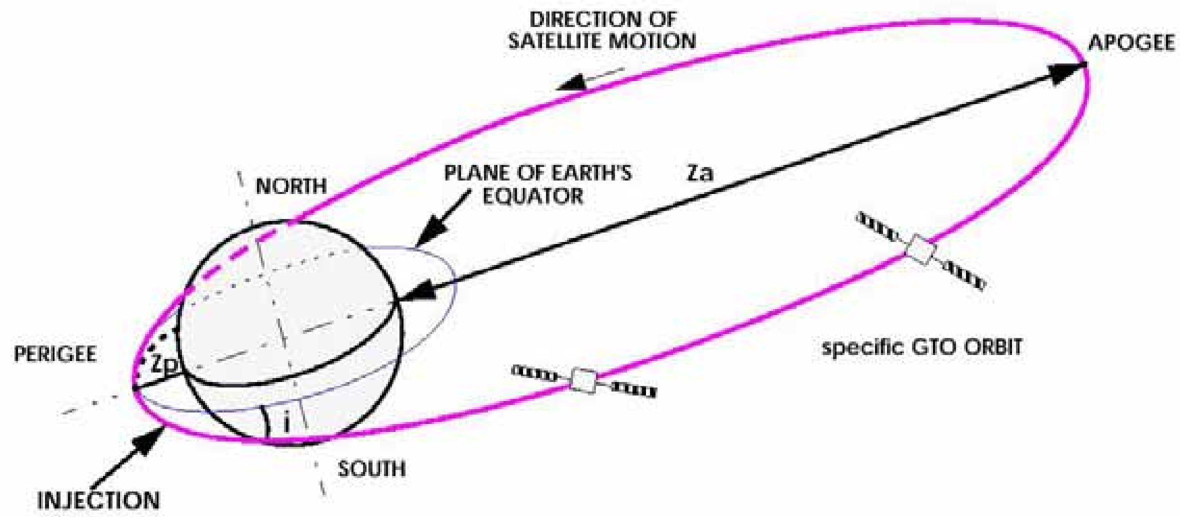
3. Mission V182

Payload mission

The main mission of flight 182 is to place the **STAR ONE C2** and **VINASAT-1** commercial payloads into a nearly-standard geostationary transfer orbit (GTO):

Apogee altitude	35,786 km
Perigee altitude	250 km
Inclination	2.0°
Perigee argument	178°
Ascending node longitude	-121.8° (*)

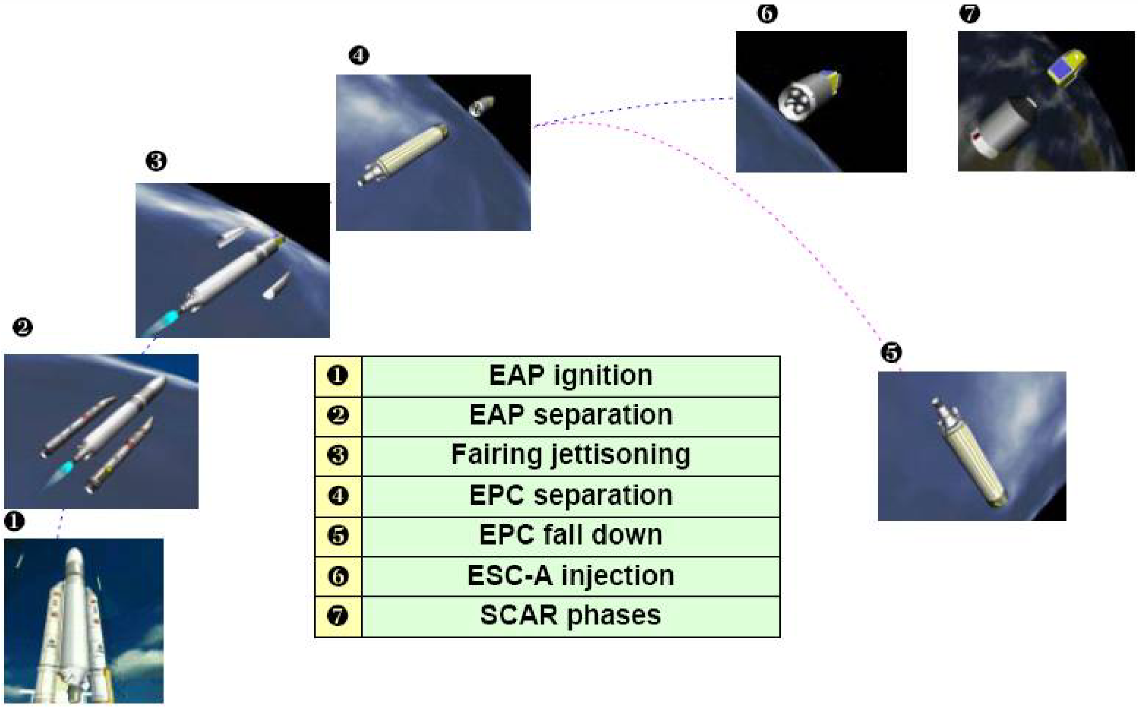
(*) in relation to a fixed axis, frozen at H_0 - 3s and passing through the ELA3 launch complex in Kourou.



The mass of **STAR ONE C2** is **4,100 kg**, with **2,637 kg** for **VINASAT-1**.

Allowing for the adaptors and **SYLDA 5**, total performance required from the launcher for the orbit described above is **7,529 kg**, below the maximal performance supplied by the ESC-A version (9,500 kg).

Flight phases



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

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

Lift-off mass is about 776 tons, and initial thrust 13,100 kN (of which 90% is delivered by the EAPs).

After a vertical ascent lasting 5s to enable the launcher to clear the **ELA3** complex, including the lightning arrestor pylon in particular, the launcher executes a **tilt operation** in the trajectory plane, followed by a **roll operation** 5 seconds later to position the plane of the EAPs perpendicularly to the trajectory plane. The launch azimuth angle for this mission is 80° with respect to North.

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

The purpose of these operations is to:

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

The EAP separation sequence is initiated when an **acceleration threshold** is **detected**, when the solid propellant thrust level drops. Actual separation occurs within one second.

*This is reference time **H_1**, and occurs at about **H_0** + 139.6 s at an altitude of 65.9 km and a relative velocity of 1,975 m/s.*

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

The **fairing** is jettisoned during the EPC flight phase as soon as aerothermodynamic flux levels are sufficiently low not to impact the upper (outer) payload. For this mission, the fairing is jettisoned at 189 s, at an altitude of 104.8 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	210.9 km
Perigee altitude	-1,404.9 km
Inclination	7.4°
Perigee argument	-35.5°
Ascending node longitude	-125.5°

This is time reference $\mathbf{H_2}$. It happens at $\mathbf{H_0}$+534.6s.

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

The stage must be depressurized (**passivated**) to avoid any risk of explosion of the stage due to overheating of residual hydrogen. A hydrogen tank lateral nozzle, actuated by a time delay relay initiated on EPC separation, is used for this purpose.

This lateral thrust is also used to spin the EPC, and thus limit breakup-induced debris dispersion on re-entry.

The main cryogenic stage angle of re-entry is **-4.0°**. Point of impact longitude is **3.97° W**.

The subsequent **ESC-A** powered **flight phase** lasts a little over 15 minutes. This phase is terminated by a command signal from the OBC, when the computer estimates, from data calculated by the inertial guidance unit, that the **target orbit** has been acquired.

This is time reference $\mathbf{H_3}$. It happens at $\mathbf{H_0}$+1,480.7 s

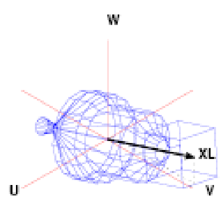
The purpose of the following **ballistic phase** is to ensure:

- Pointing of the upper composite, firstly in the direction required by **STAR ONE C2**, and **VINASAT-1** and then in that required for **SYLDA5**,
- slow spin-up before separation of **STAR ONE C2,**
- triple axis stabilization of the launcher before separation of **SYLDA5**,
- slow spin-up before separation of **VINASAT-1,**
- separation of **STAR ONE C2**, the **SYLDA5** and **VINASAT-1**
- final spin-up of the composite at 45°/s,
- passivation of the ESC-A stage pressurized LOX tank and LH_2 tank, preceded by a pre-passivation phase involving simultaneous opening of the eight SCAR nozzles

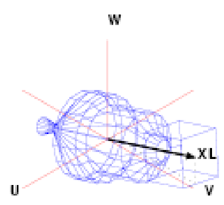
These operations contribute to short- and medium-term management of the mutual distancing of objects in orbit.

The **ballistic phase** for the mission comprises 20 elementary phases described hereafter. These include separation of **STAR ONE C2** (phase 6), **SYLDA5** separation (phase 9) and **VINASAT-1** separation (phase 13).

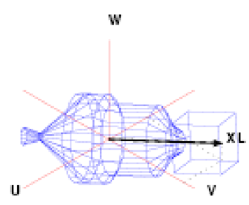
PHASE NUMBER 1
TRANSVERSE VELOCITY CONTROL
DURATION = 3.000 S



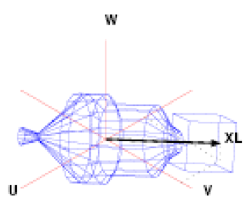
PHASE NUMBER 2
SPIN DOWN
DURATION = 0.500 S



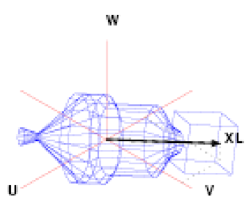
PHASE NUMBER 3
ORIENTATION
DURATION = 55.000 S



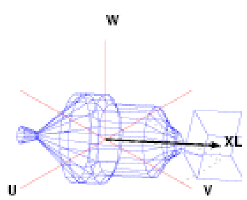
PHASE NUMBER 4
SLOW SPIN -1.5 °/S
DURATION = 20.000 S



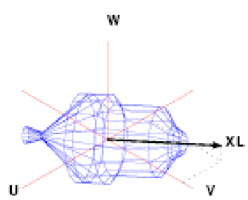
PHASE NUMBER 5
SPIN UP -1.5 °/S
DURATION = 3.000 S



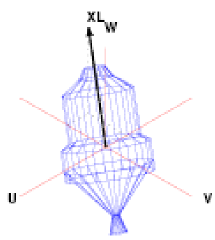
PHASE NUMBER 6
SEPARATION
DURATION = 10.000 S



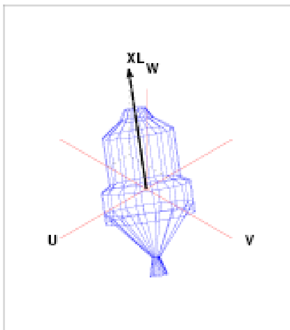
PHASE NUMBER 7
SPIN DOWN
DURATION = 3.000 S

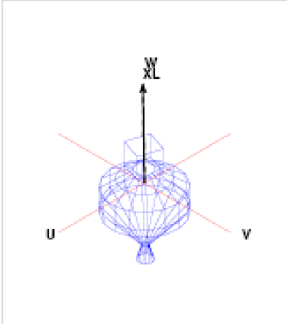


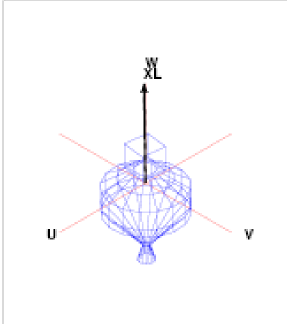
PHASE NUMBER 8
ORIENTATION
DURATION = 145.000 S

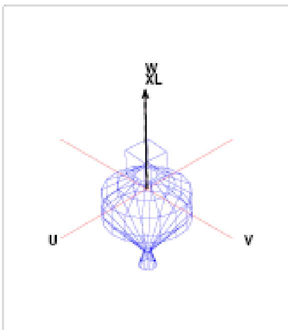


PHASE NUMBER 9 SEPARATION DURATION = 10.000 S	PHASE NUMBER 10 ORIENTATION DURATION = 100.000 S	PHASE NUMBER 11 SLOW SPIN 0.6 ° /S DURATION = 20.000 S	PHASE NUMBER 12 SPIN UP 0.6 ° /S DURATION = 2.000 S

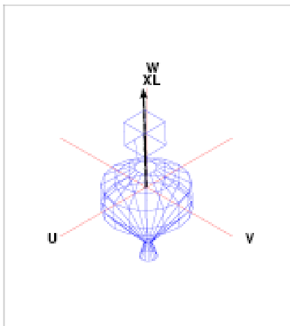


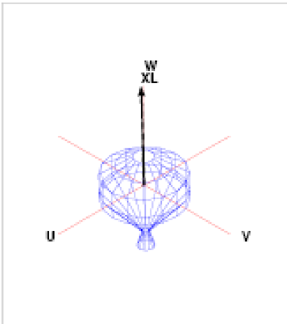


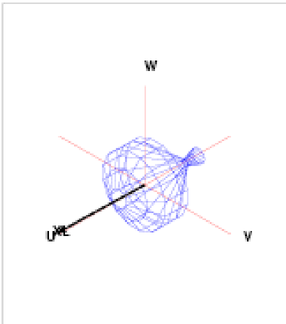


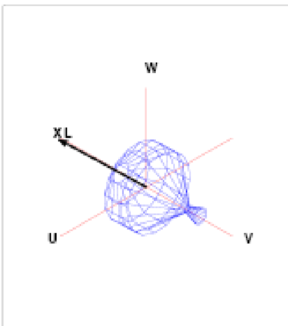


PHASE NUMBER 13 SEPARATION DURATION = 10.000 S	PHASE NUMBER 14 SPIN DOWN DURATION = 2.000 S	PHASE NUMBER 15 ORIENTATION DURATION = 163.000 S	PHASE NUMBER 16 ORIENTATION DURATION = 130.000 S

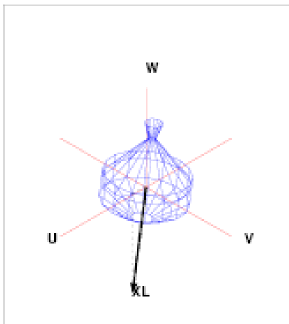


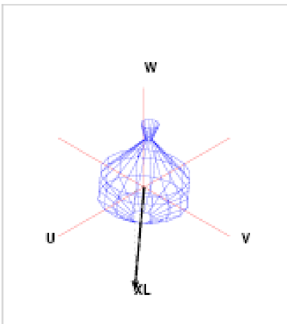


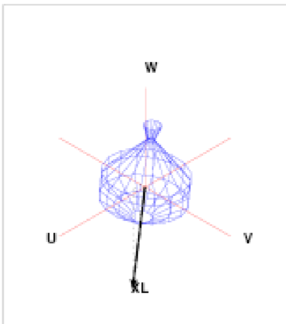


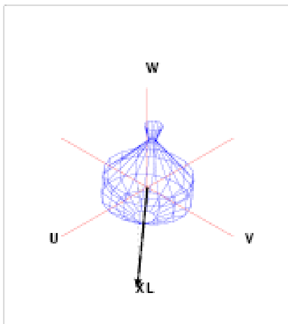


PHASE NUMBER 17 ORIENTATION DURATION = 119.000 S	PHASE NUMBER 18 SPIN UP 45.0 ° /S DURATION = 102.000 S	PHASE NUMBER 19 LH2 PRE-PASSIVATION DURATION = 127.000 S	PHASE NUMBER 20 STAND BY DURATION = 170.000 S



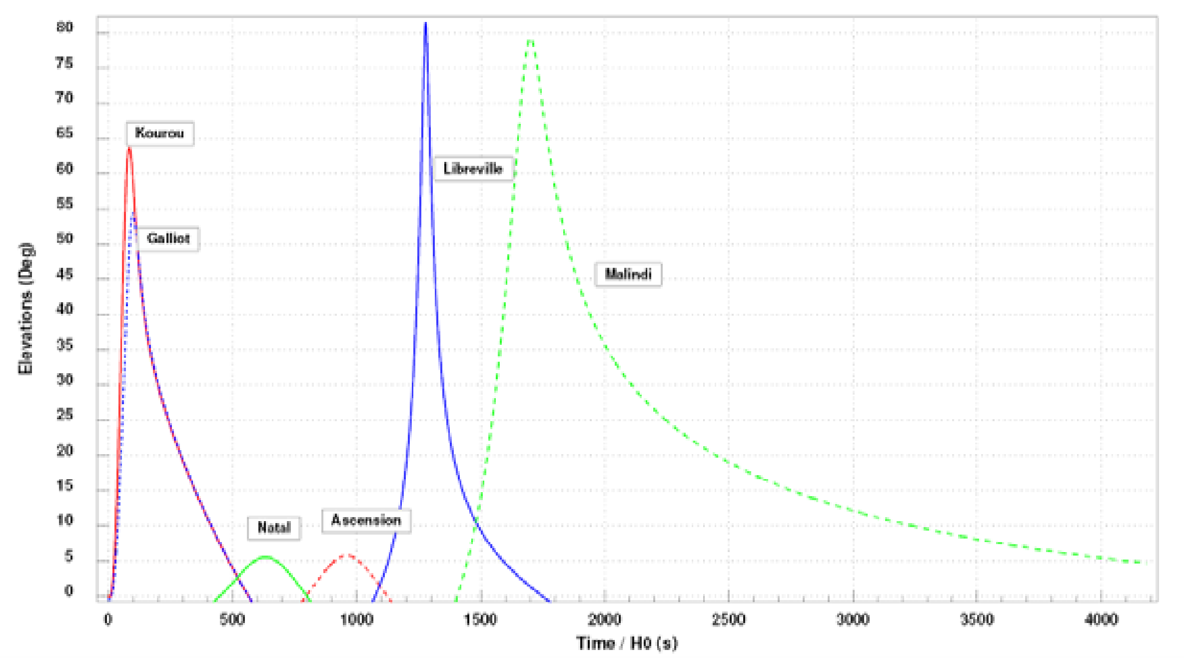






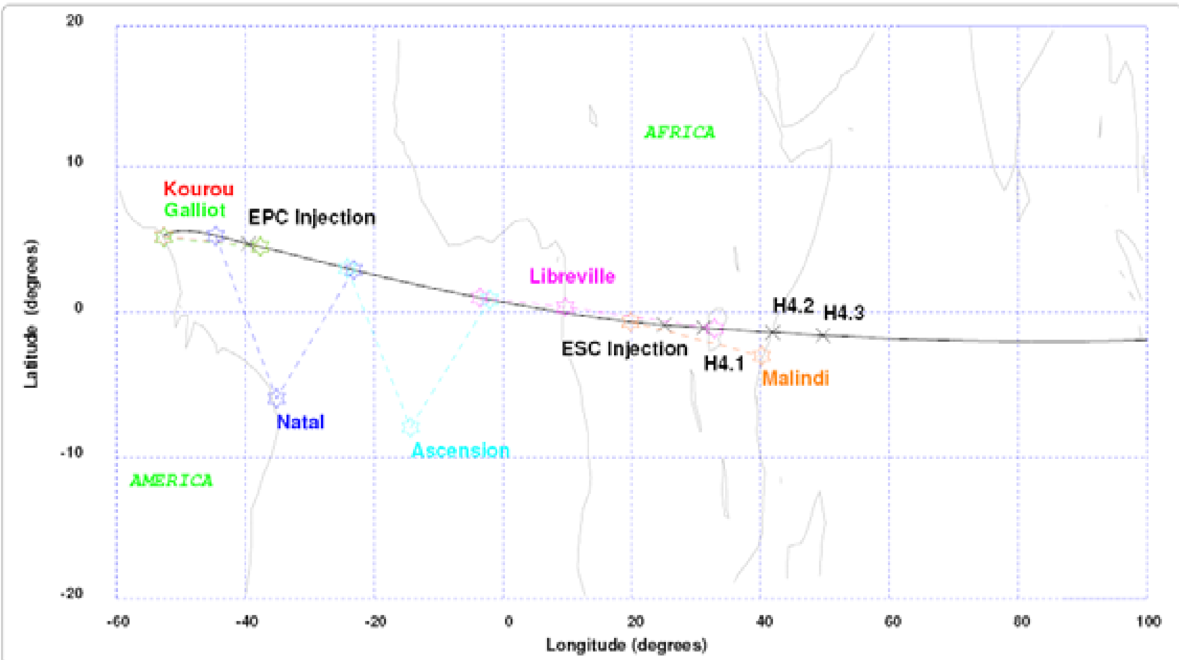
The launcher will be under **radar monitoring** by tracking stations in Kourou, Galliot, Natal, Ascension Island, Libreville and Malindi throughout the mission.

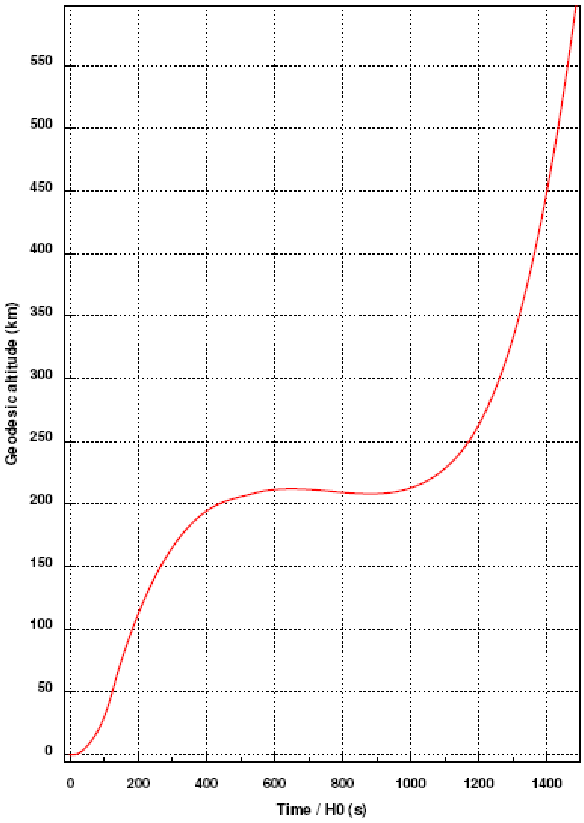
Given the performance requirements for this mission, the trajectory has been adjusted so that the launcher will remain permanently visible for a ground station.

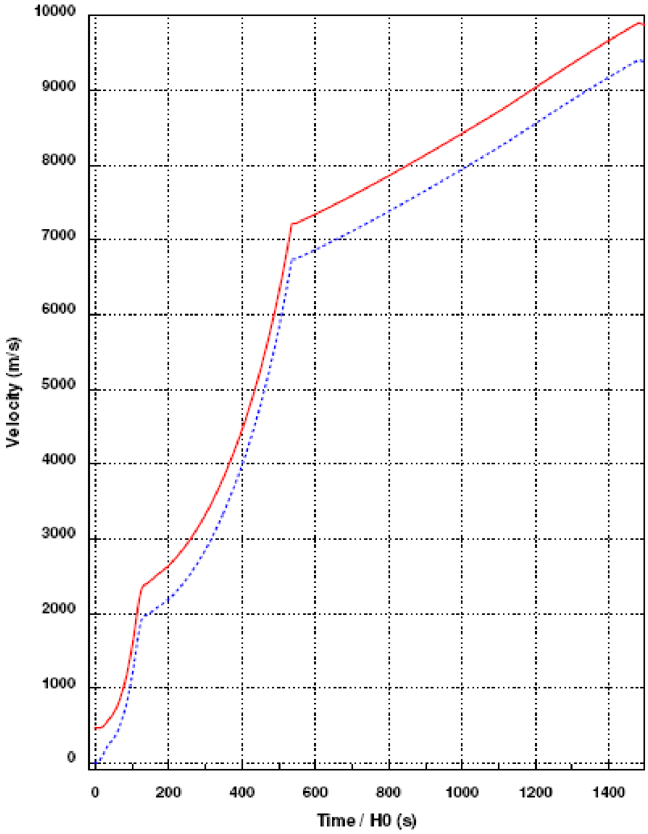


The following plates show:

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




Geodesic altitude (km)
0
50
100
150
200
250
300
350
400
450
500
550
0
200
400
600
800
1000
1200
1400
Time / H0 (s)


Velocity (m/s)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
200
400
600
800
1000
1200
1400
Time / H0 (s)

4. Payloads

STAR ONE C2

Programme and Mission

STAR ONE C2 is a telecommunications satellite built by **THALES ALENIA Space** at its Cannes (France) facility for the Brazilian company **Star One** (**Embratel** 80% and **GE International Holdings** 20%).

STAR ONE C2 will supply Latin America with telecommunications, multimedia and high-rate Internet services. **Star One** will strengthen its major regional operator position in Latin America with this satellite. **STAR ONE C2** will replace **BRASILSAT B2**.

This will be the 8th Brazilian satellite to be launched by **ARIANESPACE**, following:

• **BRASILSAT F1**	8 February 1985	V12	A3	with Arabsat 1A
• **BRASILSAT F2**	28 March 1986	V17	A3	with GSTAR 2
• **BRASILSAT B1**	10 August 1994	V66	A44LP	with Turksat 1B
• **BRASILSAT B2**	28 March 1995	V71	A44LP	with Eutelsat 2 FM6
• **BRASILSAT B3**	4 February 1998	V105	A44LP	with Inmarsat 3F5
• **BRASILSAT B4**	17 August 2000	V131	A44LP	with Nilesat 102
• **STAR ONE C1**	14 November 2007	V179	L538	with SKYNET 5B

Cannes: STAR ONE C2 loading in its transport container
© Star One S.A.

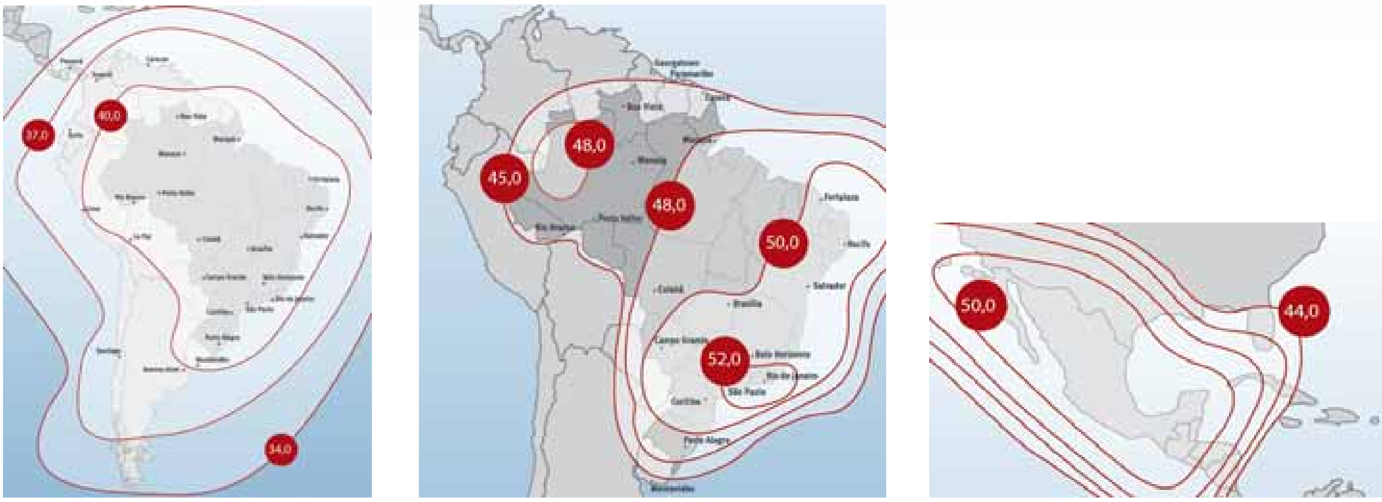
Kourou: Arrival of STAR ONE C2 at the S5 building
© Star One S.A.

Kourou: STAR ONE C2 on its flight adaptor
© Star One S.A.

The satellite

The **STAR ONE C2** satellite is based on a **SPACEBUS 3000 B3** platform.

* Dimensions	• 5.3 x 3.3 x 2.5 m • in-orbit span 37 m (solar panels deployed)
* Mass	• lift-off 4,100 kg • dry mass 1,754 kg
* Power	• > 10kW BOL • batteries: N_iH_2 cells
* Propulsion	• apogee kick motor and biliquid propellant (MMH & MON)
* Stabilization	• slow spin (1.5°/s) at separation • Triple-axis stabilisation in orbit
* Transmission capacity	• 28 C band transponders, 14 Ku band transponders, 1 X band transponder
* Orbit Position	• 65° West
* Ground station	• Latin America for C band • Brazil, Mexico et South Florida for Ku band
Expected lifetime : 15 years	



STAR ONE C2 footprint (C and Ku bands)
© Star One S.A.

STAR ONE C2 in orbit (artist's impression)
© Star One S.A.

STAR ONE C2 anechoic chamber testing

VINASAT-1

Programme and Mission

The **VINASAT-1** satellite was built by **Lockheed Martin Commercial Space System** at its Newtown (Pennsylvania) facility for **Vietnamese Posts and Telecommunications Group (VNPT).** **VINASAT-1** is a **telecommunications** satellite with a transmission capacity of 10,000 Internet or mobile telephone channels and 120 digital TV programmes. It will enhance telecommunication infrastructures by covering the whole of Vietnam, three-quarters of which comprises mountain areas, while reducing the dependence of Vietnam in terms of satellite transmission. This will be the first Vietnamese satellite and will induce savings of between $8 and 10 million per year of channel rental charges paid to foreign operators (Russia, Australia, Indonesia, etc.).

The **VINASAT** project was initiated in 1995, and the preliminary feasibility studies were approved by the Vietnamese Government in 1998. The contract for **turnkey in-orbit delivery of the satellite** was signed in Hanoi on 12 May 2006. The Canadian company **TELESAT** has acted as technical consultant to **VNPT,** designated prime contractor by the Vietnamese Government and main investor in the project, throughout implementation of the project.

VINASAT-1 in orbit (artist's impression)
© VINASAT Center

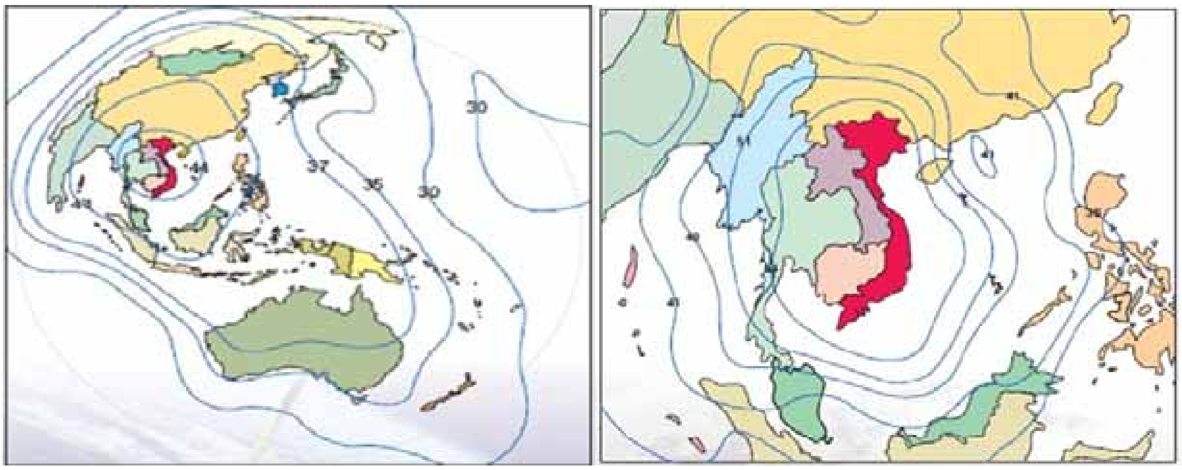
After injection into geostationary orbit under the responsibility of **LOCKHEED MARTIN CSS** management, control of the satellite will be transferred to the **Quê Duong** station in the Ha Tay province in the northern part of Vietnam. This station was built in 2001. Equipment for the station was supplied by **LOCKHEED MARTIN CSS** under the terms of the **VINASAT** contract, and a 13 m diameter antenna was supplied by **SES ASTRA** under the terms of a development agreement with Luxembourg. **SES ASTRA** was also responsible for training Vietnamese engineers and technicians. This station, together with a second (replacement) station, have been operational since September 2007.

VINASAT-1 during fuelling
© ESA/CNES/ARIANESPACE/Service optique CSG

The satellite

The construction of the **VINASAT-1** satellite is based on the **A2100-A** platform. The main characteristics of the **VINASAT-1** satellite are as follows:

*** Dimensions**	• 3.8 x 1.9 x 1.9 m • 14.7 m (solar panels deployed)
*** Mass**	• Lift-off **2,637 kg** • Dry mass **1,140 kg**
*** Power**	• batteries: N_iH_2 cells • 2,0 kW BOL • Payload power: 1,4 kW
*** Propulsion**	• biliquid apogee kick motor (N_2H_4/MON) • single liquid propellant (hydrazine) in orbit • attitude control: reaction wheels - arcjets
*** Stabilization**	• slow spin (0.6°/s) at separation • Triple-axis stabilisation in orbit
*** Transmission capacity**	• 8 C band transponders, 12 Ku band transponders
*** Orbit Position**	• 132° East
*** Ground station**	• Vietnam, South-East Asia, Japan, Australia
Expected lifetime : 22 years	



VINASAT-1 footprint (C and Ku bands)
© VINASAT Center

5. Launch campaign

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

The Ariane 5 main cryogenic stage (EPC) in the integration dock at Les Mureaux, France, in course of preparation for 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 182 launch campaign:

EPC depreservation and erection in the launcher integration building (BIL)	February 18
Transfer of Solid Booster Stages (EAP)	February 19
Mating of the EAPs with the EPC	February 20
Depreservation and erection of the Upper Composite	February 25
Arrival of STAR ONE C2 in French Guiana	February 25
Assembly of the ARF on the ESC-A	February 27
Arrival of VINASAT-1 in French Guiana	March 08
Launcher Synthesis Control	March 12
Launcher acceptance by Arianespace	March 17
Transfer from BIL to BAF	April 02
STAR ONE C2 fuelling Assembly of STAR ONE C2 on its adapter Transfer to the BAF Assembly on the SYLDA 5 Integration of the fairing on the composite	March 29 April 5 April 7 April 8 April 9
VINASAT-1 fuelling Assembly of VINASAT-1 on its adapter Transfer to the BAF S/C integration on the launcher	March 29 to 31 April 8 April 9 April 10
Final integration of the upper composite	April 10
Launch Rehearsal	April 14
Arming of the launcher Flight Readiness Review	April 15 April 16
Launcher transfer from the BAF to the Pad (ZL3) Fuelling of the EPC helium sphere	April 17
Final countdown	April 18

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

Kourou: transfer of the launcher from the Launcher Integration Building (BIL) to the Final Assembly Building. Foreground: table used for flight 181 and refurbished for the flight 182 campaign

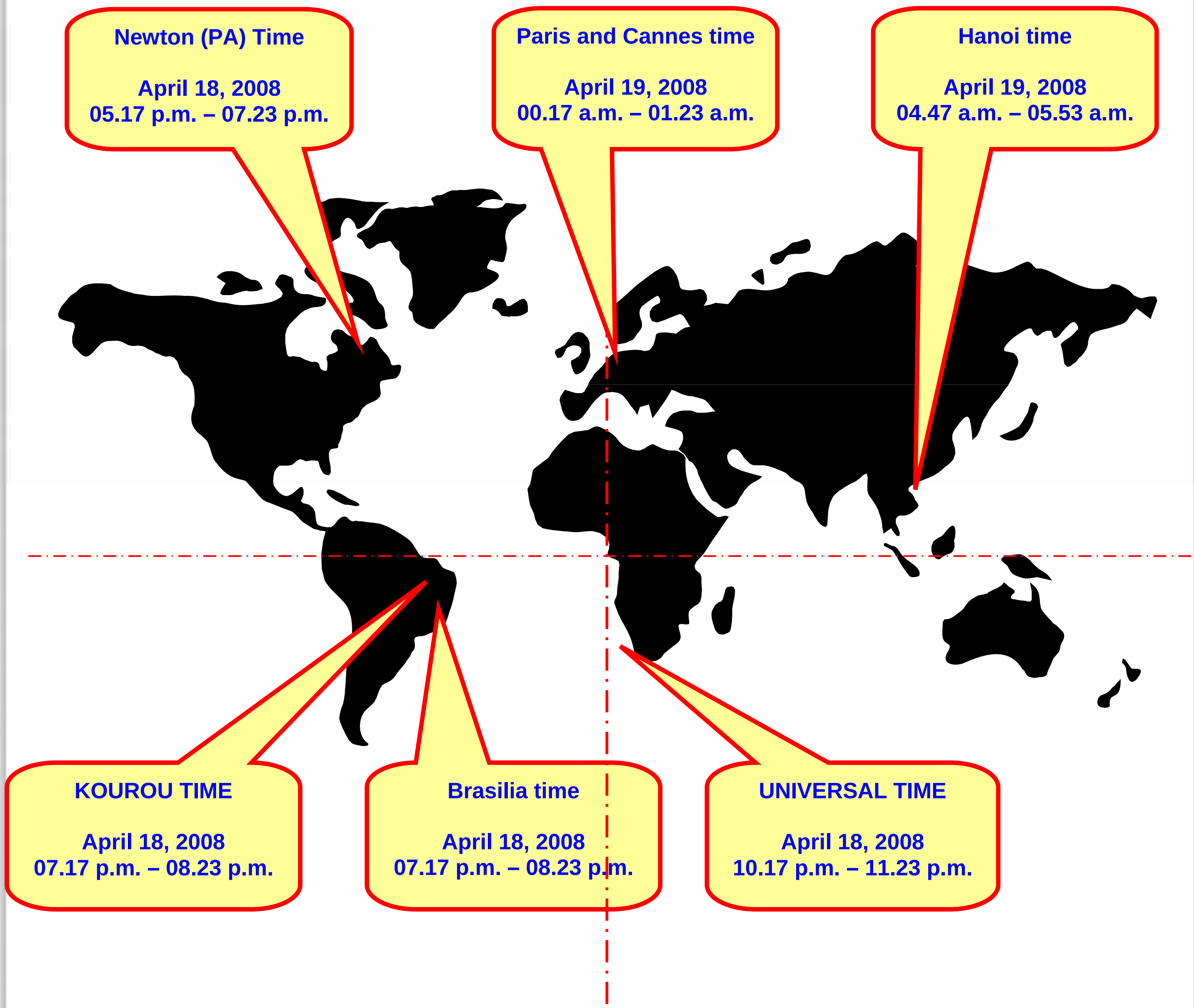
Kourou: erection of the Upper Composite in the Launcher Integration Building (BIL)

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 **April 18, 2008**, with **H_0** at **10.17 p.m. (TU)** is at **11.23 p.m. (TU)**.

The launch window will last 67 minutes:



The launch window is based on a compromise between launcher and payload constraints.

The launch window will open at the same time for a launch up to 21 April, and will then shift forward 2 minutes up to 29 April. The launch window will remain stable during this period (between 1 hour 5 minutes and 1 hour 7 minutes).

7. Final countdown

The final countdown includes all operations for preparation of the launcher, satellites and launch base. Correct execution of these operations authorizes ignition of the Vulcain engine, followed by the solid propellant boosters at the selected launch time, as early as possible inside the launch window for the satellites. The countdown terminates with a synchronized sequence managed by the Ariane ground checkout computers, starting at H_0 - 7 min. In some cases, a pre-synchronized sequence may be necessary to optimize fuelling of the main cryogenic stage (*). If a countdown hold pushes time H_0 outside the launch window, the launch is postponed to D+1 or D+2, depending on the nature of the problem and the solution adopted.

H_0 - 7 hours 30	**Checkout** of electrical systems, red status indicators and countdown time. **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: pressurization of the ground tanks (30 minutes) chill-down of the ground lines (30 minutes) fuelling of the stage tanks (2 hours) topping up (up to synchronized sequence)
H_0 - 5 hours	**Pressurization 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: pressurization of the ground tanks (30 minutes) chill-down of the ground lines (30 minutes) fuelling of the stage tanks (1 hour) topping up (up to synchronized sequence)
H_0 - 3 hours	**Chill-down of the Vulcain engine**
H_0 - 30 minutes	**Preparation of the synchronized sequence**
H_0 - 7 minutes	**Beginning of the synchronized sequence (*)**

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

Synchronized sequence

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

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

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

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

FLUID SYSTEMS	ELECTRICAL SYSTEMS
H_0 - 6 min 30s Termination of topping up (LOX and LH_2) LOX and LH_2 topped up to flight value Launch pad safety flood valves opened	**H_0 - 6 min 30s** Arming of pyrotechnic line safety barriers
H_0 - 6 min: Isolation of the ESC-A helium sphere	
H_0 - 4 min Flight pressurization of EPC tanks Isolation of tanks and start of EPC ground/OB interface umbilical circuit flushing Termination of ESC-A LOX topping up ESC-A LOX transition to flight pressure	
H_0 - 3 min 40: termination of ESC-A LH2 topping up	
H_0 - 3 min10: ESC-A LH_2 transition to flight pressure	**H_0 - 3 min 30 :** Calculation of ground H_0 and verification that the second OBC has switched to the observer mode
H_0 - 2 min: Vulcain bleeder valves opened Engine ground chill-down valve closed	**H_0 - 3 min** H_0 loaded in the 2 OBCs H_0 loaded in OBCs checked against ground H_0 **H_0 - 2 min 30s:** Electrical heating of EPC and VEB batteries, and electrical heating of the Vulcain 2 ignition system shut down
H_0 - 1min 5s Termination of ESC-A tank pressurization from the ground, and start of ESC-A valve plate seal-tightness checkout	**H_0 - 1 min 50s** Pre-deflection of the HM7B nozzle **H_0 - 1min 5s** Launcher electrical power supply switched from ground to OB
H_0 - 30s Verification of ground/OB umbilical circuit flushing EPC flue flood valves opened	**H_0 - 37s** Startup of ignition sequence automatic control system Startup of OB measurement recorders Arming of pyrotechnic line electric safety barriers
H_0 - 16.5 s Pressurization of POGO corrector system Ventilation of fairing POP and VEB POE connectors and EPC shut down	**H_0 - 22s** Activation of launcher lower stage attitude control systems Authorization for switchover to OBC control
H_0 - 12 s Flood valves opening command	

IRREVERSIBLE SEQUENCE

H_0 - 6s

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

H_0 - 5.5s

Ground information communication bus control switched to OBC

IGNITION SEQUENCE

H_0 - 3s

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

H_0 - 2.5s

Verification of **HM7B** nozzle deflection

H_0 - 1.4s

Engine flushing valve closed

H_0 - 0.2s

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

$H_0 \rightarrow H_0$ + 6.65s

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

H_0 + 6.9s

End of Vulcain engine checkout

H_0 + 7,05s

Ignition of the **EAPs**

8. Flight sequence

time $/H_0$ (s)	time$/H_0$ (mn)	event	altitude (km)	mass (kg)	Vreal (m/s)
- - - -		**EAP-EPC powered flight**			- - -
7.31	0 ' 07 ''	Lift-off	---	775.4	0
12.48	0 ' 13 ''	Start of tilt manoeuvre	0,1	748.8	37
17.05	0 ' 17 ''	Start of roll manoeuvre	0,3	724.0	76
32.05	0 ' 32 ''	End of roll manoeuvre	2,5	646.1	214
49.1	0 ' 49 ''	Transsonic (Mach = 1)	6,9	579.5	323
66.3	1 ' 06 ''	Pdyn max.	12,8	510.8	490
111.6	1 ' 52 ''	Transition to γ_{max} (41.17 m/s^2)	40,0	310.9	1,534
139.6	2 ' 20 ''	Transition to $\gamma = 6,11$ m/s² H_1	65,9	254.4	1,975
140.3	**2 ' 20 ''**	**EAP separation**	**66,6**	**175.7**	**1,976**
- - - -		**EPC powered flight**			- - - -
189	3 ' 09 ''	Fairing jettisoned	104,9	157.8	2,146
436	*7 ' 16 ''*	*Acquisition Natal*	*200,1*	*78.0*	*4,543*
535	8 ' 55 ''	EPC burnout (H_2)	208,4	46.1	6,714
541	**9 ' 01 ''**	**EPC separation**	**208,8**	**26.6**	**6,740**
- - - -		**ESC-A powered flight**			- - - -
545	9 ' 05 ''	ESC-A ignition	209,1	26.6	6,743
793	*13 ' 13 ''*	*Acquisition Ascension*	*207,1*	*23.0*	*7,362*
808	*13 ' 28 ''*	*Lost Natal*	*208,0*	*22.8*	*7,403*
1,098	*18 ' 18 ''*	*Acquisition Libreville*	*217,1*	*18.5*	*8,234*
1,120	*18 ' 40 ''*	*Lost Ascension*	*219,4*	*18.2*	*8,301*
1,414	*23 ' 34 ''*	*Acquisition Malindi*	*245,3*	*13.8*	*9,216*
1,481	24 ' 41 ''	**ESC-A burnout (H_{3-1})**	588,2	12.8	9,408

time /H_0 (s)	time/H_0 (mn)	event		altitude (km
- - - -		"Ballistic" phase		- - -
1,483	24 ' 43 "	Phases 1 / 2	Adjustment manoeuvres at start of SCAR phase	592
1,487	24 ' 47 "	Phase 3	Start of STAR ONE C2 orientation	600
1,542	25 ' 42 "	Phase 4/5	Slow spin-up for STAR ONE C2	721
1,566	**26 ' 06 "**	**STAR ONE C2 separation ($H_{4.1}$)**		**778**
1,576	26 ' 16"	Phase 7	Composite despin	802
1,579	26 ' 19 "	Phase 8	Start of SYLDA orientation	811
1,725	28 ' 45 "	**SYLDA separation ($H_{4.2}$)**		1,218
1,735	28 ' 55 "	Phase 10	Start of VINASAT-1 orientation	1,249
1,834	30 ' 34"	Phases 11 / 12	Slow spin-up for VINASAT-1	1,573
1,857	**30 ' 57 "**	**VINASAT-1 separation ($H_{4.3}$)**		**1,652**
1,867	31 ' 07 "	Phase 14	Composite despin	1,687
1,869	31 ' 09 "	Phase 15 to 17	ESC-A orientation for the final spin-up	1,695
2,281	38 ' 01 "	Phase 19	Start of spin-up at 45°/s	3,299
2,318	38 ' 38 "	Oxygen tank passivation (breakdown S34)		3,455
2,386	39 ' 46 "	Phase 20	Start of ESC-A pre-passivation	3,741
2,511	41 ' 51 "	Start of ESC-A passivation (breakdown S37)		4,272

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

9. EADS ASTRIUM and the ARIANE programmes

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

EADS Astrium, a wholly owned subsidiary of **EADS**, is dedicated to providing civil and defence space systems. In 2007, **EADS Astrium** had a turnover of €3.5 billion and 12,000 employees in France, Germany, the United Kingdom, Spain and the Netherlands.

EADS is a global leader in aerospace, defence and related services. In 2007, **EADS** generated revenues of €39.1 billion and employed a workforce of more than 116, 000.

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

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

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

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

EADS Astrium possesses the multidisciplinary expertise required to control a program of this complexity:

- program management: risk, configuration, dependability and documentation management
- technical management: approval of the definition and qualification of launcher elements, overall coherence control and interface management
- system engineering: integrated system (aerodynamic, acoustic, thermal, structural, flight mechanics, guidance and attitude control and POGO correction) studies, and testing (acoustic, thermal, dynamic and electrical models)
- flight programs: design, qualification and development of flight programs, each specific to a particular mission
- customer assistance: the company plays a major role in Ariane launch campaigns, providing support for Arianespace throughout launch operations
- mission analysis and flight data analysis after each launch

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

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

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

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

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

Ariane 5 Integration Site in Les Mureaux (France)

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

Site Internet ARIANESPACE : www.arianespace.com