

KOUROU

December 2014

# ARIANE 5

Data relating to Flight 221



DIRECTV 14



GSAT 16



जीसैट-१६  
GSAT-16

**arianespace**  
service & solutions

 **AIRBUS**  
DEFENCE & SPACE

## **Flight 221 Ariane 5**

### **Satellites: DIRECTV 14 – GSAT 16**

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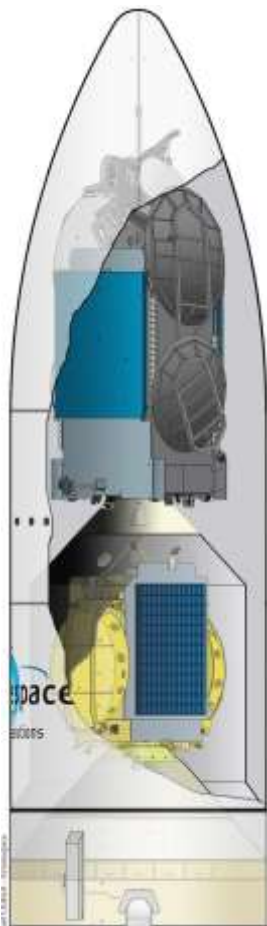


## 1. Introduction

Flight 221 is the 77<sup>th</sup> **Ariane 5 launch** and the sixth in 2014. It follows on from a series of 62 consecutive successful **Ariane 5** launches. An **ARIANE 5 ECA** (Cryogenic Evolution type **A**), the most powerful version in the **ARIANE 5** range, will be used for this flight.

Flight 221 is a commercial mission for Ariane 5. The **L575** launcher is the twenty-first to be delivered by **Airbus Defence and Space** to **Arianespace** as part of the PB production batch. The PB production contract was signed in March 2009 to guarantee continuity of the launch service after completion of the PA batch comprising 30 launchers. The PB production batch comprises 35 A5ECA launchers and covers the period from 2010 to 2016. On 14<sup>th</sup> December 2013, it was extended by an order for a further 18 ECA launchers, scheduled for launch as of 2017. L575 is consequently the fifty-first complete launcher to be delivered to **Arianespace**, integrated and checked out under **Airbus Defence and Space** responsibility in the Launcher Integration Building (BIL).

In a dual-payload configuration using the **SYLDA 5 "C"** system and a long pattern fairing (total height: 17 m), the launcher is carrying the communications satellites **DIRECTV 14** in the upper position and **GSAT 16** in the lower position.



Installed inside the long pattern fairing built by:

**RUAG Aerospace AG**

**DIRECTV 14** built by:

**SSL (Space Systems / Loral)**

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

**Airbus Defence and Space SA**

Located inside the **SYLDA 5 C** built by:

**Airbus Defence and Space SAS**

**GSAT 16** built by:

**I.S.R.O.**

Strapped to a type **PAF 1194VS** adaptor built by:

**RUAG Aerospace AB**

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 L575

### 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**
  - **LVA 3936**

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**

© Airbus Defence and Space



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

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

The main stage burns continuously for about **540 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 **160.4 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 **133 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*).

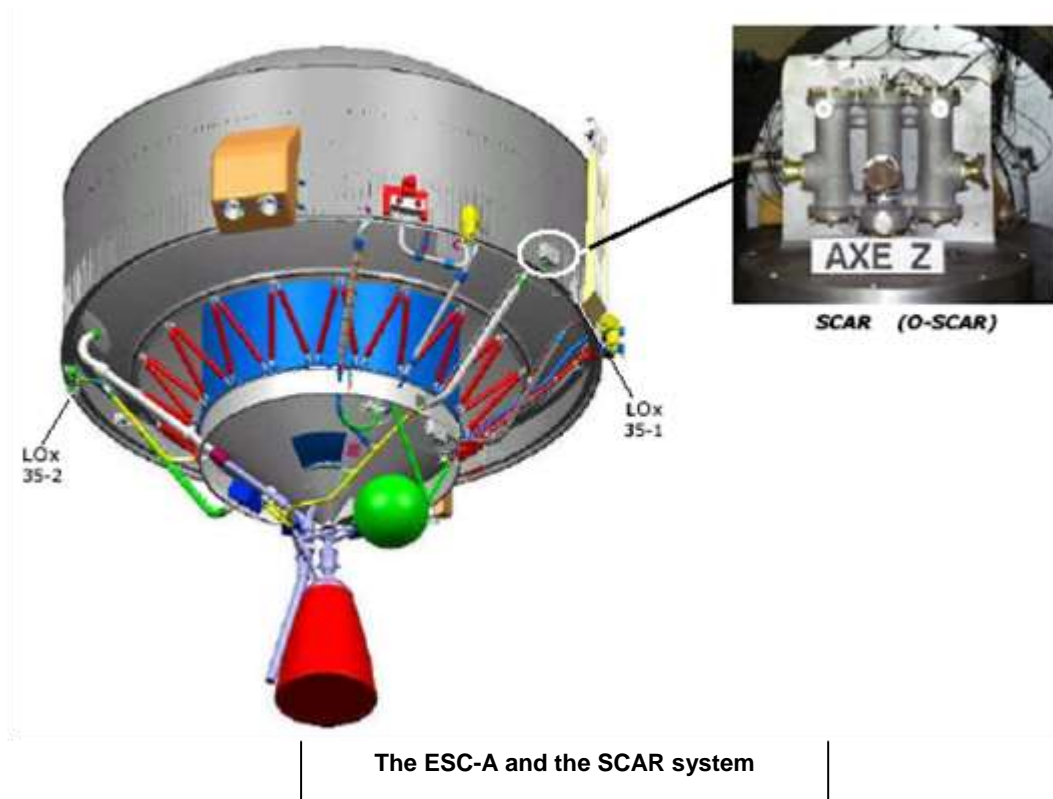
### Type-A cryogenic upper stage:

The **ESC-A** 3<sup>rd</sup> stage has been developed for the A5ECA version of the Ariane 5 Plus launcher, and is based on the **HM7b** engine previously used for the 3<sup>rd</sup> stage of the Ariane 4 launcher.

The ESC-A stage comprises:

- two tanks containing 14.7 tons propellant (LH<sub>2</sub> and LOX),
- **HM7b** engine delivering 6.5 tons thrust in vacuum for a burn time of about **960s**. 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** 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).

Thanks to the Level 1 flight operations, it was proven that the use of the **O-SCAR** blocks alone was sufficient to control the launcher during the powered flight phase (roll control) and the ballistic phase (3-axis control). This modification allows an increase of about 20 kg in the mass allocated to the satellites.



This upgrade is being applied for the second time on launcher **L575**.



**ESC-A thrust frame**  
© Airbus Defence and Space




**Ariane 5 ECA launcher in transit to launch pad ZL3 for the launch sequence rehearsal (RSL)**  
© ESA/CNES/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 twenty-second 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 L575 was assembled for the thirty-fourth time at the **Airbus Defence and Space** site in Bremen, in order to meet needs resulting from the increase in production rates for the coming years.





Data relating to Flight 221

**Assembly of the Upper Composite at the Bremen site**  
© Airbus Defence and Space



## Nose fairing

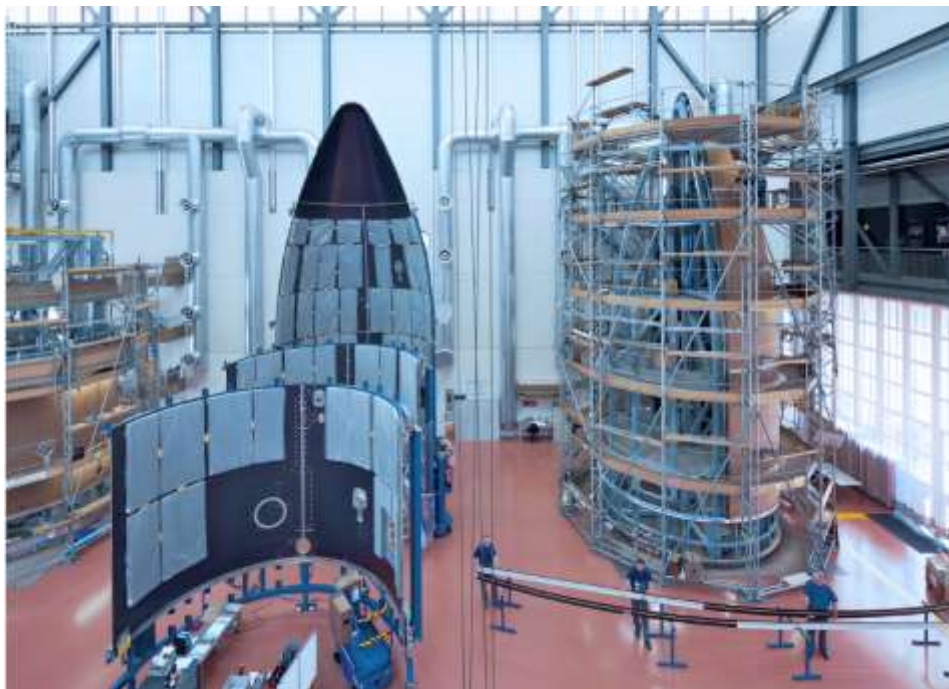


The ogival nose fairing protects the payloads during the atmospheric flight phase (acoustic protection on lift-off and during transonic flight, aerothermodynamic flux).

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.



**Fairing production line**

© RUAG Aerospace AG

### **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<sup>3</sup>.

For this mission, as for the previous one, a **SYLDA 5 'C'** with a **height of 5.80 m** will be used. It enables the carriage of a payload in the lower position, **GSAT 16**. For the eleventh time on this flight, the structure was manufactured using a new "co-curing" method, enabling the industrial process to be rationalised.



**SYLDA 5 No. 62-C for launcher L575 at Les Mureaux**  
© Airbus Defence and Space



### LVA 3936 (Launch Vehicle Adapter 3936 mm):

Launcher **L575** is the first one equipped with an **LVA 3936**.

This conical part enables the launcher diameter to be adapted to that of its payload attach fittings (PAF) with a diameter of 1780 mm. It transmits launcher thrust to the payloads and, by means of a tight membrane, it contributes to ensuring the cleanness and thermal environment of the compartment under the fairing.



It mainly consists of a carbon fibre cone, metal interface flanges and the flexible membrane.

It was developed in Spain by **Airbus Defence & Space SA** as part of the "**Performance Improvement Plan**" and replaces the Cone 3936 and LVA 2624 assembly, allowing an increase of about 80 kg in the mass allocated to the satellites, by eliminating a bolted connection and through structural optimisation, for a payload in the lower position in a dual launch.

The **Cone 3936**, initially integrated into the Upper Composite in Bremen, was replaced by the **LVA 3936** during the BIL campaign in Kourou.



LVA 3936 in Barajas and in Kourou  
© Airbus Defence and Space



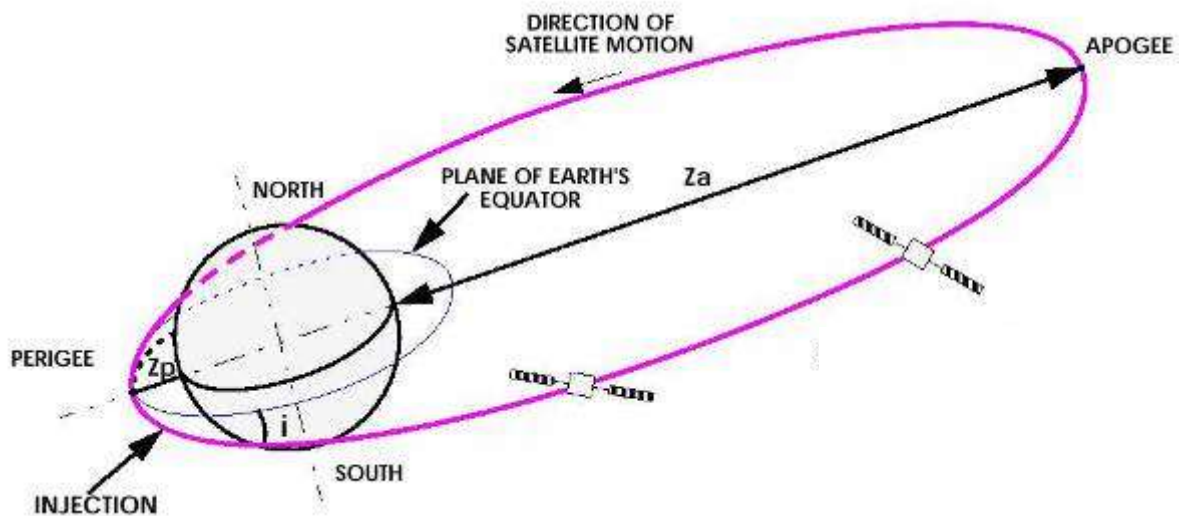
### 3. Mission V221

#### Payload mission

The main mission of Flight 221 is to place the **DIRECTV 14** and **GSAT 16** commercial payloads into a standard GTO orbit:

Apogee altitude	35,786 km
Perigee altitude	249.5 km
Inclination	6°
Perigee argument	177.988°
Ascending node longitude	-122.002°(*)

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



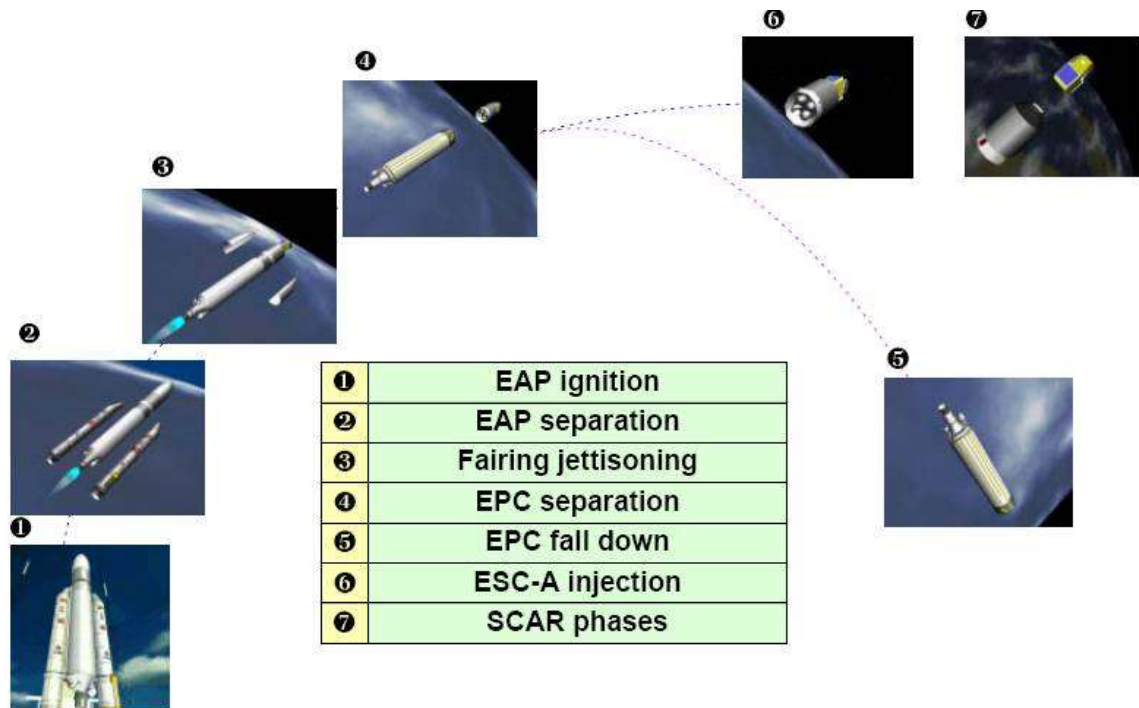
The mass of **DIRECTV 14** is **6,299 kg**, with **3,182 kg** for **GSAT 16**. Allowing for the adaptors and the **SYLDA 5** structure, total performance required from the launcher for the orbit described above is **10,194 kg**.

For the **fourth** consecutive time, the total performance required of the **ARIANE 5 ECA** launcher exceeds 10 tonnes.

It should be remembered that the maximum performance offered by the Ariane 5 ESC-A launcher exceeds 10,300 kg (**10,317 kg**, performance recorded by Ariane 5 ECA L568-V212, on 7 February 2013, with **AZERSPACE / AFRICASAT-1A** for **AZERCOSMOS OJS Co.**, and **AMAZONAS-3** for **Grupo HISPASAT**) for a standard orbit inclined at 6°.

This shows the launcher's adaptability in terms of payload weight.

## 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 774.5 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 **92°** 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  $H_0 + 139.6$  s at an altitude of 65.4 km and a relative velocity of 2009.2 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 199 s after lift-off at an altitude of 108.7 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	160.7 km
Perigee altitude	-983.0 km
Inclination	6.32°
Perigee argument	-43.77°
Ascending node longitude	-121.66°

This is time reference  $H_2$ . It happens at  $H_0 + 539.3$  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  $-2.20^\circ$ . The longitude of the point of impact is  $6.94^\circ \text{W}$ .

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.

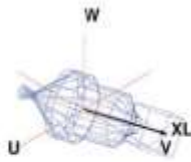
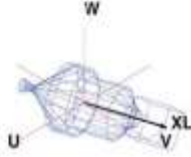
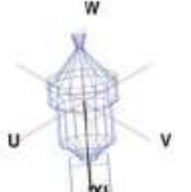
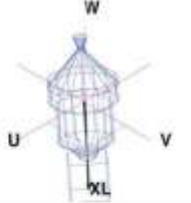
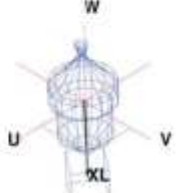
This is time reference  $H_3$ . It happens at  $H_0 + 1,507.2$  s.

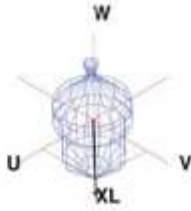
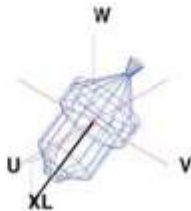
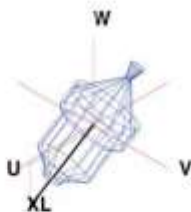
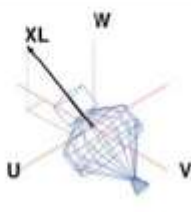
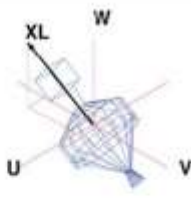
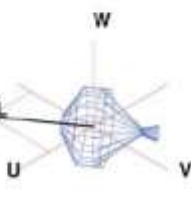


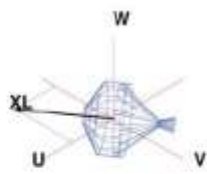
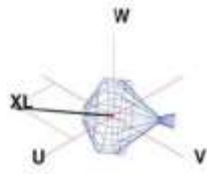
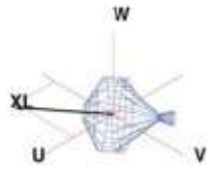
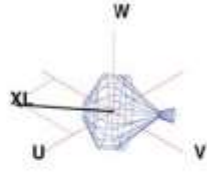
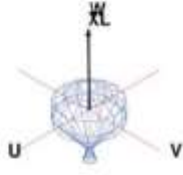
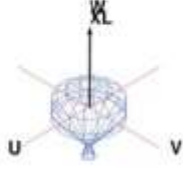
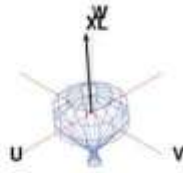
The purpose of the following ballistic phase is to ensure:

- Pointing of the upper composite in the directions required by **DIRECTV 14** and **GSAT 16** and then in that required for **SYLDA 5**,
- Launcher transverse spin-up before separation of **DIRECTV 14**
- Triple-axis stabilisation of the launcher before separation of **SYLDA 5** and **GSAT 16**,
- Separation of **DIRECTV 14**, **SYLDA 5** and **GSAT 16**,
- Final spin-up of the composite at 45°/s,
- Passivation of the ESC-A stage pressurised LOX tank and LH<sub>2</sub> tank, preceded by a pre-passivation phase involving simultaneous opening of the 4 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 18 elementary phases described hereafter. These include separation of **DIRECTV 14** (phase 5), **SYLDA 5** separation (phase 8), and **GSAT 16** separation (phase 10).

<p><u>Phase n° 1</u> Transverse velocity control (minimizing the transverse angular rate) Duration: 0.57600 s LOX valves are closed.</p>	
<p><u>Phase n° 2</u> Despin Duration: 0.57600 s LOX valves are closed.</p>	
<p><u>Phase n° 3</u> Tilting aiming at the following orientation: U = 0.1826 V = 0.2990 W = -0.9366 Duration: 120.0 s The LOX valves are opened from 30.0 to 100.0s</p>	
<p><u>Phase n° 4</u> Slow spin up to 1.50000 °/s Duration: 40.0 s LOX valves are closed.</p>	
<p><u>Phase n° 5</u> Transverse angular velocity control Stand-by of 10s for DIRECTV 14 separation LOX valves are closed.</p>	

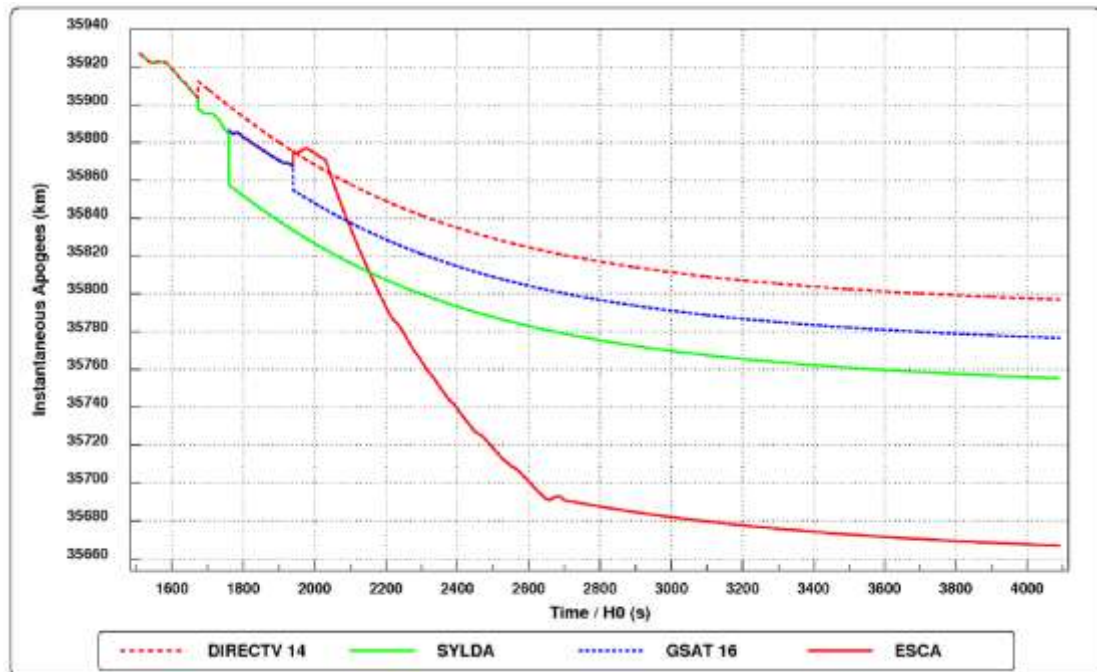
<p><u>Phase n° 6</u>  Transverse velocity control  (minimizing the transverse angular rate)  Duration: 5.0 s  LOX valves are closed.</p>	
<p><u>Phase n° 7</u>  Tilting aiming at the following orientation:  <math>U = 0.8677</math>  <math>V = 0.0593</math>  <math>W = -0.4935</math>  Duration: 70.0 s  LOX valves are closed.</p>	
<p><u>Phase n° 8</u>  Transverse angular velocity control  Stand-by of 10s for SYLDA5 C separation  LOX valves are closed.</p>	
<p><u>Phase n° 9</u>  Tilting aiming at the following orientation:  <math>U_{beg} = 0.2141 / U_{end} = 0.0088</math>  <math>V_{beg} = -0.6420 / V_{end} = -0.8013</math>  <math>W_{beg} = 0.7362 / W_{end} = 0.5982</math>  Duration: 170.0 s  LOX valves are closed.</p>	
<p><u>Phase n° 10</u>  Transverse angular velocity control  Stand-by of 10s for GSAT 16 separation  LOX valves are closed.</p>	
<p><u>Phase n° 11</u>  Tilting aiming at the following orientation:  <math>U = 0.5785</math>  <math>V = -0.8157</math>  <math>W = 0.0000</math>  Duration: 80.0 s  LOX valves are closed.</p>	

<p><u>Phase n° 12</u>  Tilting aiming at the following orientation:  <math>U = 0.5785</math>  <math>V = -0.8157</math>  <math>W = 0.0000</math>  Duration: 140.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 13</u>  Low consumption manoeuvre using "CA=4" pilot mode  Duration: 350.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 14</u>  Transverse velocity control  (minimizing the transverse angular rate)  Duration: 10.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 15</u>  Despin  Duration: 5.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 16</u>  Tilting aiming at the following orientation:  <math>U = 0.0000</math>  <math>V = 0.0000</math>  <math>W = 1.0000</math>  Duration: 150.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 17</u>  Spin up to 45.0 °/s  Duration: 60.0 s  The LOX valves are opened during the whole manoeuvre</p>	
<p><u>Phase n° 18</u>  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 1137.600 s after GSAT 16 separation (<math>H_{4,3}</math>), which also ends this manoeuvre.  The LOX valves are opened during the whole manoeuvre</p>	



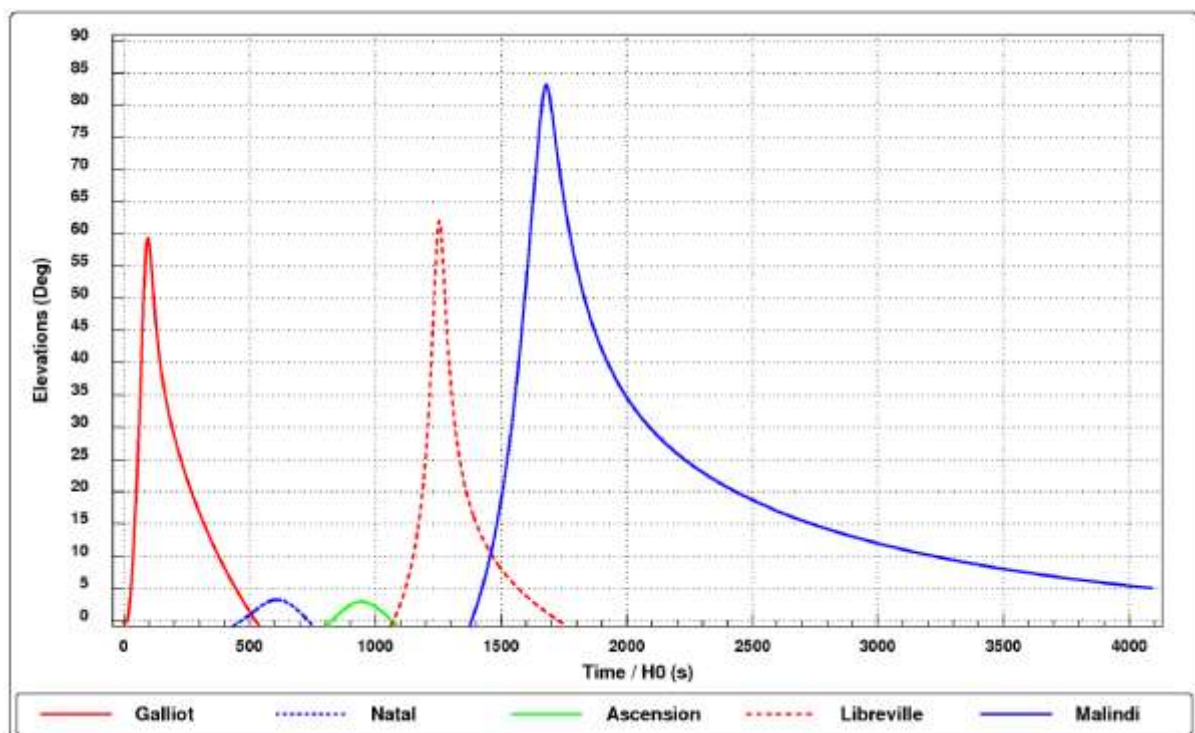
## Data relating to Flight 221

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.

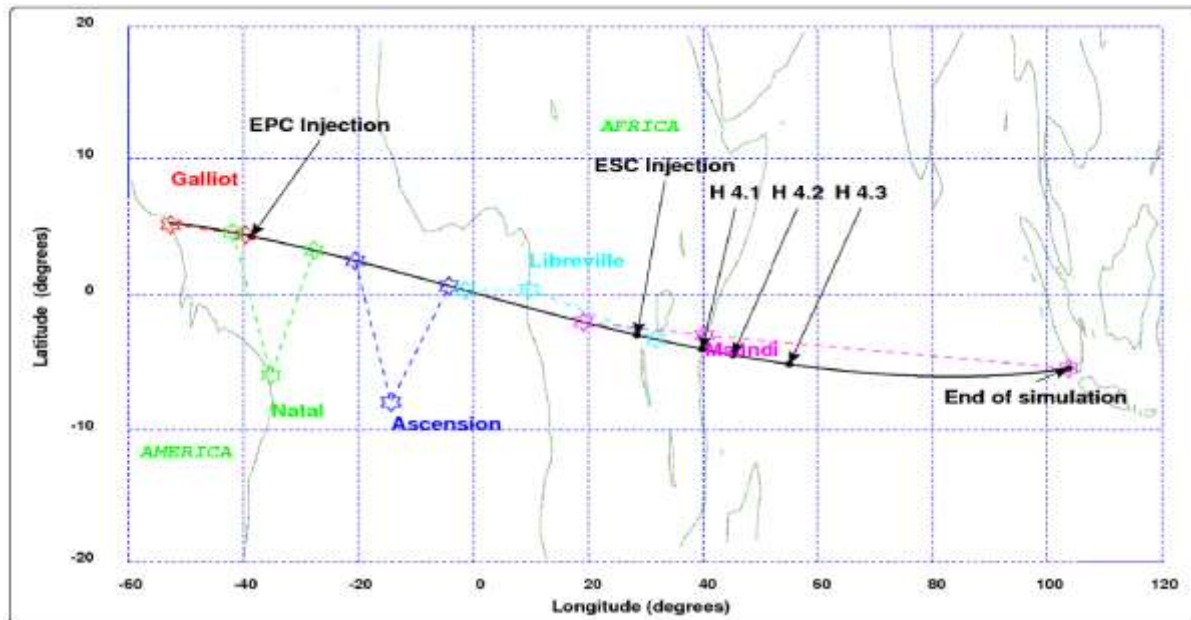
With the performance necessary for this mission, the trajectory includes two periods of visibility loss: between Natal and Ascension (~109 s.) and between Ascension and Libreville (~39 s.):



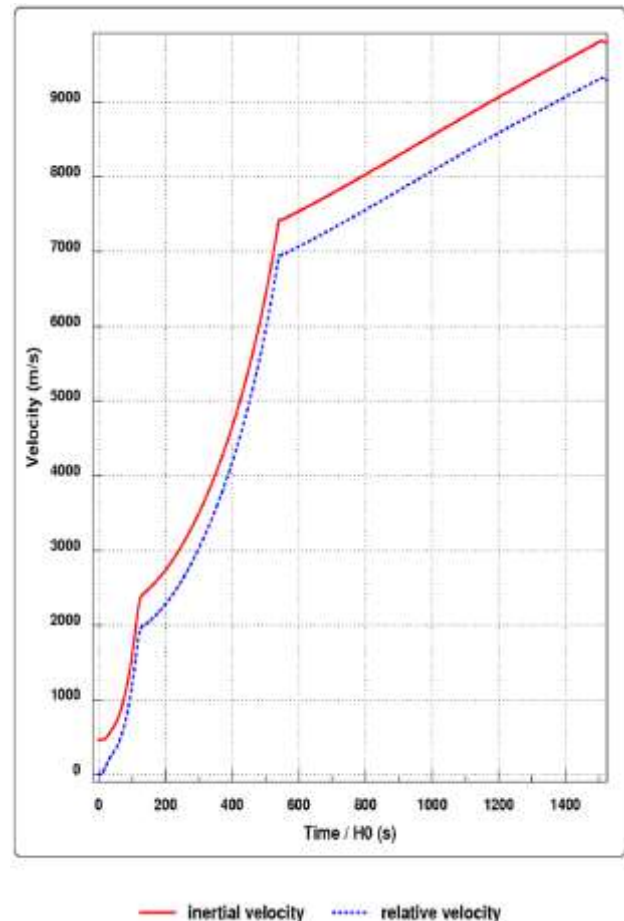
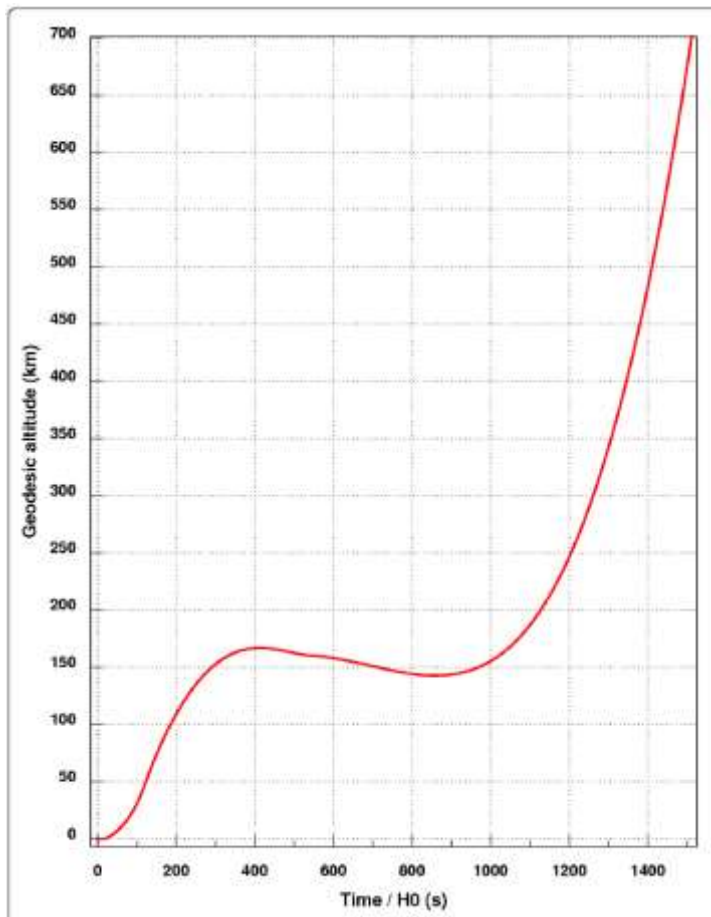
## Data relating to Flight 221

The following plates show:

- Situation of the main events of the flight



- Evolution of launcher altitude during powered flight.





## 4. Payloads

### DIRECTV 14

#### DIRECTV

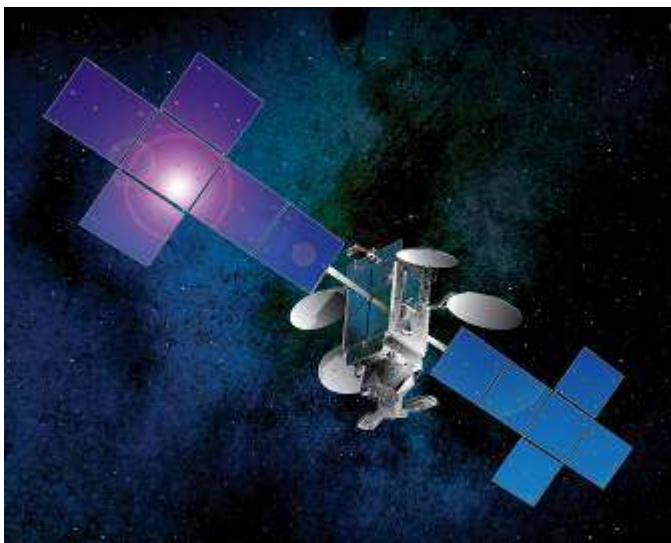
**DIRECTV** is based in **El Segundo** and is one of the world's leaders in the field of satellite television. With its various subsidiaries and stakeholdings in the United States, Brazil, Mexico and other countries of South America and the Caribbean, **DIRECTV** supplies TV programmes to more than 20 million customers in the USA and more than 18 million in Latin America.

The **Hughes Aircraft** company set up **DIRECTV** in 1990. The service came on-stream in June 1994 and the company then enjoyed rapid growth. In November 1995, **DIRECTV** reached one million subscribers, in July 2001 ten million and in October 2005 fifteen million. In January 2006, **DIRECTV** completed its acquisition of **DIRECTV Latin America**.

Working mainly in Ku, Ka and Reverse bands, currently with a fleet of 11 satellites, **DIRECTV** operates from 5 orbital positions (99° West, 101°W, 103°W, 110°W and 119°W). **DIRECTV Latin America** currently leases transponders on other satellites (for example **Intelsat-30**, with the **DLA-1** payload, launched last October on an **ARIANE 5**), but the company is on the point of launching its first two satellites **SKY Mexico-1** and **SKY Brasil-1**.

**DIRECTV** will soon be entrusting a further two satellites to the **Ariane 5** launcher: **DIRECTV 15** and **SKY Mexico-1** in the spring of 2015.

### DIRECTV 14



DIRECTV 14 in orbit (Artist's impression)

© SSL

The **DIRECTV 14** satellite is the 16<sup>th</sup> satellite launched for the **DIRECTV** operator, and will thus be the 12<sup>th</sup> satellite in its fleet. Using the latest technological advances in high-power transmission and narrow beams, it will provide direct to home (**DTH**) television in **HD** and **Ultra HD** in North America. It will enable the **DIRECTV** operator to boost its offering, in particular by increasing the number of 3D channels and "video on demand" services.





**DIRECTV 14**, based on the **1300 Bus** platform from **SSL**, is the **7<sup>th</sup>** satellite launched by Arianespace for **DIRECTV** and has the following main characteristics:

* Dimensions	<ul style="list-style-type: none"> <li>• 8.45 x 2.40 x 2.20 m</li> <li>• In-orbit span: 32.50 m</li> </ul>
* Mass	<ul style="list-style-type: none"> <li>• Lift-off 6,299.4 kg</li> </ul>
* Power	<ul style="list-style-type: none"> <li>• 3 Batteries Li-Ion</li> </ul>
* Propulsion	<ul style="list-style-type: none"> <li>• Biliquid propellant tanks (MMH &amp; MON3)</li> <li>• 455 N apogee kick motor and 22 N nozzles for orbit control</li> <li>• Plasma nozzles SPT 100 (0.1 N)</li> </ul>
* Stabilisation	<ul style="list-style-type: none"> <li>• Transverse spin-up at separation</li> <li>• Triple-axis stabilisation in orbit</li> </ul>
* Transmission capacity	<ul style="list-style-type: none"> <li>• 16 Ka-band transponders</li> <li>• 18 Reverse-band transponders</li> </ul>
* Orbit Position	<ul style="list-style-type: none"> <li>• 99° West</li> </ul>
* Coverage	<ul style="list-style-type: none"> <li>• United-States (with Alaska and Hawaii), Puerto-Rico</li> </ul>
Expected lifetime exceeds 15 years	



**DIRECTV 14 in Palo-Alto (CA)**

© SSL



**DIRECTV 14 in Palo-Alto**

© SSL





**DIRECTV 14 being positioned under the fairing in Kourou**

© ESA-CNES-ARIANESPACE-Optique du CSG-JM Guillon

## GSAT 16



The Indian space programme was launched with the aim of developing independent space technology for a range of national projects (TV broadcasting, telecommunications, meteorology, natural resources management, etc.). The **I.S.R.O.** (Indian **S**pace **R**esearch **O**rganisation) has therefore successfully developed:

- Two major satellite systems:
  - **INSAT** (Indian **N**ational **SAT**ellites) for communications,
  - **IRS** (Indian **R**emote **S**ensing) for natural resources management
- Two families of launchers:
  - **PSLV** (**P**olar **S**atellite **L**aunch **V**ehicle) to launch IRS type satellites,
  - **GSLV** (**G**eostationary **S**atellite **L**aunch **V**ehicle) for INSAT type satellites

**I.S.R.O.** today operates a constellation of ten Telecommunications satellites, three Navigation satellites, two Meteorological satellites and ten Earth Observation satellites. An Indian probe is also at present in an elliptical orbit around the planet Mars.

**I.S.R.O.** has so far run a large number of projects, in particular the production of 71 satellites and the performance of 44 launches, with 40 non-Indian payloads.

## GSAT 16

Indian National Satellite (**INSAT**) system, established in 1983, is one of the largest domestic communication satellite systems in the Asia-Pacific Region. It presently comprises ten satellites providing transponders in **Ku**, **C**, **S** and **C 'Upper Extended'** bands.



**GSAT 16 (Artist's impression)**

© I.S.R.O.

**GSAT 16**, an advanced multiband communication satellite, weighing 3182 kg at lift-off, is being inducted into the INSAT/GSAT system. **GSAT 16** is configured to carry a total of 48 communication transponders - the largest number of transponders carried by a communication satellite developed by **ISRO** so far - in **C**, **C 'Upper Extended'** and **Ku** band. **GSAT 16** carries a Ku-band beacon as well to help accurately point ground antennas towards the satellite.

The designed on-orbit operational life of **GSAT 16** exceeds 12 years. The multi-band payload, with a power of 4.6 kW, offers a complete and varied range of services over the coverage area. It ensures secure continuity of service by the **INSAT** system, while offering additional capacity.

Launch and early orbit phase satellite manoeuvres for the satellite will be controlled by the Indian Hassan station.

**GSAT 16** will be positioned at 55° East. It will be co-located with the **GSAT 8**, **IRNSS 1A** and **IRNSS 1B** satellites.



**GSAT 16**, based on the **I-3K** platform, is the 18<sup>th</sup> satellite entrusted by **I.S.R.O.** to **Arianespace** and has the following main characteristics:

* Dimensions	<ul style="list-style-type: none"> <li>3.10 x 2.00 x 1.77 m</li> <li>In-orbit span: 15.50 m</li> </ul>
* Mass	<ul style="list-style-type: none"> <li>Lift-off 3,181.6 kg</li> </ul>
* Power	<ul style="list-style-type: none"> <li>Payload power: &gt; 5,600 W</li> <li>2 Batteries Li-Ion</li> </ul>
* Propulsion	<ul style="list-style-type: none"> <li>Biliquid propellant tanks (MMH &amp; MON3)</li> <li>440 N apogee kick motor</li> </ul>
* Stabilisation	<ul style="list-style-type: none"> <li>Transverse spin-up at separation</li> <li>Triple-axis stabilisation in orbit</li> </ul>
* Transmission capacity	<ul style="list-style-type: none"> <li>12 Ku-band transponders</li> <li>24 C-band transponders</li> <li>12 C-band 'Upper Extended' transponders</li> </ul>
* Orbit Position	<ul style="list-style-type: none"> <li>55° East</li> </ul>
* Coverage	<ul style="list-style-type: none"> <li>Indian subcontinent</li> </ul>
Expected lifetime exceeds 12 years	



**GSAT 16 in Kourou  
during composite integration**

© ESA-CNES-ARIANESPACE-Optique du CSG-JM Guillon



**GSAT 16**  
**before vacuum testing in Bangalore**

© I.S.R.O.





जीसैट-१६  
GSAT-16



GSAT 16 during testing in Bangalore

© I.S.R.O.



## 5. Launch campaign



The Ariane 5 main cryogenic stage (EPC) in the integration dock at Les Mureaux, France, in course of preparation for tilt and containerization

© Airbus Defence and Space photo: Studio Bernot



ESC-A undergoing integration at ASTRIUM Bremen

© Airbus Defence and Space

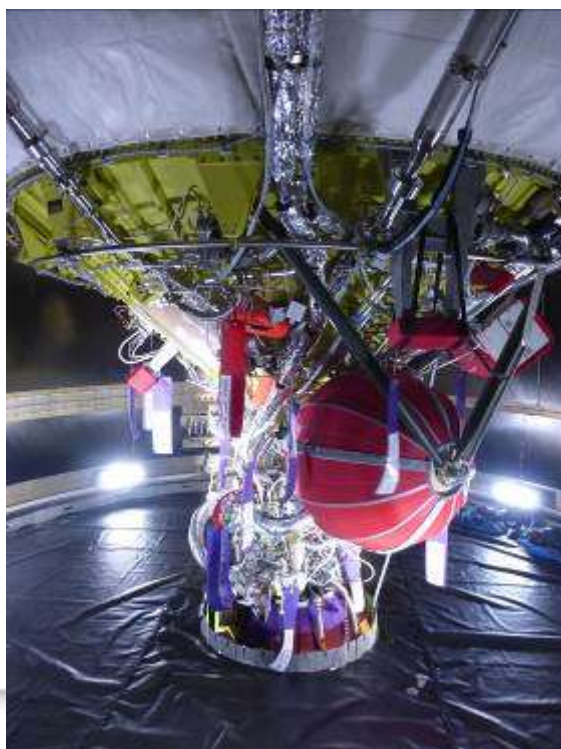
The main cryogenic stage loading on board the "Toucan" in the port of Le Havre for shipment to French Guiana

© Airbus Defence and Space photo: JL



Principal phases of the Flight 221 launch campaign:

EPC depreservation and erection in the launcher integration building (BIL)	6 & 7 October 2014
Transfer of Solid Booster Stages (EAP)	7 & 8 October 2014
Mating of the EAPs with the EPC	8 October 2014
Arrival of <b>DIRECTV 14</b> in Kourou	8 October 2014
Depreservation and erection of the Upper Composite	13 October 2014
<b>VA220: Success of the Intelsat 30 / ARSAT 1 mission on L574</b>	<b>16 October 2014</b>
Transfer of <b>GSAT 16</b> in Kourou	21 October 2014
Launcher Synthesis Control	28 October 2014
Launcher acceptance by Arianespace	12 November 2014
Transfer from BIL to BAF	13 November 2014
<b>DIRECTV 14</b> fuelling Assembly on its adaptor Transfer to the BAF Integration on the SYLDA	23 to 27 October 2014 28 October 2014 29 October 2014 30 October 2014
<b>GSAT 16</b> fuelling Assembly on its adaptor Transfer to the BAF Integration on the launcher	13 to 17 November 22 November 2014 24 November 2014 25 November 2014
Integration of the fairing on the SYLDA with <b>DIRECTV 14</b>	24 November 2014
Integration of the composite ( <b>DIRECTV 14</b> + PAS 1194C + SYLDA C + fairing) on the launcher	26 & 27 November
General rehearsal	28 November 2014
Arming of the launcher Flight Readiness Review	1 <sup>st</sup> December 2014 2 <sup>nd</sup> December 2014
Launcher transfer from the BAF to the Pad (ZL3) Fuelling of the EPC helium sphere	3 December 2014
<b>Final countdown</b>	4 December 2014



**Thrust frame after stage integration  
in the BIL**

© Airbus Defence and Space



Data relating to Flight 221



**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)**

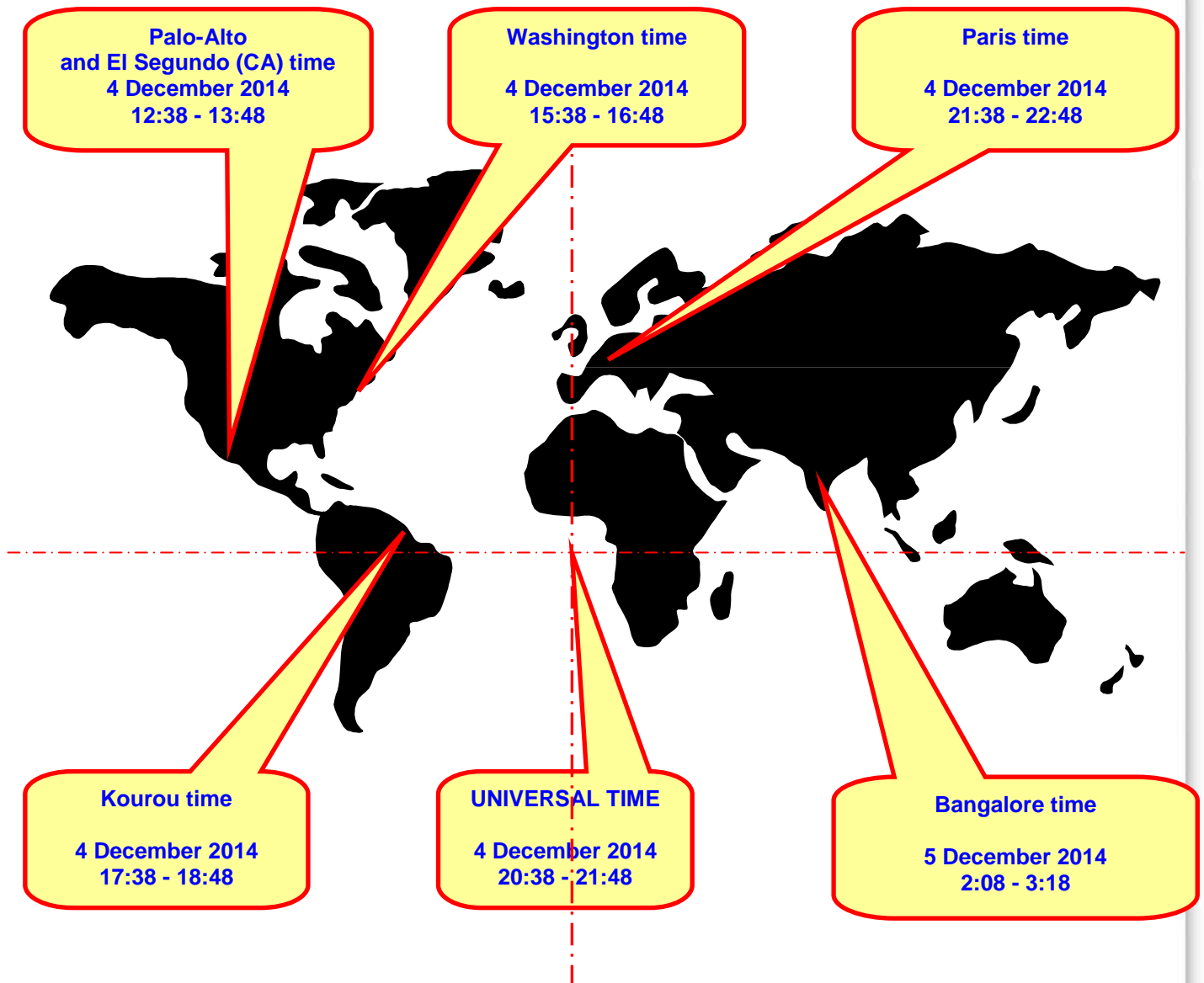
© ESA/ARIANESPACE/Service optique CSG



## 6. Launch window

The window for a launch on **4 December 2014** is with  $H_0$  at **20:38 (UT)**. The closing of the window is at **21:48 (UT)**.

The launch window will last **70 minutes**:



The launch window for this mission is dictated principally by launcher and payloads constraints. In the event of a launch postponement, the window changes as follows:

- ↳ 20:39 - 21:48 on 5 December,
- ↳ 20:40 - 21:49 on 6 and 7 December,
- ↳ 20:41 - 21:49 on 8 December,
- ↳ 20:41 - 21:50 on 9 December.

## 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	<b>Checkout</b> of electrical systems. <b>Flushing</b> and configuration of the <b>EPC</b> and <b>Vulcain</b> engine for fuelling and chill-down
$H_0 - 6$ hours	<b>Final preparation of the launch pad:</b> closure of doors, removal of safety barriers, configuration of the fluid circuits for fuelling. <b>Loading of the flight program</b> <b>Testing of radio links</b> between the launcher and BLA <b>Alignment of inertial guidance units</b>
$H_0 - 5$ hours	<b>Evacuation of personnel from the launch pad</b> <b>Fuelling of the EPC</b> 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	<b>Pressurisation of the attitude control and command systems:</b> (GAT for the EAPs and GAM for the EPC)
$H_0 - 4$ hours	<b>Fuelling of the ESC-A</b> 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	<b>Chill-down of the Vulcain engine</b>
$H_0 - 30$ minutes	<b>Preparation of the synchronised sequence</b>
$H_0 - 7$ minutes	<b>Beginning of the synchronised sequence (*)</b>

(\*) 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  $H_0 - 7 \text{ min}$ .

In the second irreversible phase of the sequence ( $H_0 - 6 \text{ s}$  to  $H_0 - 3.2 \text{ s}$ ), 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
<p><b>H<sub>0</sub> - 6 min 30s</b> Termination of topping up (LOX and LH<sub>2</sub>) LOX and LH<sub>2</sub> topped up to flight value Launch pad safety flood valves opened</p> <p><b>H<sub>0</sub> - 6 min</b> Isolation of the ESC-A helium sphere</p> <p><b>H<sub>0</sub> - 4 min</b> 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</p> <p><b>H<sub>0</sub> - 3 min 40s:</b> termination of ESC-A LH<sub>2</sub> topping up</p> <p><b>H<sub>0</sub> - 3 min 10s:</b> ESC-A LH<sub>2</sub> transition to flight pressure</p> <p><b>H<sub>0</sub> - 2 min:</b> Vulcain 2 bleeder valves opened Engine ground chill-down valve closed</p> <p><b>H<sub>0</sub> - 1 min 5s</b> Termination of ESC-A tank pressurisation from the ground, and start of ESC-A valve plate seal-tightness checkout</p> <p><b>H<sub>0</sub> - 30s</b> Verification of ground/OB umbilical circuit flushing EPC flue flood valves opened</p> <p><b>H<sub>0</sub> - 16.5 s</b> Pressurisation of POGO corrector system Ventilation of fairing POP and VEB POE connectors and EPC shut down</p> <p><b>H<sub>0</sub> - 12 s</b> Flood valves opening command</p>	<p><b>H<sub>0</sub> - 6 min 30s</b> Arming of pyrotechnic line safety barriers</p> <p><b>H<sub>0</sub> - 3 min 30s:</b> Calculation of ground H<sub>0</sub> and verification that the second OBC has switched to the observer mode</p> <p><b>H<sub>0</sub> - 3 min</b> H<sub>0</sub> loaded in the 2 OBCs H<sub>0</sub> loaded in OBCs checked against ground H<sub>0</sub></p> <p><b>H<sub>0</sub> - 2 min 30s:</b> Electrical heating of EPC and VEB batteries, and electrical heating of the Vulcain 2 ignition system shut down</p> <p><b>H<sub>0</sub> - 1 min 50s</b> Pre-deflection of the HM7B nozzle</p> <p><b>H<sub>0</sub> - 1 min 5s</b> Launcher electrical power supply switched from ground to OB</p> <p><b>H<sub>0</sub> - 37s</b> Start-up of ignition sequence automatic control system Start-up of OB measurement recorders Arming of pyrotechnic line electric safety barriers</p> <p><b>H<sub>0</sub> - 22s</b> Activation of launcher lower stage attitude control systems Authorisation for switchover to OBC control</p>

IRREVERSIBLE SEQUENCE	
H <sub>0</sub> - 6s	Arming <b>and</b> 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 <sub>0</sub> - 5.5s	Ground information communication bus control switched to OBC
IGNITION SEQUENCE	
H <sub>0</sub> - 3s	Checkout of computer status Switchover of inertial guidance systems to flight mode Helium pressurisation activated LOX and LH <sub>2</sub> pressures monitored Navigation, guidance and attitude control functions activated
H <sub>0</sub> - 2.5s	Verification of HM7B nozzle deflection
H <sub>0</sub> - 1.4s	Engine flushing valve closed
H <sub>0</sub> - 0.2s	Verification of acquisition of the “cryogenic arms retracted” report by the OBC at the latest moment
H <sub>0</sub> → H <sub>0</sub> + 6.65s	Vulcain engine ignition and verification of its correct operation (H <sub>0</sub> +1s corresponds to opening of the hydrogen chamber valve)
H <sub>0</sub> + 6.9s	End of Vulcain engine checkout
H <sub>0</sub> + 7,05s	Ignition of the EAPs

## 8. Flight sequence

time /H <sub>0</sub> (s)	time/H <sub>0</sub> (mn)	event	altitude (km)	mass (t)	V <sub>real</sub> (m/s)
EAP-EPC powered flight					
7.30	0 ' 07 "	Lift-off	---	774.5	0
12.48	0 ' 12 "	Start of tilt manoeuvre	0.09	747.5	36.5
17.05	0 ' 17 "	Start of roll manoeuvre	0.34	722.5	76.2
22.6	0 ' 23 "	End of tilt manoeuvre	0.91	691.7	129.1
32.05	0 ' 32 "	End of roll manoeuvre	2.52	643.2	217.2
48.37	0 ' 48 "	Transsonic (Mach = 1)	6.71	578.1	324.9
67.63	1 ' 08 "	Speed at P <sub>dyn</sub> max	13.4	499.9	523.3
111.25	1 ' 51 "	Transition to $\gamma_{\max}$ (41.72 m/s <sup>2</sup> )	39.8	307.2	1579.8
139.6	2 ' 20 "	Transition to $\gamma = 6.22$ m/s <sup>2</sup> H <sub>1</sub>	65.4	253.5	2009.3
<b>140.4</b>	<b>2 ' 20 "</b>	<b>EAP separation</b>	<b>66.1</b>	<b>178.4</b>	<b>2011</b>
EPC powered flight					
199.2	3 ' 19 "	Fairing jettisoned	108.7	157.2	2275
351	5 ' 51 "	Intermediate point	163.1	108.5	3558
491	8 ' 11 "	Acquisition Natal	163.2	63.3	5747
531	8 ' 51 "	Lost Galliot	160.7	50.4	6697
539.3	8 ' 59 "	EPC burnout (H <sub>2</sub> )	160.4	47.8	6925
<b>545.3</b>	<b>9 ' 05 "</b>	<b>EPC separation</b>	<b>160.3</b>	<b>29.4</b>	<b>6952</b>
ESC-A powered flight					
549.2	9 ' 09 "	ESC-A ignition	160.2	29.4	6954
722	12 ' 02 "	Lost Natal	149.2	26.9	7359
821	13 ' 41 "	Acquisition Ascension	143.4	25.4	7611
860	14 ' 20 "	Minimum altitude	142.8	24.9	7711
1076	17 ' 56 "	Lost Ascension	177.0	21.6	8275
1106	18 ' 26 "	Acquisition Libreville	189.6	21.2	8352
1241	20 ' 41 "	Intermediate point	280.8	19.2	8689
1376	22 ' 56 "	Acquisition Malindi	444.2	17.2	9012
1507.2	25 ' 07 "	ESC-A burnout (H <sub>3-1</sub> )	690.4	15.2	9323



## Data relating to Flight 221

time /H <sub>0</sub> (s)	time/H <sub>0</sub> (mn)	event		altitude (km)
----		"Ballistic" phase		---
1513	25 ' 13 "	Phase 3	Start of <b>DIRECTV 14</b> orientation	703
1633	27 ' 13 "	Phase 4	Start of <b>DIRECTV 14</b> spin-up	1010
<b>1674</b>	<b>27 ' 54 "</b>		<b>DIRECTV 14 separation (H<sub>4.1</sub>)</b>	<b>1128</b>
1684	28 ' 04 "	Phase 6	Upper composite despin	1158
1689	28 ' 09 "	Phase 7	Start of SYLDA orientation	1174
<b>1759</b>	<b>29 ' 19 "</b>		<b>SYLDA separation (H<sub>4.2</sub>)</b>	<b>1396</b>
1769	29 ' 29 "	Phase 9	Start of GSAT 16 orientation	1429
<b>1940</b>	<b>32 ' 20 "</b>		<b>GSAT 16 separation (H<sub>4.3</sub>)</b>	<b>2032</b>
1950	32 ' 30 "	Phase 11	Removal manoeuvre orientation	2069
2030	33 ' 50 "	Phase 12 to 15	Removal manoeuvre	2375
2546	42 ' 26 "	Phase 16	ESC-A orientation for the final spin-up	4515
2697	44 ' 57 "	Phase 17	Start of spin-up at 45°/s	5160
2804	46 ' 44 "		Oxygen tank passivation (breakdown S34)	5622
3078	51 ' 18 "		ESC-A passivation (breakdown S37)	6785

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



Launcher **L574**, mission **Intelsat 30 (DLA-1)**  
/ **ARSAT-1**, 16 October 2014

## 9. Airbus Defence and Space and the ARIANE programmes

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

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

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

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

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

Integration site in Les Mureaux



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

- 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.

Aquitaine site



Integration Site in Bremen



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



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

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

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

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

AIRBUS Defence and Space web site : [www.astrium.eads.net](http://www.astrium.eads.net)

ARIANESPACE web site : [www.arianespace.com](http://www.arianespace.com)