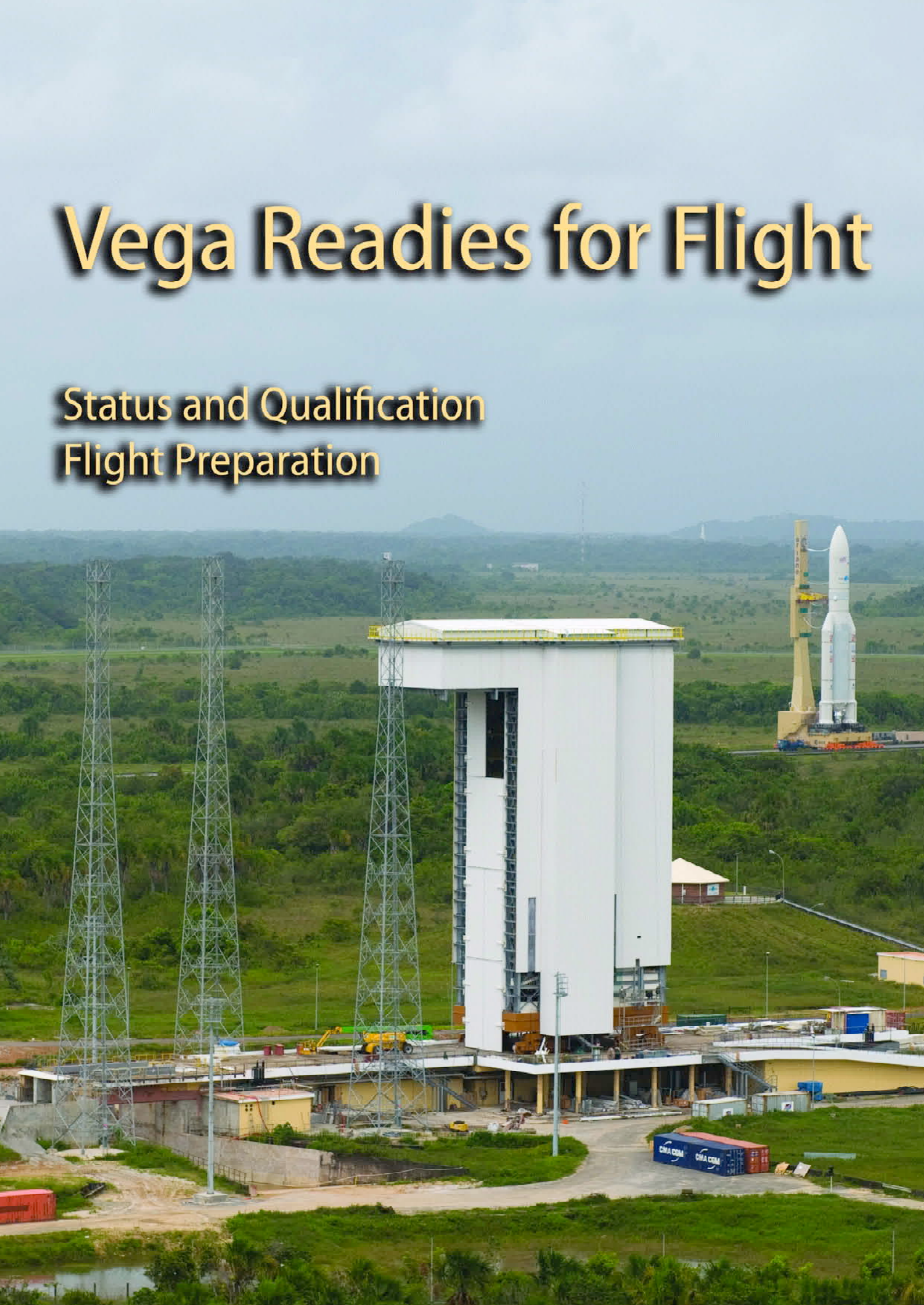
Vega Readies for Flight

Status and Qualification
Flight Preparation



The former ELA-1 Ariane-1 launch pad at Kourou has been transformed for Vega. The Mobile Gantry is in place and the site almost complete. In the background, an Ariane-5 is seen being moved to its launch site ELA-3

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A key element of the European launcher strategy for access to space, the Vega small launcher is being preparing for its maiden flight in November 2009.

The development of Vega passed major milestones in 2007 and 2008, providing essential results in terms of test data and design consolidation. These will lead to the Qualification Flight from Europe's Spaceport in French Guiana at the end of 2009. This will be an important step in the implementation of the European strategy in the launcher sector and the guarantee of access to space for Europe, as endorsed by the ESA Ministerial Council in 2003.

The exploitation of this new ESA developed launcher will widen the range of launch services offered by launchers developed and produced by European industry and will improve launch flexibility by providing a more adapted response for a wide range of European institutional space missions, as well as an optimised family of launchers to serve commercial market needs.

The Vega and VERTA Programmes

The Vega launch system, currently developed by ESA, has an essential role within the family of launchers that will be operated by Arianespace at the European Spaceport in French Guiana (Centre Spatial Guyanais, CSG). It will complement the European Ariane and the Russian Soyuz: Ariane is optimised for larger spacecraft and missions to Geostationary Transfer Orbit (GTO) as well as Earth gravity escape missions, while Soyuz is suitable for medium satellites in GTO and heavy satellites in Low Earth Orbit (LEO).

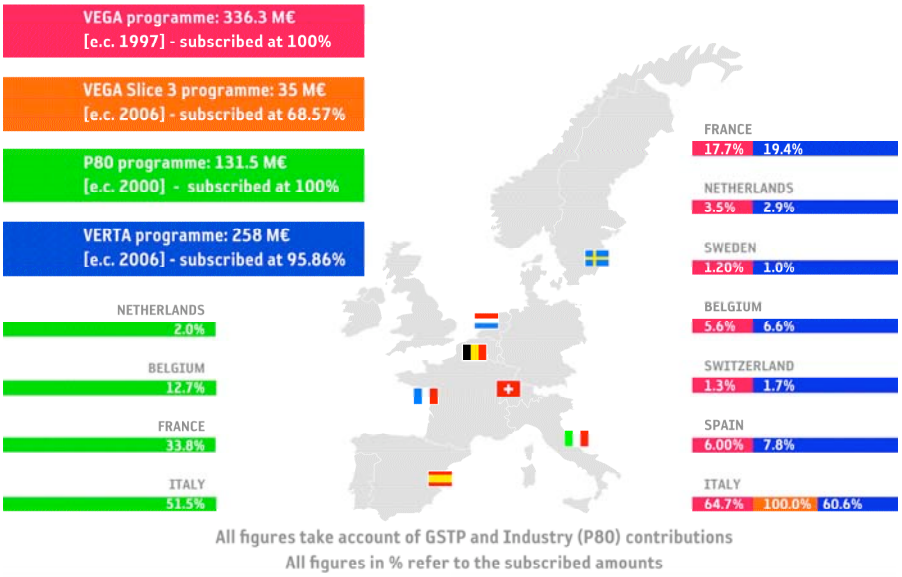
Vega is a four-stage launch vehicle designed to cover a wide range of small satellite missions in LEO. The main system requirements, in terms of payload mass and dimensions as well as mission range, were driven by the market projection showing a broad need of different missions as follows:

- Reference: 1500 kg in polar circular 700 km orbit,
- Mission range: inclination 5° to sun-synchronous orbit, LEO and small-to-medium payload mass range, from micro and mini-satellites up to 2.5-tonne satellites.

In 2010–15, the addressable market consists of five to seven satellites a year with a mass greater than 250 kg and compatible with the Vega reference capability. This fully consolidates the planned launch rate of two launches per year as a minimum.

The Vega programme is composed of three ESA optional programmes (the Small Launcher programme, the P80 demonstrator programme and an additional programme slice, decided at the end of 2007) organised into three projects: the launch vehicle, the P80 (first stage solid-rocket motor) and the ground segment.

The Vega launch system includes also the dedicated launcher infrastructure at CSG and the worldwide ground station network necessary to launch a payload and to place it into the required orbit, respecting the specified environment for the payload, the safety and operational constraints.



Participation in the Vega and VERTA programmes

In order to prepare the exploitation phase, the Vega Research and Technology Accompaniment (VERTA) programme, including the launch services for five ESA missions, was decided by the participating states at the ESA Ministerial Council in December 2005. This programme has the objective

ESA's family of launchers: Vega, Soyuz, Ariane-5 and Ariane-5 ECA

to enlarge the qualification domain, sustaining its reliability, demonstrating its flexibility through various missions and enhancing its affordability for future customers.

The Vega and VERTA programmes are funded by the following participating states: Belgium, France, Italy, The Netherlands, Switzerland, Spain and Sweden.

The programme is managed by an Integrated Project Team composed of staff from ESA, the Italian space agency ASI and the French space agency CNES, based at ESRIN in Frascati, Italy, for the launch vehicle and ground segment, and at CNES-DLA in Evry, France, for the P80 demonstrator.

The industrial organisation is based on a prime contractor for each project: ELV (I) for the launch vehicle, AVIO (I) with delegation to Europropulsion (I/F) for the P80 demonstrator, and Vitrociset (I) for the ground segment.

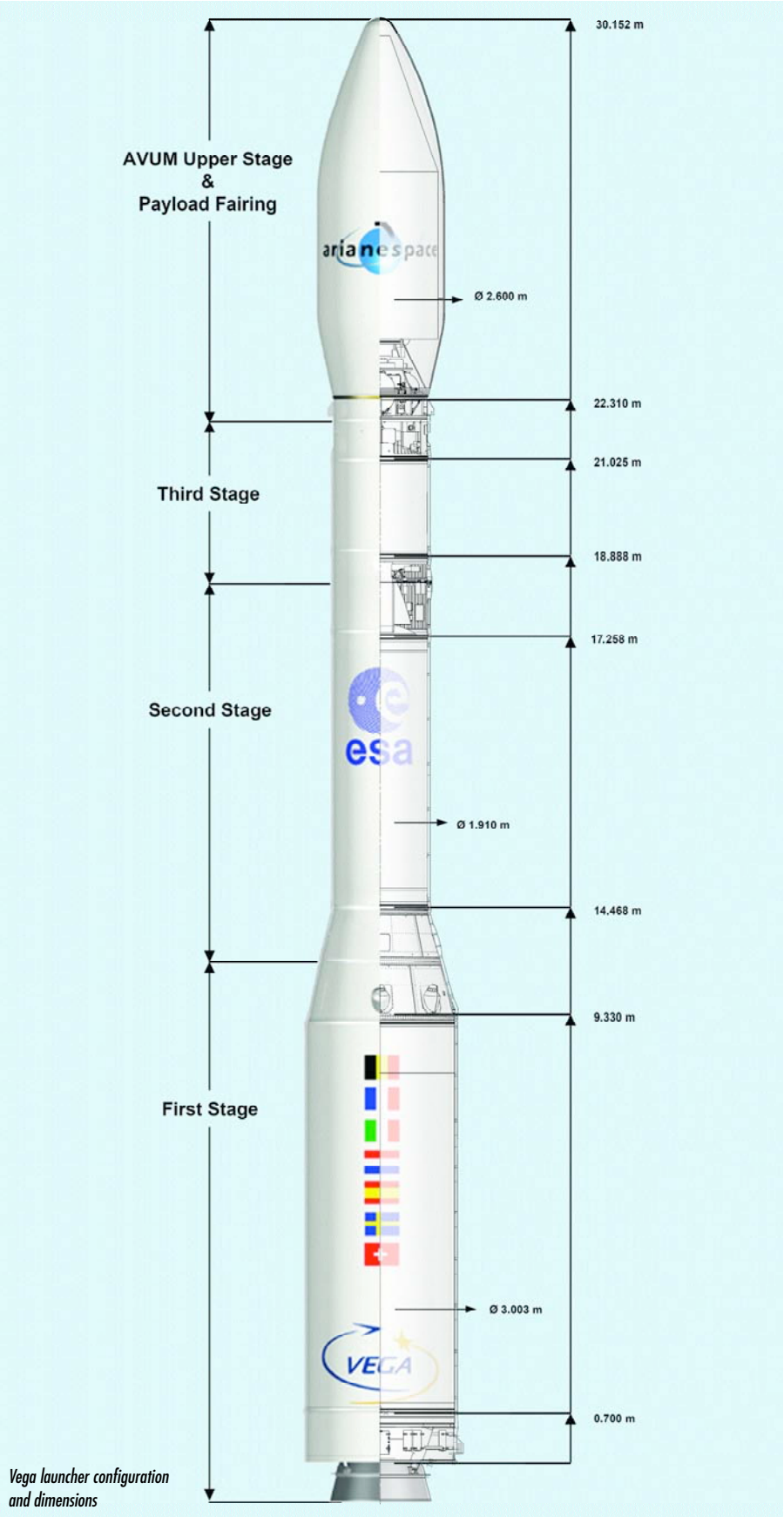
The Vega Launcher

The Vega launcher is a single-body vehicle composed of three solid-rocket motor (SRM) stages (P80, Zefiro-23 and Zefiro-9), a liquid-propulsion upper stage (Attitude Vernier Upper Module, AVUM) and a fairing. At lift-off, the launcher is 30.2 m high and weighs 139 tonnes.

To minimise risks and costs, the development has been based on a mix of well-proven technologies, benefiting from synergy with Ariane-5 development and with new technologies aimed at reaching low recurring cost objectives. The choice of solid-rocket motors was driven mainly by demonstrated high reliability on Ariane programmes and by low development and recurrent costs.

The three solid-propellant stages perform the main ascent phase while the fourth stage compensates for the solid-propulsion performance scattering, circularises the orbit and executes the de-orbiting manoeuvres.

The diameter of the first stage has been set to 3 m in order to exploit fully the synergies with already existing Ariane facilities for casting and



Vega launcher configuration and dimensions

The P80 firing tests at the the Booster Test Stand at the Centre Spatial Guyanais in December 2007

integration. The P80 is the largest monolithic solid-rocket motor with a filament winding CFRP motor case ever developed in the world.

The fourth stage (AVUM) includes a bipropellant (NTO/UDMH) liquid-propulsion system (LPS) that provides the necessary velocity changes for reaching the final launcher orbit, and a monopropellant (hydrazine) Roll and Attitude Control System (fulfilling the main functions of roll control during flight, attitude control during coasting phases, attitude recovery during second-stage separation, payload pointing manoeuvre and orbit control for the collision avoidance manoeuvre).

The Upper Composite, composed by the payload adapter, the payload and the fairing is mated on the top of the fourth stage.

In a single launch configuration, Vega provides a minimum volume allocated to the payload consisting of a cylindrical volume of 2.35 m diameter and 3.5 m height plus a frustum volume of 2.8 m height.

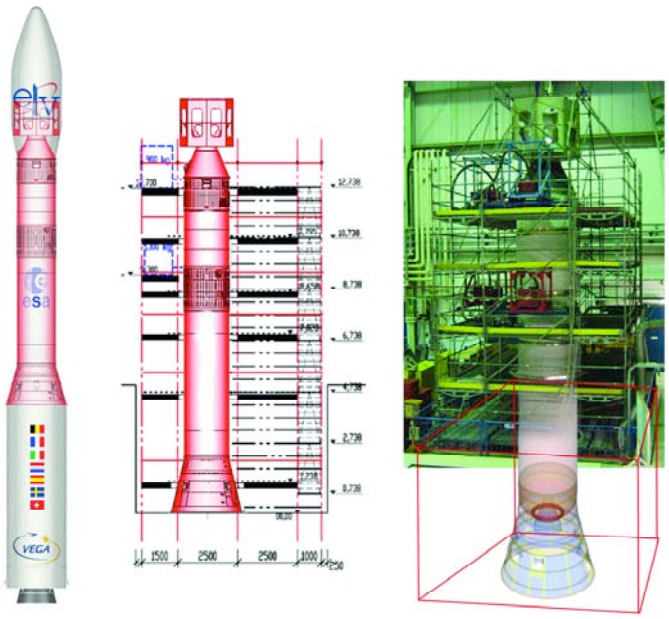
Avionics functions are distributed among hardware items and onboard software. They are split into three subsystems:

- the guidance, navigation and control subsystem, grouping all acquisition and execution means, data processing and data communication needed by the flight control function (during pre-launch and flight mission phases);
- the electrical safeguard subsystem, consisting of all the equipment for power generation, reception, processing and transmission to ground needed by the safety functions;
- the telemetry subsystem, including all the means to acquire and process the telemetry monitoring functions, and transmit to the ground.

In order to reduce as much as possible the development and recurring costs, the Vega avionics system is based on the use of existing hardware and/or components from Ariane and other ESA programmes. As an example, the Vega on-board computer (OBC) is based on existing blocks and components from ESA satellite programmes.

The Ground Segment

As with Ariane-4, the Vega launcher is assembled and tested on its launch pad. The launcher preparation takes place inside a Mobile Gantry, housing all the Ground Support Equipment needed to assemble and check the launcher, which is moved back a few hours before the launch.



Characterisation of launch vehicle bending modes and structural damping at IABG in Germany (ELV)

The former Ariane-1 platform (bunker) is being refurbished and upgraded for Vega. The launch pad itself is equipped with several pipe networks which fulfil the different functions required, e.g. pressurisation, cooling, ventilation, flushing and propellants loading.

The Upper Composite assembly and checks will be done inside the payload integration facilities at CSG (Ensemble de Préparation des Charges Utiles, EPCU).

The Vega Control Bench facilities will be located in the Centre De Lancement (Launch Centre) No. 3 (next to that for Ariane-5).

	P80	Z23	Z9
Overall length (mm)	10 791	7585	3953
Outer diameter (mm)	3003	1904	1907
Propellant mass (kg)	87 733 23	823 10	570
Inert mass (kg)	7030	1951	915
Burn time (s)	110	77	118
Vacuum specific impulse (s)	280	288	296
Nozzle expansion ratio 16	27	72.5	

SRM nominal characteristics and performances

Characteristics and performances	
AVUM stage dry mass (kg)	615
Propellant loading (kg)	577
Pressuring (GHe) gas loading (kg)	4.1
Main engine thrust (N)	2450
LPS total impulse (kN s)	1634
Restart capability	5

AVUM nominal characteristics and performances

Vega Development Status

Launch vehicle

System activities in 2007 were devoted to the consolidation of the launch system design in the frame of the Vega System Critical Design Review activities, allowing the start the qualification loop activities in December.

In parallel, the development activities at equipment and subsystem levels have allowed the completion of most of the critical design reviews. For some of the elements, like the fairing, the inter-stage 0/1, the ignition and separation pyro-chains, the AVUM structure, the On-Board Computer and the safety units, Qualification Reviews have already been performed.

Testing activities have been very intense too. The Upper Composite Mechanical model (UCMEC) underwent vibration and acoustic testing at the ESTEC Test Centre from summer 2006 until the beginning of October. The third and fourth stage separation and fairing horizontal separation system (HSS) tests have been performed, in EADS-CASA facilities in Spain, in December 2006 and February 2007 respectively. During November 2007, the characterisation of the launch vehicle bending modes and structural damping was carried out at IABG (D) with the integration of all the launch vehicle subassemblies except the first stage (P80 plus inter-stage 0/1).

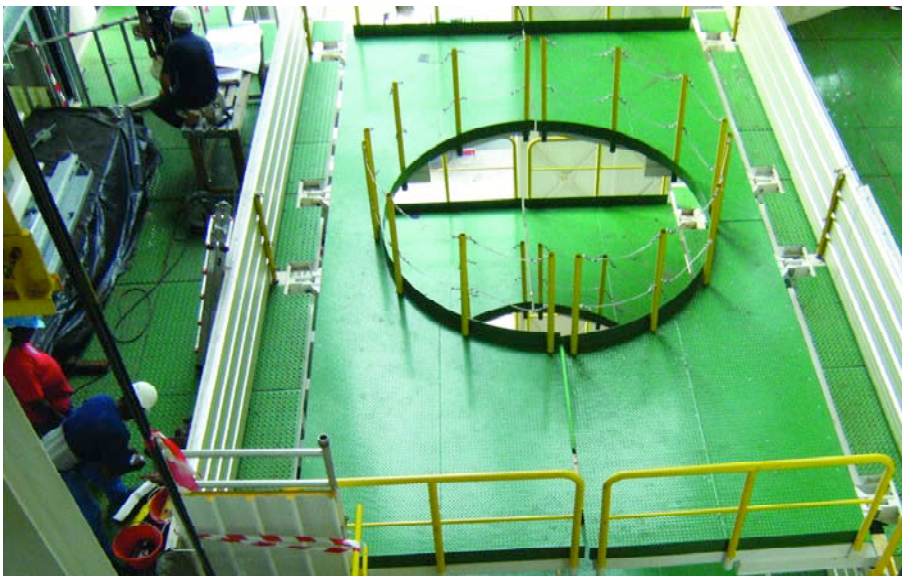
The Vega Upper Composite electromagnetic compatibility tests were completed successfully in Colleferro (I) during summer 2007, and in INTA (E) for the final part of the conducted and radiated susceptibility tests at the end of 2007/early 2008.

The qualification of the avionics has made significant steps ahead with the set up of the 'hardware in the loop' facility, now nearly finished, and the completion of the first validation campaigns of the safeguard subsystem (SAS) and communication subsystem.

The P80 solid-rocket motor – the first stage – successfully completed its qualification firing test in December 2007, one year after the test-firing of the development model, confirming the predicted performances and behaviour. Due to its size, the P80 firing tests are performed at the Booster Test Stand (Bâtiment d'Essais des Accélérateurs à Poudre, BEAP) at CSG.

A few months later, in March 2008, at the Italian Air Force Salto di Quirra Range (Sardinia), the Zefiro-23 solid-rocket motor – the second stage – also completed its functional qualification with a successful second test-firing.

The qualification firing test of the Zefiro-9 solid-rocket motor took place in March 2007, but failed with the ejection of the nozzle after 35 seconds of operating time. An inquiry board was put in place, and pointed some weaknesses in the design of the nozzle and in manufacturing quality on some of its components. Intense work was made by Avio teams in order to recover the situation, with a complete material characterisation campaign (in particular of the carbon-phenolic (C-Ph) materials used in the insulators of the carbon-carbon nozzle throat, operating at up to 2000°C), redesign of the nozzle, and improvement in the manufacturing process and then quality of the C-Ph



Mobile Gantry integration activities in CSG (Vitrociset)

insulators. Most of these improvements were applied on the nozzle of the Zefiro-23 qualification model and the nozzle expertise after its successful firing test confirmed the soundness of the modifications.

Taking advantage of the schedule shift because of the redesign of the Zefiro-9 nozzle, the project decided to increase the Zefiro-9 performance with an overloading of propellant (by 560 kg), allowing and improvement in launcher payload capability of more than 60 kg. Following a review of the impact at motor and system levels, the implementation of this modification was endorsed through the System Critical Design Review.

Because of these significant changes in the third-stage motor configuration (now named Zefiro-9A), two firing tests are still needed to demonstrate the qualification. They are scheduled in October 2008 and February 2009.

Not only do solid-rocket motor firing tests verify the correct overall behaviour of the Vega motors and demonstrate that the ballistic performances comply with the system requirements, but they also contribute to the Thrust Vector Control (TVC) subsystems qualification as well. Large amplitude movements of the TVC system were executed during the P80 and Zefiro tests, simulating worst-case manoeuvres, and the performance was satisfactory.

For the liquid-propulsion subsystem – the fourth-stage main engine – derived from the Ukrainian RD-869 engine (Yuzhnoye) has already successfully undergone several test campaigns with two qualification models. The firing test at subsystems level (complete liquid propulsion subsystem in the flight configuration) is under preparation at the P2 test stand in Lampoldshausen (D) and the test campaign will start in summer 2008. This will be the final step to demonstrate the liquid-propulsion system suitability for the Qualification Flight. The manufac-turing, assembly and integration of the units for the Qualification Flight have already started, according to their qualification status.

The focus in 2008 on the launch vehicle side will be the closure of the major actions resulting from the development activities and reviews, the completion of all the qualification reviews at equipment and subsystem levels and the acceptance of the flight units, as well as of course the preparation of the ground qualification review of the launch system, scheduled to start in the first quarter of 2009, and the preparation for the maiden flight.

Ground Segment

The Vega ground segment has entered in its final phase with the completion of the detailed design of the various subsystems (mechanical, fluid and control centre).

At CSG, the civil works of refurbishment of the bunker and integration of the Mobile Gantry main structure have been completed as well as the installation of equipments for heating, ventilation and air conditioning. The launch table has been integrated in its position, and will be soon completed with the upper and lower pallets. The umbilical mast is being erected in the launch area, in parallel with the integration of piping for fluid installation.

Fluid panels factory acceptance has been completed in Europe and they will be shipped to Kourou and connected to the networks on the launch pad.

The Vega Control Centre (CCV), fully developed and tested at the ground segment prime contractor premises with a first release of software, has been shipped to the launch site. This release will be used to start the ground segment integrated tests phase. Further releases are foreseen to cover late changes.

The next important milestone for the Vega ground segment is the Test Readiness Review for the integrated test phase under the responsibility of the industrial prime contractor and closely followed by ESA/IPT with a dedicated team on site. The closure of this test phase will allow pronouncing the technical qualification of the Vega ground segment.

Launch System

Activities at launch system level are now focused at the preparation of the Combined Test Campaign. This will be the major step of the launch system development, being the first time that the launcher (a representative mock-up) and the ground segment will meet together.

These tests will allow the validation of all processes, from the delivery of subassemblies in Europe, their trans-

portation to Kourou, storage, integration on the launch table and the final preparation of the launch vehicle as for flight, which includes the propellant loading and the validation of the countdown phase.

A dedicated Integrated Operations Team has been set up to manage this Combined Test Campaign, taking advantage of the cooperation between the different players and securing at the same time the continuity of technical competences through the different phases of realisation and validation of products up to the integration and launch campaigns. Specialists from industrial contractors, support services and the future operator Arianespace are involved under the coordination of the Vega Integrated Project Team.

After completion of the combined tests and Ground Qualification Review, the Flight Readiness Review will enable the start of the Qualification Flight campaign that will complete the preparation for the maiden flight. The Launch Readiness Review will give the green light for the maiden flight, and this will be followed by a detailed exploitation of the flight results and by the Flight Qualification Review.

The Qualification Flight

The mission for the Qualification Flight has been defined to take into account different targets: mitigation of risks inherent to the first flight, representativeness of the mission within the flight qualification domain, compliance with ground/flight safety and programmatic constraints.

In particular, due to the larger uncertainties in a first flight, specific constraints are introduced to limit the risks safetywise. Hence the payload mass has been reduced for this flight.

The main passenger of the maiden flight is the LARES experiment developed by ASI. This is a satellite laser-ranging experiment, completely passive with no sensors or on-board electronics. The main scientific objective of the LARES mission is the measurement of the dragging of inertial frame due to Earth's angular momentum (or 'Lense-Thirring effect') and a high precision test of Earth's gravitomagnetic field. Gravitomagnetic field and inertial frame drag are predictions of Einstein's theory of General Relativity.

AVUM and fairing at ESTEC for upper-composite mechanical tests (ELV)

The secondary payloads of the maiden flight are educational micro-satellites.

From Development to Exploitation

For a smooth transition between development and exploitation, the VERTA programme will undertake five flexibility demonstration flights, primarily for ESA user missions. Different ESA user mission candidates are already identified for these five launches:

- ADM-Aeolus Earth observation mission, weighing around 1400 kg, to be placed in a sun-synchronous orbit at about 400 km altitude;
- SWARM Earth observation mission, comprising a constellation of three satellites in near-polar orbits, between 450 and 550 km altitude;
- LISA Pathfinder science mission, weighing about 1900 kg, with an operational orbit around the first Earth-Sun Lagrange point (L1) after a transfer trajectory from a low Earth parking orbit;
- Proba-3, a formation-flying cluster of two mini-satellites, with a highly elliptical final orbit;
- ESA IXV demonstrator for re-entry applications, weighing around 1850 kg, to be de-orbited by the Vega upper stage before starting its re-entry phase at 120 km altitude.

For the first VERTA flight, scheduled six months after the maiden flight, ESA will issue an international Announcement of Opportunity (AO). The response to the AO will be assessed by ESA, with the participation of Arianespace, and building upon such an assessment, in a second step, a Call(s) for Proposals will be published, and the payload(s) for the first VERTA flight will be selected.