

# *The Small Launcher for Europe*



# VEGA

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## *Preface*



The European small launcher, called 'Vega', will make its inaugural flight from Europe's Spaceport in French Guiana before the end of 2007. This will be an important milestone 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 Council at Ministerial Level in 2003. The exploitation of this new ESA-developed launcher will widen the range of European launch services on offer 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.

By being developed as an ESA programme, Vega is taking significant advantage of launcher technologies developed previously at European level, particularly in the solid-propulsion and avionics fields. Furthermore, Vega constitutes a trail-blazer not only because its development benefits from a single overall programme management structure involving ESA and national space agencies, in this case ASI and CNES, but also because its industrial organisation already relies on a launcher industrial prime contractor (ELV).

For its exploitation, Vega will be operated by Arianespace from the Guiana Space Centre (CSG). This approach will foster additional synergies in the exploitation of ESA-developed launchers from Europe's Spaceport.

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*Director of Launchers, ESA*



# Vega

## *The Small Launcher for Europe*

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# The Background



ESA has elaborated a strategy for the launcher sector in Europe targeted at preserving the objectives of guaranteed access to space and commercial success in the new global environment, as well as being consistent with current European strategic, economic, cultural and political interests.

The first objective of the European strategy is to guarantee affordable access to space for Europe through a family of launchers providing the flexibility and competitiveness needed to respond optimally to institutional and commercial needs. In this respect, the Ariane launch system will continue to serve primarily the heavy-payload class of missions, while the Vega launch system will serve the small-payload class mainly for low Earth orbits. The addition of the exploitation of Soyuz from the Guiana Space Centre (CSG) will complete the range of launch services on offer by catering for the medium-payload class.

The second element is to foster international cooperation, in order to open new market opportunities for European Industry, to consolidate the guarantee of access to space, and to maximise technological cooperation. In parallel, technologies need to be prepared for the timely development of new systems in order to meet the long-term competition (2015-2020).

The last element of the strategy is to maintain the industrial capabilities needed to ensure the continued high quality of the launch services and operations offered to customers by the European Spaceport in French Guiana.

## The History

The Vega Programme has its origins back in the 1990's, when studies were performed in several European countries to investigate the possibility of complementing the range of performance offered by the Ariane family of launchers with a capability for smaller payloads. The Italian Space Agency (ASI) and Italian industry not only developed concepts, but also began pre-development work based on their established knowhow in solid propulsion. Vega officially became an ESA Programme in June 1998, when the Agency succeeded in Europeanising the national ASI small-launcher programme – in the meantime called 'Vega' – as a co-operative project with other Member States within the ESA framework.

For more background information see:  
<http://www.esa.int/launchers>

# The Market

The 21st century has begun with a significant interest in smaller satellites and therefore in the need for appropriate launch services. In order to maintain its competitiveness in the World market, Europe is therefore expanding the range of missions that it can handle by developing the Vega small launcher.

## The growing need for smaller satellites

Two main factors, namely changes in space-programme policies and the evolution in satellite technologies, explain the recent reduction in the sizes and the weights of many satellites, especially in the field of Earth Observation. These smaller satellites can be divided into three categories:

Micro-satellites : up to 300 kg

Mini-satellites : from 300 to 1000 kg

Small satellites : from 1000 to 2000 kg.

The micro/mini-satellite market is almost exclusively driven by institutional programmes, with Earth Observation and scientific missions representing the most significant sector. The orbits required are mainly Sun Synchronous Orbits (SSO) and Low Earth Orbits (LEO).

The Vega-addressable market therefore currently stands at around 3 to 5 missions per year, split between single launches for small and mini-satellites and multiple launches for one mini-satellite and/or several micro-satellites.

## A wide range of launch services

ESA's launcher strategy is founded on the principle of offering the nations of Europe



guaranteed access to space, implying that Europe should be able to launch by its own means any size or category of mission.

Vega, together with the mid-class Soyuz launcher and the heavy-class Ariane-5 launcher, will ensure that a full range of launch services will indeed be available for Europe, thereby allowing optimised mission planning based on the exact performance required in each case for the lowest cost. The standard performances of the European launcher family when operated from the European Spaceport are as follows:

Launcher	Vega	Soyuz	Ariane-5 Generic	Ariane-5 ECA
Orbit	SSO/LEO	GTO	GTO	GTO
Payload mass, kg	1500 (700 km)	3000	6600	10000

SSO/LEO: Sun Synchronous Orbit/Low Earth Orbit, GTO: Geostationary Transfer Orbit

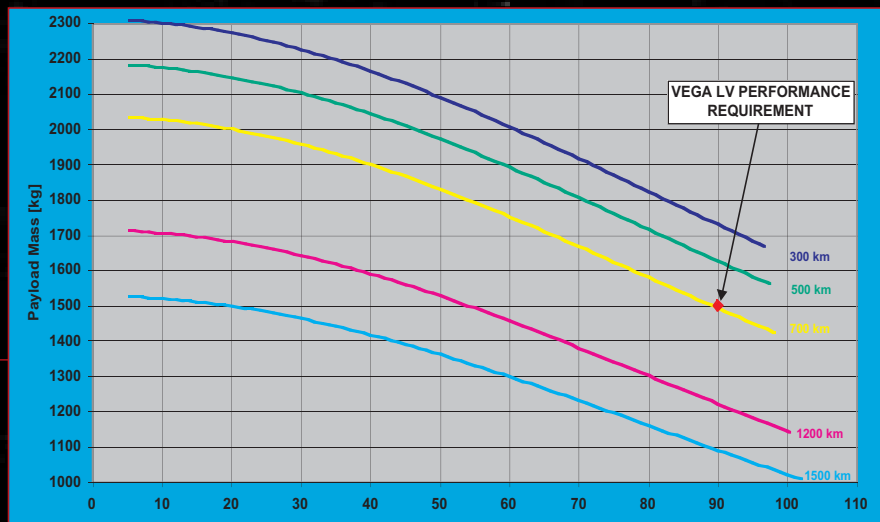
# The Mission

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Vega is designed to cope with a wide range of missions and payload configurations in order to respond to different market opportunities and therefore provide the flexibility needed by the customers. In particular, it might offer configurations able to handle payloads ranging from a single satellite up to one main satellite plus six micro-satellites. Vega is compatible with payload masses ranging from 300 kg to 2500 kg, depending on the type and altitude of the orbit required by the customer. In this respect, it can provide

launch services for a wide variety of missions, from equatorial to Sun-synchronous.

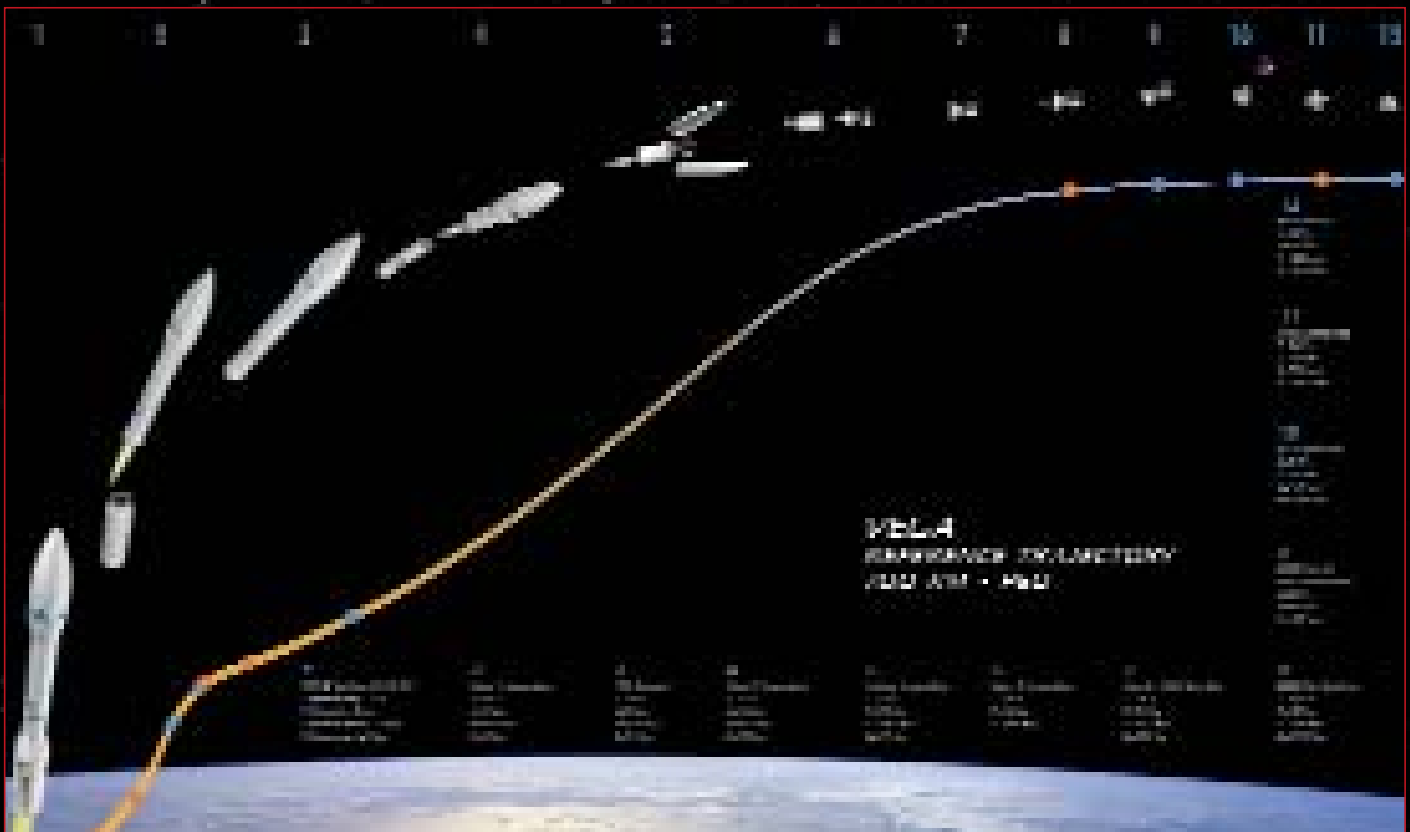
The benchmark for Vega's in-orbit launch capacity is 1500 kg into a 700 km-altitude polar orbit. The complete performance matrix is shown in the accompanying table.



A typical launch can be divided into three main phases:

- The first phase corresponds to the launch vehicle's propulsive ascent phase into a low elliptical trajectory (sub-orbital profile). During this phase, the fairing will be jettisoned, once the aero-thermal fluxes are low enough for the unprotected payload.

- The second phase corresponds to the circularization of the orbit and satellite(s) release and injection into the required orbit(s), with the specified parameters.
- The third and final phase of the mission is usually devoted to the removal of the satellite(s) from operational orbit to comply with international regulations concerning space debris.



# The Organisation

## Launch Vehicle + Ground Segment

Belgium : 5.63%  
France : 15%  
Italy : 65%  
Netherlands : 2.75-3.5%  
Spain : 6%  
Sweden : 0.80%  
Switzerland 1.34%

## P80

Belgium : 19%  
France : 66%  
Italy : 9.3% + contribution from Industry  
Netherlands : 4.5%



Member State Contributions to the Vega Programme

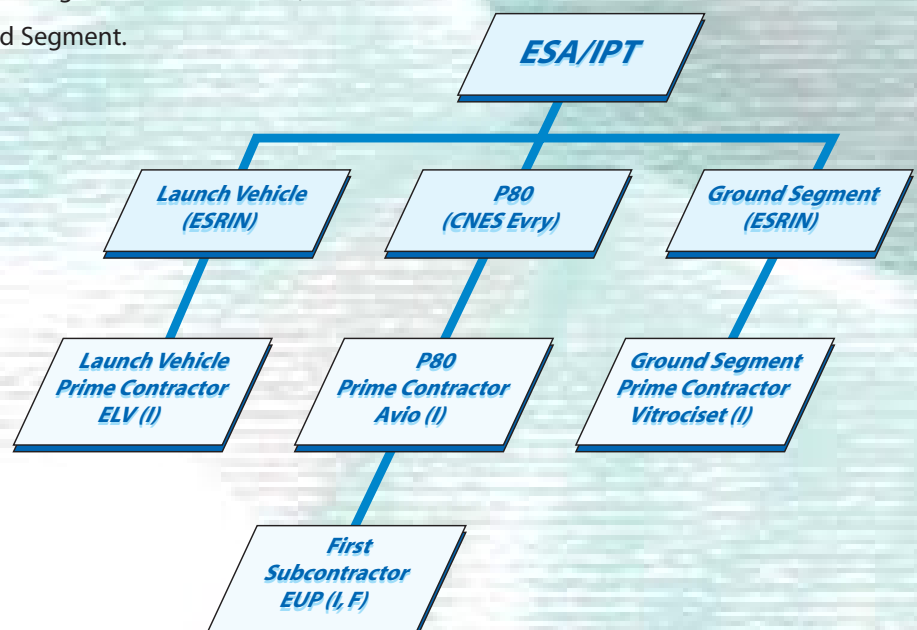
The Programme is managed jointly by an Integrated Project Team (IPT) composed of staff from ESA, ASI and CNES, based at ESRIN in Frascati, Italy, for the Launch Vehicle and Ground Segment, and at CNES in Evry, France, for the P80 motor. It therefore benefits from the technical support and expertise of both ESA and CNES.

The industrial organisation for Vega is considered a forerunner of the future organisation for European launcher development and is based on having a Prime Contractor for each project: ELV (I) for the Launch Vehicle, AVIO (I) with delegation to Europropulsion (I, F) for the P80, and Vitrociset (I) for the Ground Segment.

Vega is an ESA Optional Programme managed by the Vega Department within the Agency's Directorate of Launchers. The development activities are organised into three projects addressing:

- The Launch Vehicle
- The P80 (1st-stage solid-rocket motor)
- The Ground Segment.

The complete development effort is based on two programme declarations, one for the Launch Vehicle including the Ground Segment, and another for the P80 motor.



### Launch Vehicle and P80

The industrial Prime Contractor for the Vega launch vehicle is the company ELV SpA, 30% of which is owned by ASI (Italian Space Agency) and 70% by AVIO.

### Ground Segment

Under the umbrella of the Ground-System Prime Contractor Vitrociset, the work is divided across three main 'subsystems', with an industrial contractor responsible for each of them. These subsystems are:

- the Civil Infrastructure, which covers the refurbishment of the existing infrastructure (the former Ariane-1 pad, ELA1) as well as the construction of the new infrastructure, including civil works, air conditioning and energy installations. The main contractor is Vitrociset (F), with Cogel (I) responsible for the system engineering.
- the Mechanical, Fluids and General Means, which includes the design, manufacture and installation of the mobile gantry, launcher interfaces, gas supplies, communication systems and low-voltage installation. The main contractor is Carlo Gavazzi Space (I). Oerlikon Contraves Italy (I) is responsible for the mechanical part, Telematic Solutions (I) for the low-voltage installation, and Cegelec (F, NL) for the fluid installations.
- the Control Systems, which include the Vega Control Centre, the computer centre, and monitoring and control of Ground Segment house-keeping processes. Vitrociset (I) is the main subsystem contractor, with Dataspazio (I), Laben (I) and GTD (E) as subcontractors responsible for control-system packages.

CNES is supporting the development of the Vega Ground System in terms of design, systems engineering, configuration management, interfacing with CSG and test campaigns. CNES is also responsible for the Vega-related modifications needed to the Kourou installations, such as the tracking, localisation and telemetry systems.



**Contraves Space**  
Switzerland, Fairing

**EADS CASA**  
Spain, Adapter

**Thales, Zodiac, Galileo Avionica, CRISA, SAAB, SAFT**  
AVUM Avionics

**Avio**  
Italy, AVUM (stage integration and test)

**EADS CASA**  
Spain, AVUM Structure and AVUMT3 Skirt

**Avio**  
Italy, AVUM Propulsion System

**Avio**  
Italy, 3rd Stage (production, integration and test)

**SABCA**  
Belgium, 3rd Stage TVC

**Oerlikon Contraves Italia (OCI)**  
Italy, 2/3 Interstage

**Avio**  
Italy, 2nd Stage (production, integration and test)

**SABCA**  
Belgium, 2nd Stage TVC

**Dutch Space**  
The Netherlands, 1/2 Interstage

**Stork Product Engineering**  
The Netherlands, Igniters of Stages 1-2

**Avio**  
Italy, 1st Stage (stage integration and test)

**Europropulsion**  
France, P80FW Motor

**SABCA**  
Belgium, 2CT: Interstage Skirt

**SABCA**  
Belgium, 1st Stage TVC

**SNECMA Propulsion Solid**  
France, Nozzle

# The Launch Vehicle

Vega is a single-body launcher composed of three solid-propellant stages and a liquid-propellant upper module. It is approximately 30 metres high, has a maximum diameter of 3 metres, and weighs a total of 137 tons at lift-off. It has three main sections, namely the Lower Composite, the Restartable Upper Module and the Payload Composite.

The Lower Composite consists of three solid-propellant stages:

- 1st stage: P80-FW / 88 tons of propellant
- 2nd stage: Z23 (Zefiro23) / 23 tons of propellant
- 3rd stage: Z9 (Zefiro9) / 10 tons of propellant

plus the four stage-interfacing structures.

The Restartable Upper Module or 4th stage, known as AVUM (Altitude and Vernier Upper Module), hosts:

- the AVUM Propulsion Module
- the AVUM Avionics Module.

The Payload Composite that accommodates the satellite(s) is composed of:

- the fairing
- the payload/launcher interface structure

(adaptor 937, dual carrying structure, dispenser, etc.).

## The Lower Composite

The motors of the three solid-propellant stages – P80, Z23 and Z9 – benefit from the strong experience acquired by Europe over the years in the field of solid propulsion. Their technology is derived from the Zefiro-16 motor, which has already performed three firing tests (in June 1998, June 1999 and December 2000) with good results.

Each motor is composed of:

- A carbon-epoxy filament-wound monolithic case protected by low-density thermal insulation packed with micro-spheres (EPDM).
- The solid propellant HTPB 1912 (Finocyl-type grain shape with star section on nozzle side).
- A nozzle (3-D carbon/carbon throat, flexible joint for a maximum deflection, carbon phenolic exhaust cone).
- A thrust-vector control system driven by two electro-actuators that operate the movable nozzle, and a local control unit providing pitch and yaw control during the flight of each stage (located in the inter-stage structures).

Courtesy of SABCA, B



P80 TVC on the test stand



Interstage 1/2



Interstage 2/3

Each equipped stage also includes a pyrotechnic ignition subsystem, a safety subsystem, and interfaces to the other stages or, for the P80, the ground segment by means of the inter-stage structures.

	<b>P80 FW</b>	<b>Zefiro23</b>	<b>Zefiro9</b>
<b>Burn time (s)</b>	<b>107</b>	<b>71</b>	<b>117</b>
Vacuum specific impulse(s)	279.5	289	294
Max. vacuum thrust (kN)	3040	1200	313
MEOP (bar)	95	106	74
Nozzle expansion ratio	16	25	56
Nozzle deflection angle (deg)	± 6.5	± 6.5	± 6.0
<b>Attitude control</b>	<b>Pitch &amp; Yaw</b>	<b>Pitch &amp; Yaw</b>	<b>Pitch &amp; Yaw</b>

### Main Features of the P80 Motor

The improvement of solid-propulsion capabilities by the adoption of advanced technologies is one of the building blocks of the European Launcher Strategy. The development activities have two primary objectives: firstly the qualification of the Vega first stage, representing the first step towards a new generation of European solid-rocket motors, and secondly the demonstration of many of the technologies necessary to guarantee the Ariane-5 solid-rocket booster's competitiveness. The P80 motor is tailored to the Vega small launcher, but its scale is also representative for validating technologies applicable at a later stage to a new generation of Ariane-5 solid boosters.

- Component: P80 new technology
- Case: CFRP monolithic carbon fibre, 3 m diameter
- Propellant grain: Monolithic Finoxil, aft star
- Insulation: EG1LDB3 low-density EPDM-based rubber
- Nozzle throat: 3D C/C new low-cost material
- Exit cone: Composite, structural carbon phenolic
- Flex joint: Self-protected/low-torque
- TVC actuator: Electro-mechanical

Maximum reduction of recurring costs is a driving parameter at all levels of the solid-rocket motor's design (subsystems, components, equipment, ground infrastructure, operations, etc.). A significant reduction with respect to the current metal-case boosters is a specific goal for both the Vega first stage and the new-generation Ariane-5 booster.



Z9 igniter under test



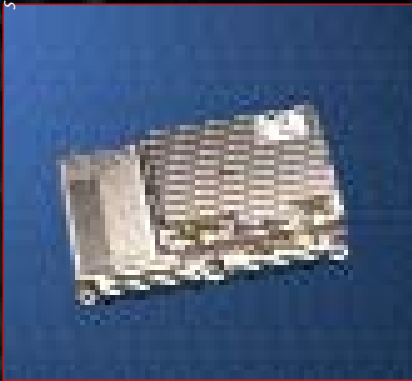
*P80 winding machine*



The avionics Multi-Function Unit



Courtesy of Saab Ericsson Space. Courtesy of CRISA, E



Onboard computer



Safeguard Master Unit

Courtesy of Galileo Avionica, I

	<b>AVUM</b>
<b>Burn time (s)</b>	<b>317</b>
<b>Ignition</b>	
Vacuum specific impulse(s)	315.2
Max, Vacuum thrust (kN)	2450
Number of restarting	5
Nozzle deflection angle (deg)	± 10.0
<b>Attitude control</b>	<b>Roll control during Z9 and AVUM flight</b>
<b>Orbital flight control</b>	<b>3-axis or spin-up</b>

in-orbit phases

- correction of axial velocity error due to solid-rocket motor performance scatter
- generation of the velocity change required for orbit circularisation
- satellite pointing
- satellite-release manoeuvres
- empty-stage de-orbiting.

**AVUM Avionics Module**

The avionics system is composed of both hardware and software and its architecture is based on a non-redundant approach, except for the safety functions. To keep the development and recurring costs to a minimum, Vega's avionics are largely adapted from existing hardware and/or components already under development. For the same reason, particular attention has been paid to defining the most appropriate architecture for the avionics subsystems, with the baseline consisting of a centralised approach somewhat similar to the concept used for Ariane-5.

**The Restartable Upper Module**

The Altitude and Vernier Upper Module (AVUM) has two different sections, one hosting the propulsion elements (AVUM Propulsion Module) and one dedicated to the vehicle equipment bay (AVUM Avionics Module).

The liquid-propulsion system consists of a single-chamber engine fed with NTO and UDMH propellants at an inlet pressure of 30 bars. The propellants are stored in two identical titanium tanks (142 litres/6 bars) pressurised in flight by a gaseous-helium vessel (88 litres/310 bars). The total propellant load will be between 250 and 500 kg depending on the type of launch to be performed.

The AVUM Propulsion Module provides attitude control and axial thrust during the final phases of Vega's flight to fulfil the following functions:

- roll control during all flight phases
- attitude control during the coasting and

The electrical system has four main subsystems:

- Power Supply and Distribution
- Telemetry
- Localisation and Safeguard
- Flight Control and Mission Management.

The Safeguard subsystem is fully redundant, in order to comply with launch-safety requirements. For the other subsystems, failure detection and means of recovery have been implemented, where relevant, in order to improve the launcher's reliability.

The Flight Control subsystem will use an on-board programmable flight computer, an inertial measurement unit (derived directly



Half-fairing qualification model

from that used on Ariane-5), and thrust-vector control electronics for guidance, navigation and control. A multi-functional box will deliver electrical commands for mission management, and stage and payload separation on receipt of signals from the on-board computer. The Telemetry subsystem will be based on Ariane-5 elements, as it must be compatible with existing ground-station standards and protocols.

For the Safeguard subsystem, the Ariane-5 tracking architecture will be applied, reusing already developed components (transponders, antennas). The neutralisation functions will be managed via new Safeguard Master Units (SMUs) and Safeguard Remote Units (SRUs) located in the stages.

## The Payload Composite

### The fairing

The dimensions of the fairing define the usable payload volume of the launcher. It is composed of two carbon-fibre-reinforced plastic shells with an aluminium honeycomb structure, which are jettisoned during flight after the separation of the second stage. Separation of the two halves of the fairing is ensured by a horizontal and vertical separation system that has already been used on the Ariane-4 launcher and

proved to be highly reliable.

Vega's fairing also provides the interfaces required for preparing the payload for flight, including access doors, which can be radio-transparent, an electrical umbilical interface, and if needed a radio-frequency repeater.

### The launcher/satellite interface structure

The Adaptor 937 on Vega is a standard launcher/satellite interface used on the European launchers. It is a 60 kg, cone-shaped carbon-fibre structure, with a diameter of 937 mm at the separation plane between launcher and satellite. The standard version is equipped with a separation system and two brackets for electrical connectors. Optional hardware can be added for specific missions at the customer's request.

The separation system consists of a clamp-band set, four separation springs, and two separation-feedback micro-switches. The four separation springs ensure an equilibrated separation push between launcher and satellite, and the two micro-switches provide confirmation of separation.

Additional payload adapters/dispensers are foreseen for multi-payload missions.

# *The Ground Segment*

## **The European Spaceport**

Vega will benefit from the exceptional location and existing launch infrastructure of the European Spaceport at Kourou in French Guiana. This French Overseas Department lies close to equator on the Atlantic coast of South America (latitude: 2 to 6 deg North / longitude: 50 deg West).

The choice of French Guiana to launch Vega meets one of the programme's main requirements, namely to provide a high-quality launch service (the Spaceport's launch-preparation facilities have a worldwide reputation for excellence in the space industry) whilst limiting costs (re-use of ELA1 civil works and sharing of preparation facilities).

The Spaceport will ultimately accommodate launch-preparation facilities for Soyuz, as well as those for Vega and Ariane-5. It will also provide the necessary launch-support infrastructure such as payload-preparation facilities, transport, flight tracking, flight data processing for post-flight analysis, and meteorological data. A dedicated launch zone is foreseen for each type of launcher, but the payload-preparation complex (EPCU) will be shared.



## The Vega Facilities

Vega's dedicated Ground Segment comprises the Launch Zone (ZLV: Zone de Lancement Vega) and the Operational Control Centre.

### The Launch Zone

The Vega Launch Zone is being built on the site in the old ELA1 zone (previously used for Ariane-1), and consists primarily of two elements: a fixed infrastructure (the bunker) and a mobile building (the gantry).

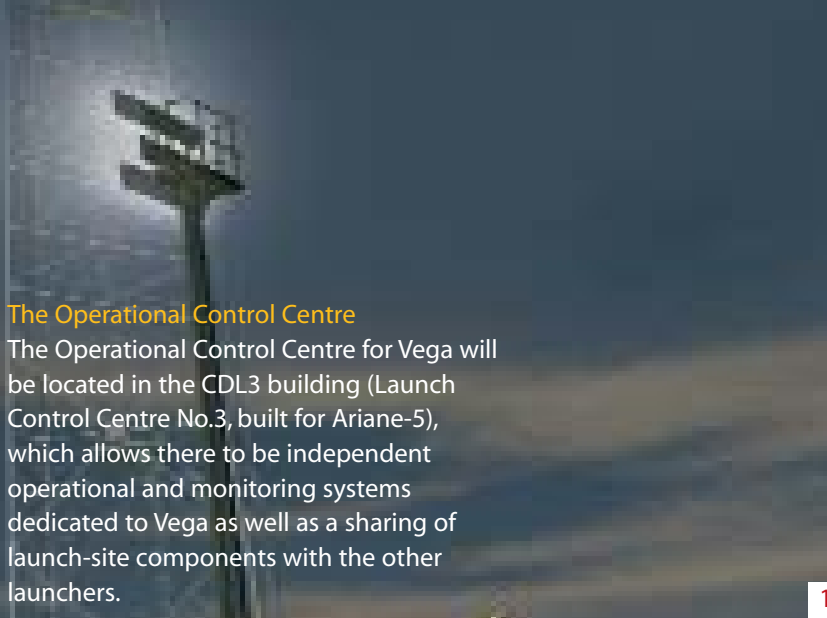
The bunker mainly comprises:

- The launch table, which ensures that the launcher maintains its vertical position and provides the interface with the exhaust ducts.
- The umbilical mast, which ensures continuity of the launcher's and payload's thermal conditioning and power supply until the very last moment, as well as correct disconnection of those systems from the launcher during lift-off.
- The exhaust ducts through which the burning gases are channeled when the motor is ignited on the launch pad.
- The four anti-lightning masts.
- Various premises such as safety room, fluid room, gantry connection room, etc.

The mobile gantry provides the infrastructure necessary for integration of the launcher, such as hoisting devices for the erection of the stages, platforms to access to the different levels of the launcher, connection and supply facilities, fuelling installations for the fourth-stage AVUM, safety systems, etc. The gantry is rolled-back before launch, prior to the final countdown.



*The Vega Launch Zone*



### The Operational Control Centre

The Operational Control Centre for Vega will be located in the CDL3 building (Launch Control Centre No.3, built for Ariane-5), which allows there to be independent operational and monitoring systems dedicated to Vega as well as a sharing of launch-site components with the other launchers.

### Payload Preparation Complex (EPCU)

Complementing some original CNES facilities and others built later for the Ariane development programme, ESA has constructed a satellite-preparation complex halfway between the Technical Centre and the launch site. It will be used for satellite and control equipment unpacking, mechanical inspections, and check-out of the various platform and payload subsystems. It will also be used for the final integration of the payload composite before its transfer to the mobile gantry for hoisting onto the top of the launcher.

# *The Road to Exploitation*



The qualification flight that will conclude the Vega development phase managed by ESA is planned to take place by end-2007. The development logic is based on an incremental verification approach based on analysis, simulation and testing. The various tests have been designed to ensure verification of the proper behaviour of the launch vehicle during all phases of its flight, under conditions as close as possible to the real ones. The tests are scheduled to progress from the verification of each single unit to a global functional verification.

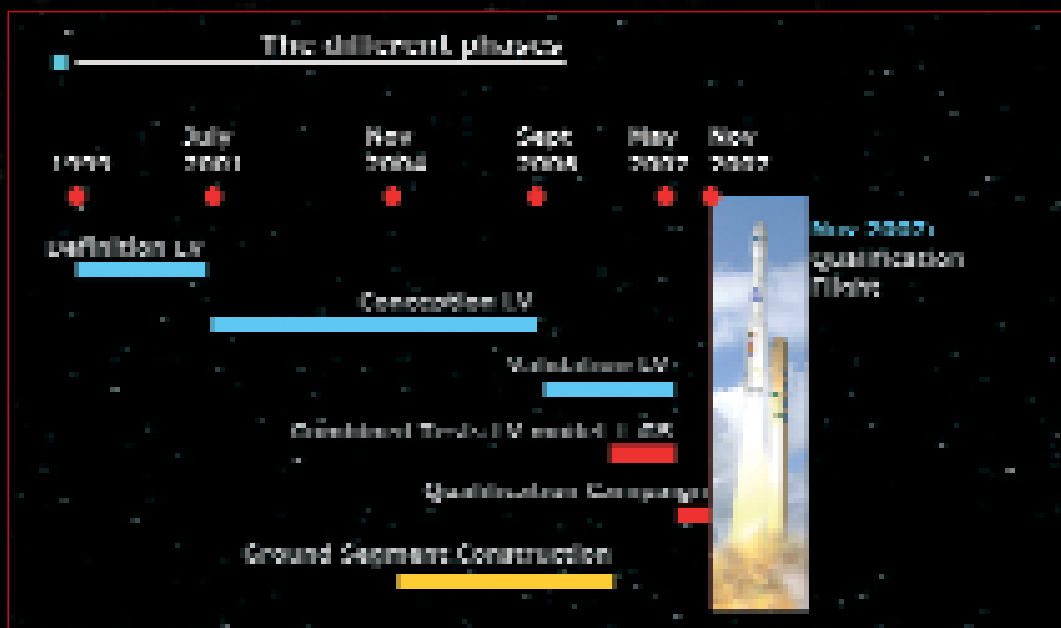
ESA will be responsible for the qualification of the launch service as overseer of the development phase, and also for sustaining the qualification status throughout the exploitation phase, when the facilities will be handed over to the Vega Operator.

After the ground qualification and successful in-flight demonstration of the launcher's suitability for various missions, Arianespace will be responsible for Vega's commercialisation and launch operations. It will therefore be responsible for all the promotional, marketing and commercial activities. It will procure vehicles from the manufacturer according to market needs and customer constraints, with an expected launch rate of up to four flights per year. It will also be responsible for the management and maintenance of the Vega Launch Zone facilities.

The Vega Production Prime Contractor, ELV (I), will be responsible for the definition and organisation of the production of the launch vehicles in accordance with the procurement plan established by the Vega Operator. ELV will also integrate the launch vehicles at the European Spaceport.



Vega at ESRIN



### Arianespace

Arianespace is a leading global commercial launch-service provider, holding more than 50 percent of the World market for satellite launches to geostationary transfer orbit (GTO). It was created as the first European commercial space-transportation company in 1980 and has signed launch contracts for more than 250 satellite payloads. Arianespace is also responsible for the production, operation and marketing of the Ariane-5 launchers, and will be the commercial operator for Soyuz at Kourou.

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Published by: ESA Publications Division  
ESTEC, PO Box 299  
2200 AG Noordwijk, The Netherlands

Editor: Bruce Batrick

Design and Layout: Jules Perel

Copyright: © 2005 European Space Agency

ISSN: 0250-1589

ISBN: 92-9092-446-2