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VEGA

Realising Europe's Small Launcher

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Contents

European Space Agency
Agence spatiale européenne

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The History of Vega

The Vega Programme has its origins back in the early 1990s, when studies were being performed in several European countries to investigate the possibility of complementing the performance range offered by the Ariane family of launchers with a capability for smaller payloads. The Italian Space Agency (ASI) and Italian industry, in particular, were very active in developing concepts and starting pre-development work based on their established knowhow in solid propulsion. When the various configuration options began to converge and the technical feasibility of such a small launcher was confirmed, the investigations were extended to include a more detailed definition in terms of a market analysis and related cost targets. As a conclusion to these preparatory activities, in February 1998 ASI proposed that a small launcher – in the meantime called 'Vega' – be developed as a co-operative project with other Member States within the ESA framework.

The Vega Programme was officially adopted by ESA in June 1998, but the funding was limited to a 'Step 1', with the aim of obtaining the full approval from the Ministers of the ESA Member States at their forthcoming meeting in Brussels in May 1999. This milestone was not met, however, because it was not possible to achieve a wide consensus among the Member States regarding participation in the programme. This gave rise to a period of political uncertainty and to a series of negotiations aimed at finding an acceptable compromise. The subsequent prolongation of Step 1 provided the opportunity to revisit and update the market analysis, based on the evolution taking place in terms of potential customers and competitors. The result of this exercise indicated the need to refocus on Earth-observation payloads, and to increase Vega's performance to be able to launch a slightly heavier, 1500 kg satellite into a 700 km polar orbit, whilst still maintaining the original cost target.

One of the major outcomes of the technical and programmatic trade-offs was the adoption for Vega's first stage of a new high-performance solid-propellant motor known as P80 FW. Featuring several technology advances, including a novel filament-wound (FW) casing structure, this new motor not only offered increased performance and lower production costs, but will also pave the way to future applications for medium-size launchers complementary to Ariane-5 and for a new generation of boosters for Ariane-5 itself.

The European Launcher Family

Illustration by D. Ducros, ©ESA

After about two years of definition and consolidation activities, the current Vega configuration, including the new P80 FW first stage, two additional solid-propellant stages (Zefiro 23 and Zefiro 9) as, respectively, second and third stages, and the AVUM upper module, had been established and was ready for development as an ESA programme. The formal funding was granted by the participating European States in December 2000, with a financial envelope of 335 million Euros. Seven countries subscribed to the programme: Italy, France, Spain, Belgium, The Netherlands, Switzerland and Sweden. The parallel development of the P80 FW motor was also approved, with a budget of 123 million Euros, about half of which is provided by Fiat-Avio as an industrial contribution. In addition to Italy, France, Belgium and The Netherlands are participating in the funding of the P80 development effort.

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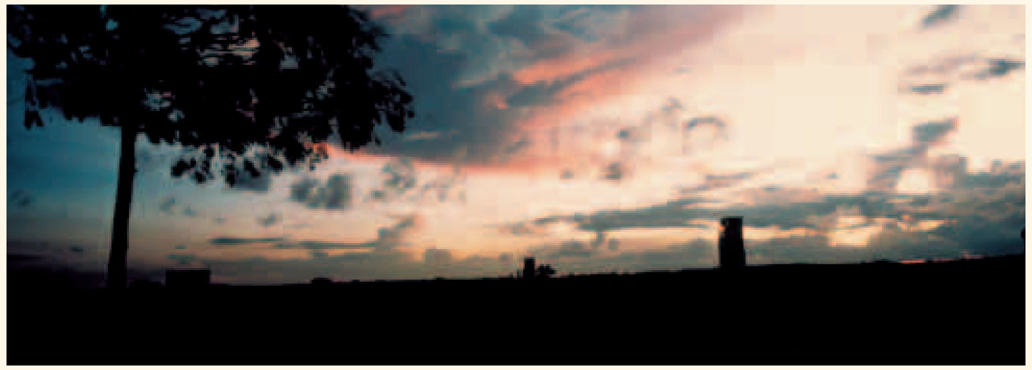
The Role of Vega

On the basis of the European needs and requirements that emerged from the ESA market survey, the specified mission for Vega is:



- launch of a payload of up to 1500 kg into a circular, 700 km-altitude polar orbit
- use of Kourou as the launch site.

Vega will be able to launch satellites for a wide range of missions and applications, into orbits with a range of inclinations from 5.2 degrees to Sun-Synchronous Orbit (SSO), with altitudes between 300 and 1500 km, and with payload masses ranging between 300 and 2500 kg.

Limiting the cost whilst still preserving and improving the launcher's competitiveness has been one of the major objectives during Vega's development. The key factor in that cost limitation has been the streamlining of the industrial organisation and the maximisation of synergy with the Ariane launcher family, by using the same components, the same production facilities and launch infrastructure, and relying on technologies, facilities and hardware developed within the Ariane programme and other national programmes. To improve its competitiveness, Vega includes several new technologies, particularly in the field of solid propulsion, all of which offer potential spin-offs to Ariane.

Consistent with the market projections and the performance to be offered, the overall programme goal is to conduct the first Vega qualification launch by the end of 2005.

The European Launcher Strategy

The European requirement for independent access to space first manifested itself in the early seventies against the background of strategic and commercial interests in telecommunications and Earth observation. As a consequence, Europe began construction of the Ariane launcher, which subsequently developed into a highly successful and profitable family of launchers (Ariane-1 to -4).

The change of political scenario in the nineties led to a new environment. Launch vehicles developed for military purposes in countries that were previously part of the Soviet Union become progressively more available to the Western market for use as commercial launchers. In the same timeframe, consolidation of the US aerospace industry created large corporations with strong capabilities in the field of space launchers. Over the same period, the satellite market evolved and diversified, with a rapid increase in the size of geostationary satellites, and the birth of LEO and MEO (Low and Medium Earth Orbit) satellite-constellation concepts for providing the entire globe with new services, and the multiplication of polar missions for Earth-observation applications.

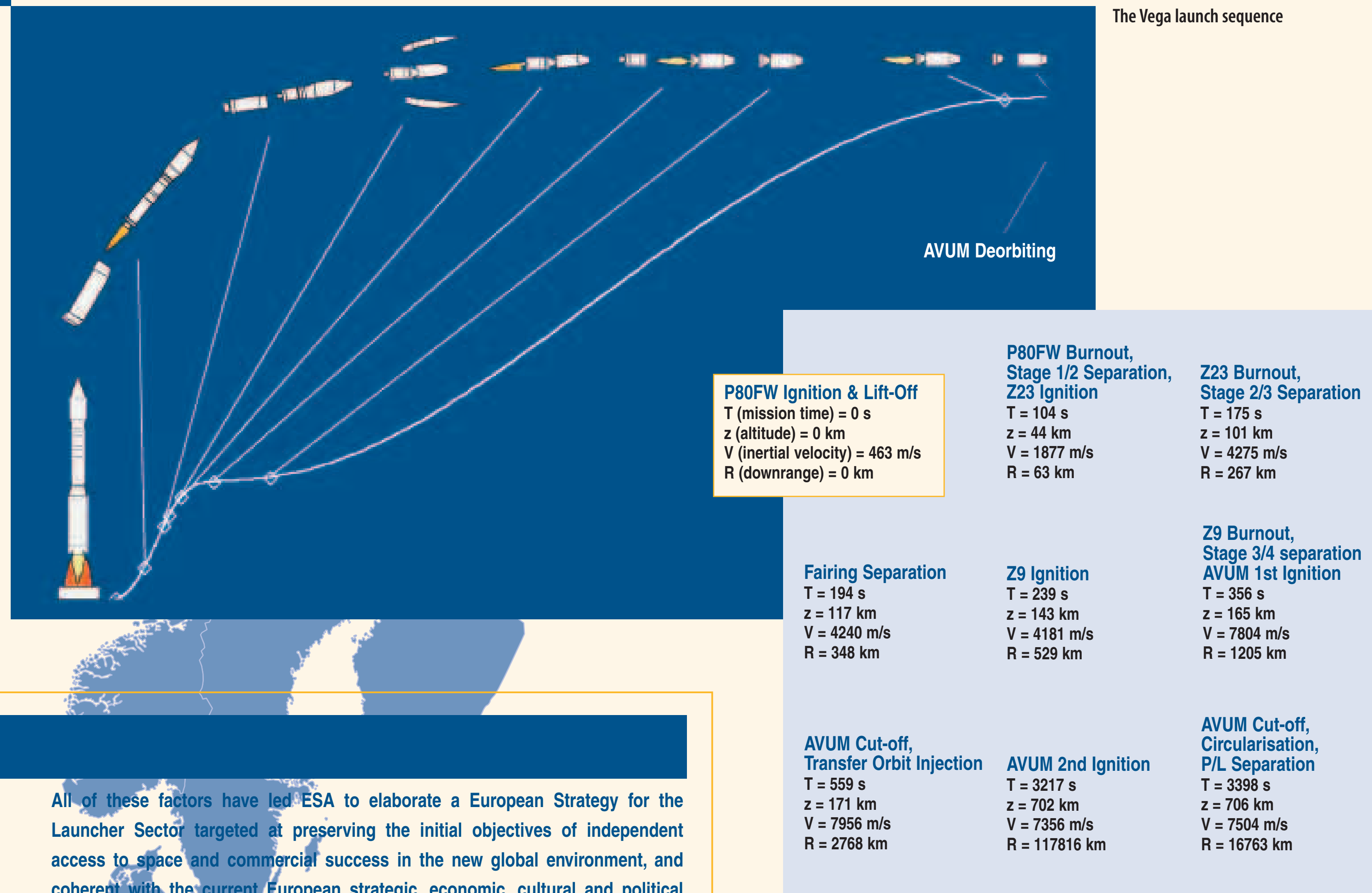
Modern society relies heavily on telecommunications, information technology and associated services, and it is therefore crucial for Europe to retain an independent satellite manufacturing and operating capability, not only for strategic and economic, but also for political and cultural reasons. Hence preserving European access to space remains a key objective, but it must be affordable to European governments, industry and service operators. Responding to today's diverse market demands requires an optimised family of European launch vehicles, exploiting common elements in terms of technologies, production facilities and operational infrastructure.

All of these factors have led ESA to elaborate a European Strategy for the Launcher Sector targeted at preserving the initial objectives of independent access to space and commercial success in the new global environment, and coherent with the current European strategic, economic, cultural and political interests. This Strategy foresees that Europe must:

- maintain Ariane-5's competitiveness on the world market, by making improvements (greater mission versatility, increased launcher performance, optimisation of production and operations) aimed at decreasing the specific launch cost;
- complete the range of launch services offered by adding European manufactured small- and medium-sized launchers, to compete on the international market;
- prepare the necessary technology for the timely development of the new systems that may be required for longer-term competition (2015-2020);
- ensure that the current quality of operations and services offered to customers at the European Spaceport in Kourou, French Guiana, is maintained.

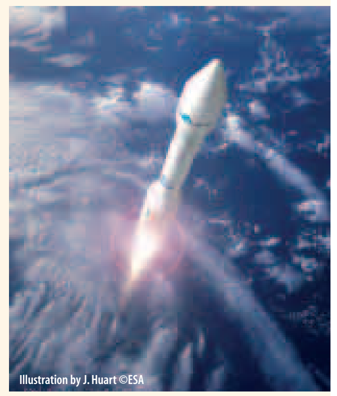
While the planned improvements to Ariane-5 will allow it to launch the heaviest payloads cost-effectively, European success in the face of the worldwide competition to provide commercial launch services involves developing a complementary family of launch vehicles. It was in this context that ESA took on the development of the Vega small launcher, targeting the market for low-cost launches into LEO for small missions with payload masses ranging between 300 and 2500 kg.

The Vega Vehicle

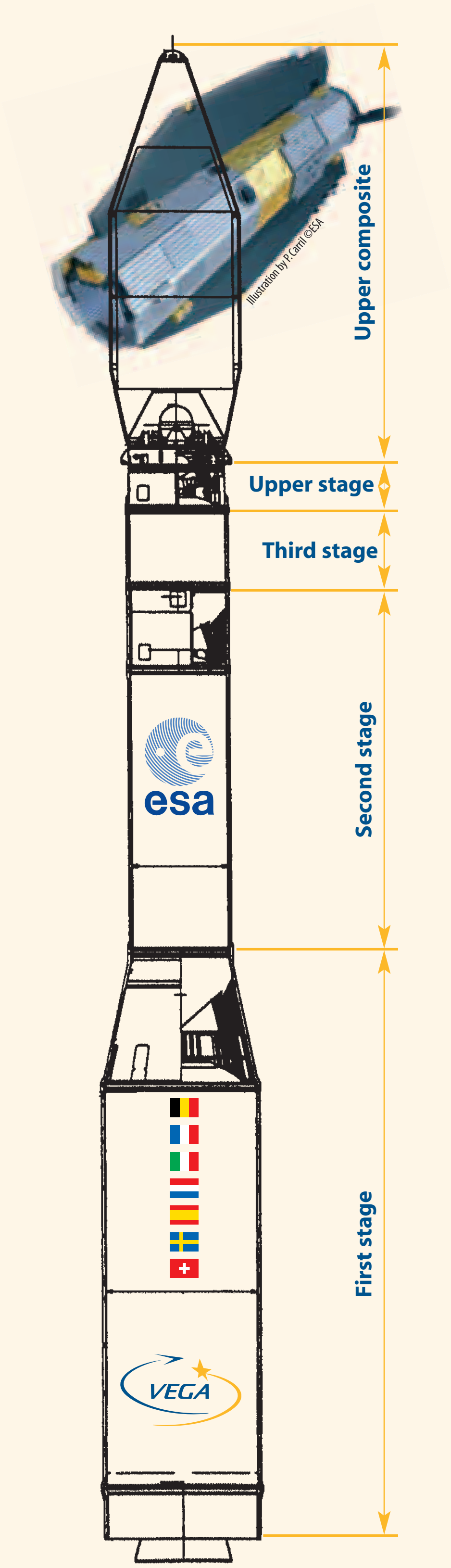


The Vega launch sequence

Vega is designed as a single-body vehicle composed of three solid-propulsion stages, an additional liquid-propulsion upper module, and a fairing for payload protection. The three solid stages perform the injection of the upper composite into a low-altitude orbit. The upper module, called 'AVUM' (Attitude and Vernier Upper Module), is used to improve the accuracy of the primary injection (compensation of solid-propulsion performance scatter), to circularise the orbit, and to perform the empty-stage de-orbiting manoeuvre. This module will also provide roll control during the third-stage boost phase and three-axis control during ballistic phases and before payload separation. The Vega launch sequence is shown in the accompanying figure.

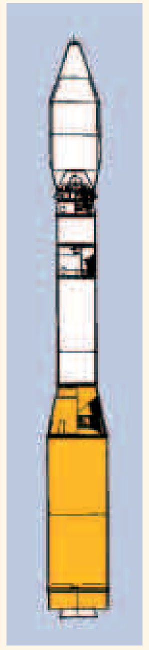


The Vega Vehicle



Main characteristics of the Vega elements

	1st stage P80 FW	2nd stage Zefiro 23	3rd stage Zefiro 9	4th stage AVUM
Length (m)	10	7.5	3.6	1.8
Diameter (m)	3	1.9	1.9	1.9
Propellant mass (ton)	88	24	9.5	0.39
Motor dry mass (kg)	6950	1880	725	336
Motor case mass (kg)	3350	865	315	-
Average thrust (kN)	2100	900	230	2.2 to 2.5
Specific impulse (s)	280	289	294	317
Combustion time (s)	105	71	116	620
Design leader	FiatAvio	FiatAvio	FiatAvio	FiatAvio



First stage

The first stage is based on the adoption of the new P80 solid-rocket motor being developed through a parallel Programme slice. The above panel provides some further details in that respect. In addition to the P80 motor, the first stage is composed of the structural elements needed to connect it to the second stage (interstage 1/2 aft part) and to the ground infrastructure (interstage 0/1), and to host the stage's avionics. Those airframes are aluminium shells, with integrated stiffeners on the inside. The rear skirt (interstage 0/1) is a cylindrical structure, while the interstage 1/2 is a conical structure in order to match the different stage diameters.

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 effort has two primary objectives:

– demonstration of many of the technologies necessary to guarantee the Ariane-5 solid-rocket booster's competitiveness, and
– qualification of the Vega first stage, representing the first step towards a new generation of European solid-rocket motors.

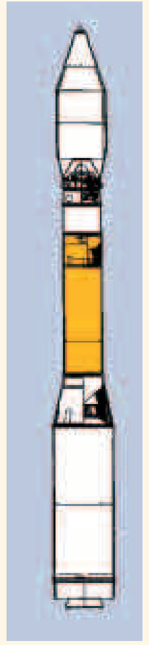
The P80 motor is tailored to the Vega small launcher, but its scale is also representative for validating technologies applicable at a later stage to a new generation of Ariane-5 solid boosters. A comparison between a Vega first stage, based on current Ariane-5 technologies, and the new P80 solid booster is shown in the accompanying table.

P80 Technology Choices

Component	P85 Metallic, Ariane-5 derived	P80 FW
Case	Metallic, re-use from Ariane-5, D6AC steel, two segments	CFRP monolithic carbon fibre
Propellant grain	Monolithic Finoxil aft star	Monolithic Finoxil aft star
Propellant	18 14 PBHT	19 12 PBHT
Insulation	GSM55-EG2 (Ariane-5)	EG1LDB3 low-density EPDM-based rubber derived from Zefiro
Nozzle throat	3D C/C	3D C/C new low-cost material
Exit cone	Metalllic housing + thermal protection	Composite, structural carbon phenolic
Flex joint	Boot-strap protection	Self-protected/low-torque
TVC actuator	Hydraulic	Electro-mechanical

The development milestones are consistent with the requirements of the Vega Small Launcher Development Plan, and the P80 Solid-Propulsion-Stage Demonstrator development, including its qualification at stage level, should therefore be completed by 2005. Maximum reduction in the recurring cost is a driving parameter at all levels of the solid-rocket motor's design (subsystems, components, equipment, ground infrastructure, operations, etc.). The target of a 25–30 % reduction with respect to the current metallic-case boosters has been set for both the Vega first stage and the new-generation Ariane-5 booster. There will be a further reduction in specific launch cost due to the increased performance of the new generation of booster.

The Vega Vehicle



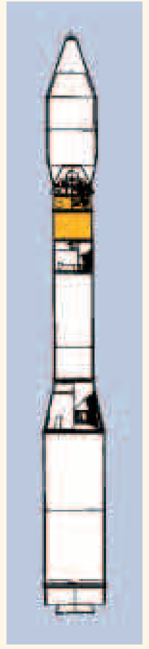
Second stage

The propulsion for the Vega second stage is based on a stretched version of the Zefiro 16 solid-rocket motor (SRM), with the propellant mass increased to 24 tons. Three Zefiro motor firing tests have been performed, in June 1998, June 1999 and December 2000, all with good results.

The new stretched SRM, known as Zefiro 23, employs:
– a lightweight carbon-epoxy case
– low-density EPDM-based thermal insulation, charged with glass microspheres
– HTPB 1912 composite propellant
– a moving nozzle, based on flexible-joint technology.

The propellant grain has a finocyl shape, with the star section in the aft zone of the motor. The Zefiro 23's combustion pressure and maximum vacuum thrust are 95 bar and 1200 kN, respectively. The nozzle has a throat diameter of 294 mm and an expansion ratio of about 25. The nominal firing time for the second stage is about 71 seconds. In addition to the Zefiro motor, the second stage includes the structural elements needed to connect it to adjacent stages and to host the stage avionics. The motor polar fittings and interstage flanges are high-strength aluminium forgings. In particular, interstage 2/3 is an aluminium cylindrical structure composed of shells with integrated stiffeners on the inside.

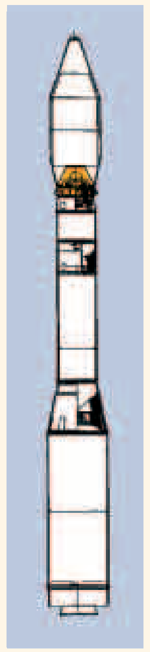
The Zefiro 16 firing test at Salto di Quirra on 15 December 2000



Third stage

The Vega third-stage propulsion is based on a solid-rocket motor with a propellant mass of 9.5 tons, known as Zefiro SRM and derived from Zefiro 16. Zefiro 9 employs a carbon-epoxy filament-wound case, a low-density EPDM-based thermal insulation, HTPB 1912 composite propellant, and a moving nozzle based on flexible-joint technology. Its combustion pressure and maximum vacuum thrust are 67 bar and 280 kN, respectively. The nozzle has a throat diameter of 164 mm and an expansion ratio of 56. Ignition occurs after a coasting phase of several seconds (depending on the required trajectory) following the Zefiro 23's burnout. The nominal firing time is about 116 seconds.

An interstage connects Zefiro 9 to the AVUM, and hosts the stage avionics and the main safeguard unit.

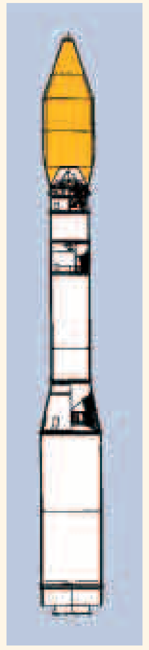


Upper stage

The AVUM upper stage is composed of two different sections, one hosting the propulsion elements (APM: AVUM Propulsion Module), and one dedicated to the vehicle equipment bay (AAM: AVUM Avionics Module). The APM provides attitude control and axial thrust during the final phases of Vega's flight, to fulfil the following functions:
– roll control during third- and fourth-stage flight
– attitude control during coasting flight and the in-orbit phase
– 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.

Preparation of the Zefiro 16 qualification-model motor for test firing at the Salto di Quirra test range in Sardinia, Italy

The total propellant loading will be between 250 and 500 kg, depending on the launcher configuration definition and the mission to be performed.



Upper composite

The upper composite includes the payload adapter and the fairing. The upper-stage configuration imposes the use of a conical structure in order to provide the required payload standard interface of 937 mm diameter. The reuse of an existing Ariane adapter is foreseen.

For the fairing, a two-shell configuration has been selected, with a 2.6 m external-diameter cylindrical part and a total height of 7.9 m – including a 3.5 m cylindrical part. The structure is made of two composite shells, composed of aluminium honeycomb and carbon skins. Several access doors are provided in each shell. Moreover, the fairing is equipped with venting ports (Ariane-5 type). The fairing is jettisoned by the combined action of a clamp-band attachment and pyrotechnic longitudinal separation system during the coasting phase between the second- and third-stage propulsion phases.

Avionics

To keep the development and recurring costs to a minimum, Vega's avionics will be largely based on the adaptation of 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. The baseline architecture consists of a centralised approach, somewhat similar to the Ariane-5 concept.

The electrical system has four main subsystems:

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

The Safeguard subsystem is the only Vega chain with complete redundancy, in order to comply with the launch safety requirements. For the other subsystems, there are specific redundancies at equipment level, where relevant, to improve the launcher's reliability.

The Flight Control subsystem will use an on-board programmable flight computer, an inertial measurement unit (derived directly 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 separations on receipt of signals from the on-board computer. The Telemetry subsystem will be similar to that on Ariane-5, as it must be compatible with the 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 destruct functions will be managed via new Safeguard Master Units (SMUs) and Safeguard Remote Units (SRUs) located in the stages.

The Vega Ground Segment

The ESA launch facility (Guiana Space Centre, CSG) in Kourou, French Guiana, offers a variety of launch-azimuth capabilities (equatorial, polar and intermediate inclinations) and existing infrastructures, services and logistical support, which made it the natural choice for Europe's new small launcher. The actual launch site selected for Vega, following a trade-off between the various options at CSG, is ELA-1, which is located between the Ariane-4 and Ariane-5 launch areas.

The new Vega ground segment will make use of the existing Ariane infrastructure, including the ELA-1 launch pad, which was originally built for Ariane-1, and the Ariane-5 Control Centre. The launcher assembly and integration operations will be performed on the pad in a new mobile BIV (Bâtiment d'Intégration Vega) building, which will be moved away after the launcher's final assembly. The actual launch operations will be conducted from a dedicated room within the Ariane-5 Control Centre (CDL-3).

Illustration by J. Huart ©ESA

The Vega launch and integration area

The Market for Vega

The decision to develop a small launcher was a response to a Resolution in the Space Transportation Strategy adopted by the ESA Council in June 2000, aiming at: *"completing, in the medium term, the range of launch services offered by the addition of a European-manufactured small and medium launcher, complementary to Ariane, consistent with diversified users' needs and relying on common elements, such as stages, subsystems, technologies, production facilities and operational infrastructure, thereby increasing the European launcher industry's competitiveness".*

Vega will also satisfy a potential market for launching small satellites identified in several forecasts. NASA, for example, is putting an emphasis on 'small missions' making use of low-mass satellites and low-capacity launch vehicles, and several European space agencies, especially the French and Italian agencies, will follow similar paths. The development of standard small-satellite platforms, such as Minisat, Proteus and Prima, has already been initiated and their availability is expected to attract several applications, allowing cost reductions and thereby stimulating new project starts.

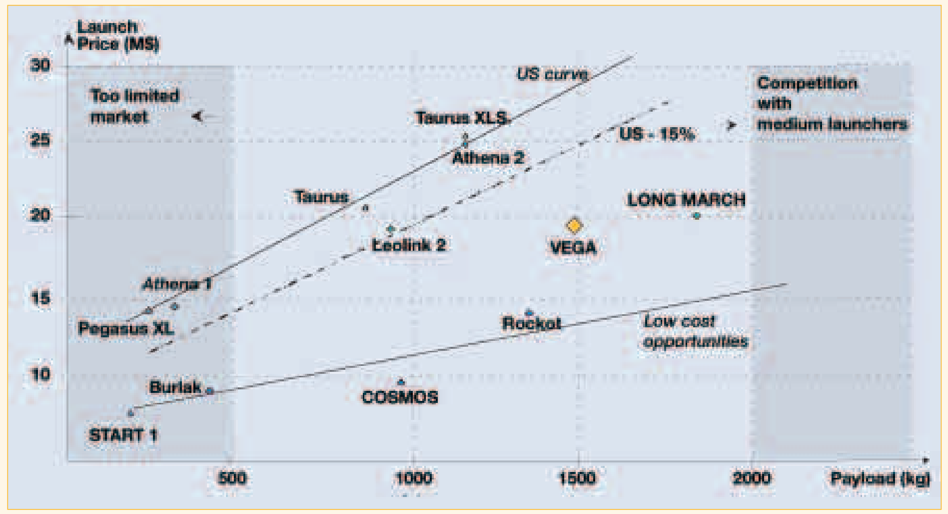
The recent evolution in Earth-observation technologies is also allowing a reduction in satellite masses. Optical and infrared detectors are now much smaller and, even in the field of radar observation, all-weather surveillance can be performed using satellites with masses of around 1 ton. ESA's Earth-Observation Programme currently has two main components: Earth Explorer science-driven missions and Earth Watch applications missions. Both are based on multiple small missions rather than another large single platform like Envisat.

For its scientific missions too, ESA is proposing a family of small satellites to demonstrate enabling technologies to be used for future larger missions (SMART missions).

In the field of telecommunications, two possible types of mission have been identified for small launchers. 'Little LEO' constellations, which are dedicated to data transmission, store-and-forward services in real time, and messaging applications, are based on satellites weighing some hundreds of kilogrammes. These satellites may be launched as a single or multiple payload by a small launcher. 'Big LEO' constellations are based on satellites of about one ton. For these systems, spares management is not a trivial process, and the timely replacement of a failed spacecraft typically in less than two months allows a major saving. With such constellations relying on a very large number of satellites, the market potential for small launchers is linked to the need for such replacements, with the initial deployment of the constellations themselves relying mainly on medium and heavy launchers.

As a result of several different, independent assessments of the potential market for a European small launcher, it has been estimated that the number of European (and a few non-European) governmental missions making use of such a launcher will initially be of the order of two per year, and may grow to four per year after 2005, with a total of 30 to 35 launches in the period 2005 – 2010.

Price/performance comparison for Vega and other launchers



Current projections show that for Little-LEO constellation deployment, and for Big-LEO (e.g. Globalstar, Iridium) and broadband LEO satellite replacement, the market is very uncertain. Taking into account the rapid changes and the uncertainties about how constellations will develop, the number of additional payloads originating from such commercial applications is estimated to be one or two per year. An increased launch rate may be envisaged in the longer term as a result of:

– confirmation of the validity of the small-mission approach
– improvements in miniaturisation technologies for small satellites.

Combining the forecasts for these various categories of customers, therefore, the projected market for a European small launcher may be three to four launches per year initially, starting from 2006. This is expected to grow once the service is well established, and the vehicle is marketed internationally by an experienced organisation such as Arianespace. This projected market represents a realistic baseline for Vega operations.

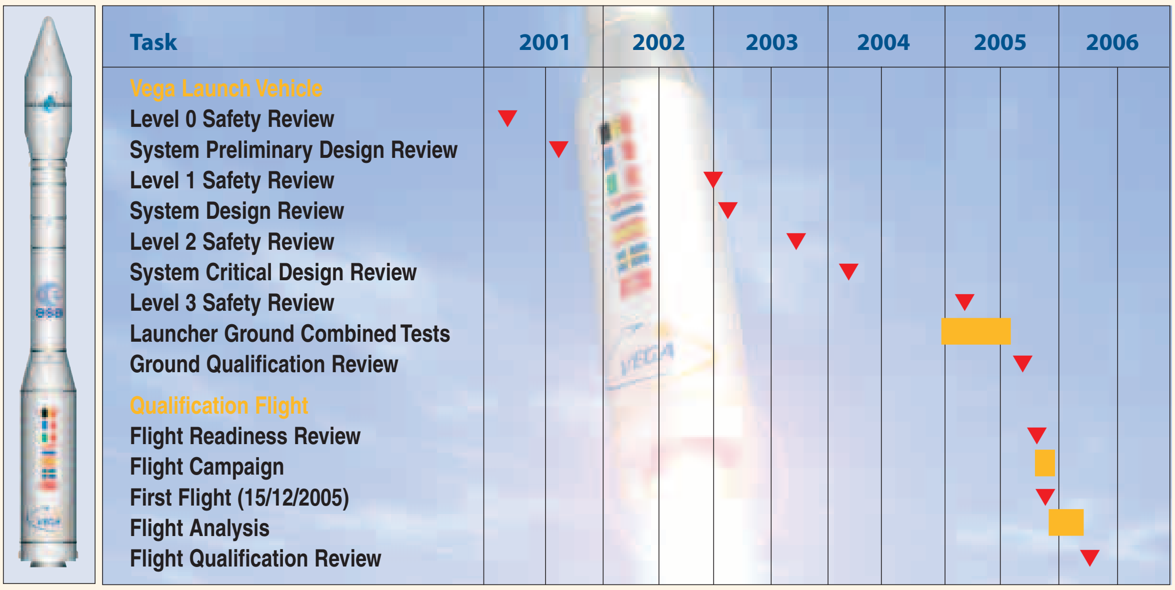
Obviously, the key parameter driving the commercial success of a new launcher is the cost of the service it can offer. The target set for Vega from the beginning of the programme was that of being at least 15% cheaper than the market competitors offering western standards of launch services.

Current Status

At the time of writing, in mid-2002, the development programme for Europe's new small Vega launcher is well underway. The System Preliminary Design Review was completed in July 2001 and confirmed that the technical baseline is sound and consistent with the strict system and programmatic requirements. At engine-development level, the Zefiro motor that will power Vega's second stage has already undergone one demonstration and two development full-scale firing tests at the Sardinia test range. The next key milestones are the System Design Review (SDR) foreseen for early 2003 and the Critical Design Review (CDR) scheduled for March 2004. The parallel development activities for Vega's new first-stage P80 motor and for the ground segment are also progressing according to plan, and are consistent with a first qualification flight for Europe's new small launcher by the end of 2005.

The latest information is available from the ESA Directorate of Launchers website at: www.esa.int

The Vega Master Development Plan



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