Educational Payload on the Vega Maiden Flight

Call For CubeSat Proposals

Education Office
Directorate of Legal Affairs and External Relations

Vega Programme Office
Directorate of Launchers

European Space Agency

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Acronyms

AD	Applicable Document
AVUM	Altitude and Vernier Upper Module
CSG	Centre Spatial Guyanais
D/LAU	Directorate of Launchers
D/LEX	Directorate of Legal Affairs and External Relations
ESTEC	European Space Research and Technology Centre
ICD	Interface Control Document
LARES	LAser RElativity Satellite
POD	Picosatellite Orbital Deployer
P-POD and X-POD	Commercial implementations of a POD
RD	Reference Document
TBC	To Be Confirmed
VERTA	VEga Research and Technology Accompaniment programme

1 Background

This Call for Proposals for educational CubeSats on the Vega Maiden Flight is issued jointly by the Education Office (LEX-E) in the Directorate of Legal Affairs and External Relations (D/LEX) and the Vega Programme Office (LAU-PV) in the Directorate of Launchers (D/LAU). The basis for this Call is the Agreement between D/LAU and D/LEX concerning the Educational Payload on the Vega Maiden Flight, signed by the two Directors on 28 May 2007. A first Announcement of Opportunity (AO) was published on the education pages of the ESA web portal on 9 October 2007.

In the meantime, the Vega Maiden Flight CubeSat Workshop was held at ESTEC on 22 – 24 January 2008 and many of the unknowns remain unresolved regarding the launch. However, the uncertainty concerning the main payload design is less critical as the CubeSats shall be of standard size (10 x 10 x 10 cm), fitting into a standard Picosatellite Orbital Deployer (POD), and their design should be independent of any other payloads.

Both, the Agreement and the AO, also foresee the possibility of other educational payload elements which remain fixed to the qualification payload. These 'fixed payload elements' are not subject of this Call and will be dealt with at a later stage after the selection of the CubeSats.

2 Applicable Documents

[AD1] Vega User's Manual, Issue 3, Rev. 0, March 2006.

[AD2] Vega Launch Vehicle Programme General Specification: Qualification and Acceptance Test of Equipments (VG-SG-1-C-040-SYS), Issue 5, Rev. 1, 13 November 2006.

[AD3] Poly Picosatellite Orbital Deployer Interface Control Document, Issue 1, 11 February 2004.

[AD4] CubeSat Design Specification, revision 10, 2 August 2006.

3 Reference Documents

[RD1] Vega Launch Vehicle Programme: Vega Launch Vehicle Qualification Mission (VG-NT-1-3-C-003-IPT), Issue 1, Rev. 0, 28 August 2006.

[RD2] The LARES mission for testing the dynamics of General Relativity, I. Ciufolini, Aerospace Conference, 2003.

4 Description of the Flight Opportunity

4.1 The VEGA Launcher

Vega is ESA's new small launch vehicle which is targeted for its maiden flight in December 2008. The Vega launch vehicle is being developed under the management of the Vega Programme (LAU-PV) in the framework of an ESA optional programme funded by Belgium, France, Italy, Spain, Sweden, Switzerland and The Netherlands. Vega is designed to launch 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 can launch payloads ranging from a single satellite up to one main satellite plus six microsatellites, it is compatible with payload masses ranging from 300 to 2500 kg and can provide launch services for a variety of orbits, from equatorial to Sun-synchronous.

Vega is a single-body launcher (i.e. no attached boosters) composed of three solid-propellant stages and a restartable liquid-propellant fourth stage. It is 30 m high, has a maximum diameter of 3 m and weighs 137 tons at lift-off. Vega has three sections: the Lower Composite; the Upper Module and the Payload Composite. The Upper Module, known as the Altitude and Vernier Upper Module (AVUM), is itself composed of a Propulsion Module and an Avionics Module. The AVUM provides attitude control and axial thrust during the final phases of Vega's flight to allow the correct orientation and orbit injection of multiple payloads, with final deorbiting of the stage once manoeuvres are completed.

The fairing of the Payload Composite 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. Also part of the Payload Composite is a standard launcher/satellite interface: a 60 kg cone-shaped carbon-fibre structure with a diameter of 937 mm at the separation plane between launcher and satellite.

4.2 LARES - the VEGA maiden flight primary science payload.

The primary scientific payload on the maiden flight is the LAser RElativity Satellite (LARES) for testing a prediction following from Einstein's theory of General Relativity, the so-called 'frame-dragging or Lense-Thirring effect'. LARES is basically a solid sphere made of Tungsten with a diameter of 376 mm and a mass of 400 kg. The surface of the sphere is covered by 92 Corner Cube Reflectors (CCR). To achieve its scientific objectives, LARES will be injected into a circular orbit at 1200 km altitude with an inclination of 71º. As LARES orbits the Earth, laser beams are emitted from a number of ground stations around the Earth, the International Laser Ranging Service, and reflected by the CCRs on LARES to the ground stations. The time delay between emission and arrival of the laser beam provides a measure of the round-trip distance to LARES, allowing a highly accurate orbit determination. Correcting for a number of effects, most importantly the deviation of the Earth gravitational field from an ideal sphere, yields the frame-dragging effect.

4.3 Qualification Flight technology payload.

The main passenger on the maiden flight will be an adaptation from the existing Upper Composite test dummy used during the Upper Composite mechanical test campaign held at ESTEC in 2006. Its purpose is to measure actual launch loads experienced by a typical payload, which will be correlated against the models used during the design of the launcher. It will have its own independent telemetry system powered by batteries. It will have passive thermal control, but no attitude control system and no solar panels, thus limiting its lifetime to the on-board battery capacity, expected to be maximum about 5 hours depending on the power consumption. The payload will be fitted with a variety of sensors to characterise the environmental parameters and demonstrate conformance with the specifications in the Vega User's Manual.

An educational payload of six European CubeSats is foreseen to be accommodated in two PODs (Picosatellite Orbital Deployers), each containing three CubeSats, attached to and deployed from the qualification payload. The AVUM multi-burn facility will be utilised to put the CubeSats into either a 1200x350Km elliptical orbit or a 350Km circular orbit (TBC). The qualification payload will be separated from the AVUM after the orbital manoeuvres.

4.4 CubeSats on the Maiden Flight

4.4.1 CubeSat concept

The CubeSat concept was developed by the California Polytechnic State University (CalPoly) and the Space Systems Development Laboratory of Stanford University [AD4]. It had the purpose of creating space research opportunities for universities previously unable to access space by defining a standard mechanical interface and deployment system.

A CubeSat is a 10 cm cube with a mass of up to 1 kg and functions fully autonomously. Worldwide over 60 universities, high schools and industries are involved in the development of CubeSats, with payloads covering a wide range of scientific, engineering and industrial objectives. The concept of double and triple CubeSats, with dimensions of 10x10x20 and 10x10x30 respectively and a corresponding increase in the mass, have also been developed, but for the purpose of the VEGA maiden flight only single CubeSat modules will be accepted by ESA.

Important note: The CubeSat specification [AD4] recommends two separation switches but permits the use of a single switch. ESA requires that two switches be used.

4.4.2 Flight Opportunity

The opportunity to fly CubeSats on the Vega maiden flight is proposed by the ESA Education Office with the purpose of giving students from European universities and other educational institutions wishing to pursue a career in the space domain a valuable hands-on experience. They can take part in this end-to-end space project including educational activities from design, integration, verification, launch and operations. The educational payloads will be entirely developed by educational institutions, with advice from ESTEC experts if requested and deemed appropriate by the Education Office. All payloads shall fully comply with the Vega general specification for qualification and acceptance test of equipment [AD2].

This Call for Proposals addresses an educational payload comprised of six CubeSats which will be released from the main passenger and can operate autonomously in orbit thereafter. Within the terms of reference of the ESA Education Office, it should be assumed that opportunities will be offered to six different education establishments in six different Member States.

4.4.3 Deployment system

The baseline chosen will be standard flight-proven CubeSat deployment systems – either P-POD from CalPoly (California, USA) or X-POD from UTIS-SFR (Toronto, Canada). Each POD is designed to carry three standard CubeSats and serves as the interface between the CubeSats and the launch vehicle. It is a rectangular aluminium box with an electrically activated spring-loaded door mechanism. After the door is opened the CubeSats are pushed out by a spring along guidance rails, ejecting them into orbit with a separation speed of a few m/s. The X-POD version has an independent release mechanism for the spring deployer and feedback to indicate deployment has taken place. The P-POD version technical interface is described in [AD3].

All educational payload elements shall have their own power supplies and communication facilities. There is no electrical interface to the CubeSats either from the POD or the main payload, and once the CubeSat is installed in the POD prior to launch there will be no opportunity for further battery charging. The CubeSats are expected to be electrically inert once inserted into the POD, with no power dissipation or RF emissions. They are expected to utilise the sensors in the feet of the CubeSat structure to determine launcher separation and begin operations.

Note that once the CubeSats are loaded into the PODs, there are still a number of launcher activities to be finalised (closing the fairing, fuelling the AVUM, etc.) and with this being the first launch, some of these activities could require an extended timescale. At this time, it is not known if the CubeSats will be loaded into the PODs before the Payload Composite is mounted on the launch vehicle. The CubeSat suppliers should expect a delay of at least several days between loading the PODs and actual launch.

4.4.4 Testing and Qualification of the CubeSat

All CubeSats proposed for launch on the Maiden Flight shall undergo a test campaign showing their compliance to the launcher requirements. Besides this, the test plan shall include also any additional testing requirements deemed necessary to ensure the safety of the payload. The tests levels shall be in accordance with the proposed model philosophy (EQM/FM and or EM/PFM) including therefore qualification testing in case of absence of previously developed flight models covering the requirements of the VEGA launcher. Until further clarification is received from the launch authority, Severity Level 2 defined in [AD2] should be assumed.

CLARIFICATION
ESA recognises that AD2 may be challenging for the compliance of CubeSats in the area of random vibration, and therefore requests that proposals contain their maximum possible vibration levels if they are below the levels specified in the document. If this is the case, then ESA will proceed to compute the loads at the base of the deployer and revise the qualification levels for CubeSat payloads as necessary.

Note that ESA gives no guarantee of the order of stacking the CubeSats in the deployers. In the event that one or more of the CubeSats is not accepted for flight and a mass dummy has to be used, then the order of loading the CubeSats in the deployers will be adjusted and arrangements will be put in place such that no mass dummy is actually deployed into orbit.

5 Orbital parameters

5.1 LARES

The LARES satellite is supposed to be placed by Vega into a circular orbit with an altitude of 1200 km and an inclination of 71º. Thereafter, the orbit will be changed by a de-orbit boost of the AVUM. The new orbit will have a perigee of 350 km and an apogee of 1200 km, the inclination is 71º as before.

5.2 CubeSats

The CubeSats will be released into the new orbit obtained through the AVUM boosting. This orbit is more compatible with the capabilities of the planned CubeSats ground stations. The braking effect of the residual atmosphere will lower the apogee by about 40 km per month (this is just a rough estimate, more detailed calculations are ongoing). In this new orbit, the lifetime will be much less than 25 years, therefore compliant with international requirements related to space debris.

Currently under investigation is the possibility to change the 350 x 1200 km orbit to a 350 x 350 km orbit by an additional firing of the AVUM liquid propellant engine.

At this time it is not known if the deployment will take place in sunlight or eclipse. This may indeed not be known until after lift off, as a last-minute launch delay could affect the deployment position relative to the sun.

6 Milestones and Schedule

The schedule of the educational payload has to comply with the Vega Maiden Flight schedule requirements. Currently the launch date is objective, and should be regarded as a 'not earlier than' date. The major milestones for the procurement of the CubeSats are the following:

Call for Proposals issued	15 February 2008
Deadline for the submission of proposals	17 March 2008
Final selection of CubeSats	15 April 2008
CubeSat Flight Acceptance Reviews (FARs)	launch – 12 weeks
CubeSat mass dummies delivery to ESTEC	launch – 12 weeks
CubeSat flight hardware shipment to CSG, Kourou	launch – 10 weeks
Target launch date	December 2008 (TBC)

In the event of a launch slippage, the milestones after the final selection of the CubeSats will also slip in accordance with the above table, and the participating groups will be notified at the earliest opportunity.

7 Project Interface

The management of the relations with the educational project teams is under the full responsibility of the Education Office. It was agreed between D/LAU and D/LEX that the Vega educational payload Project Manager in the Education Office has to be the sole point of contact for the CubeSat teams throughout the duration of the project. Direct contact from the CubeSat teams with either the Vega Project Team or their industrial contractors is not permitted and could be detrimental to future cooperation on launch opportunities.

The formal point of contact is:
Dr. Roger Walker,
Head of the Education Projects Activities Unit,
ESA Education Office,
ESTEC
2201AZ Noordwijk,
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8 Deliverables

8.1 Cubesats

- a mass dummy fully representative of the flight model in terms of volume, mass and centre of gravity
- a flight model fully tested according to the specifications required by the Vega Maiden Flight with the associated documentation including as a minimum
    - ICD (mechanical)
    - User Manual
    - Test Reports

8.2 Picosat Orbital Deployers

Two PODs will be provided by the Education Office to D/LAU, to be integrated onto the main payload. At least one additional POD, also provided by the Education Office, will be available for fit-checking and any possible additional mechanical tests. The use of P-PODs or X-PODs is still subject to ongoing negotiation, but both meet the standard for CubeSats and both have flight heritage.

9 Legal Agreement

Following selection by ESA for the flight opportunity, each educational institution will be required to sign a legal agreement committing to the provision of all deliverables by the schedule specified above. The proposing team will be sent a letter of notification of selection by the Education Office shortly after the selection has been made. This letter will be accompanied by a draft legal agreement, which will legal clauses in the areas specified below.

ESA shall have no liability to the providers of the educational payload elements, neither in case it is not possible to provide the Vega Maiden Flight launch opportunity, nor if the launch is delayed, nor if the launch or the deployment fails. The providers of the educational payload elements that benefit from the launch opportunity shall waive completely and totally all claims against ESA and its suppliers without any exception.

The providers of the educational payload elements shall commit to provide the necessary technical inputs and deliverables in accordance with the Vega Maiden Flight milestones and launch campaign preparations, knowing that, in the case of delays of deliverables not compatible with the launch campaign preparation, it will be considered that the hardware will not be accepted for the Vega Maiden Flight without any claim for compensation. If any CubeSat flight model is not ready in time, D/LAU will replace it with one of the back-up CubeSats or a mass dummy.

ESA shall organise technical interface meetings, if necessary, with the educational payload project teams, in order to finalise their technical specifications and to settle

the inputs required from the users in order to proceed with the launch campaign activities. It shall also inform payload project teams, as soon as possible, in the case of any delay of the Vega Maiden Flight, in order to avoid any unnecessary costs being incurred on the user's side, once their key programmatic milestones have been identified.

10 Funding

The launch opportunity on the Vega Maiden Flight is offered free of charge by the Directorate of Launchers (D/LAU). No insurance will be taken by D/LAU in case of flight failure and, therefore, no financial compensation shall be expected from the users if such a situation occurs.

All CubeSat payload elements (flight unit and mass dummy) will be provided by the educational institutions to the Education Office (LEX-E) at ESTEC. All costs associated with the educational payload elements until delivery of the flight hardware to ESTEC and final acceptance by LEX-E will be covered by the educational institutions. LEX-E will cover the costs for:

- the provision of deployers
- any supplementary tests of the flight CubeSats at the test facilities at ESTEC if required by the launch authority.
- the integration of the CubeSats into the deployers
- the ESTEC expert support
- the transportation of the mass dummies, deployers and flight hardware to CSG
- the travel and subsistence expenses of up to three students per CubeSat team to attend Workshops and technical interface meetings at ESTEC as required, to participate in the integration and testing campaign and to participate in the launch campaign.

11 Guidelines for preparing the proposals

CubeSat teams from ESA Member States and Cooperating States wishing to make use of the Vega flight opportunity are invited to submit proposals to the Education Office. The deadline for submission of proposals is **17 March 2008**. The proposals should not exceed, as a guideline, **15 pages.** While this is not a strict limit, concise proposals are encouraged and will be more favourably viewed by the selection board. If felt necessary detailed information can be provided in annexes. As a minimum, the proposals should contain:

- a description of the objectives of the CubeSat, with mission profile and duration
- a technical description of the CubeSat (including development and off-the-shelf items)
- the test plan and envisaged test facilities
- a discussion of the compatibility with the envisaged orbit

- a description of the envisaged ground station or ground station network and its readiness
- detailed planning schedule, including the availability of any non-flight models which may be built purely for test purposes, until the earliest flight model delivery date.
- a cost breakdown and a description of the funding sources
- composition of students involved in the project through all stages (numbers, academic level, relevant background and experience) and academic credit available to the students for this project work
- the names of the key people in the project, including a central point of contact for the team with email address and phone number

12 Selection process and criteria

The selection of the six Cubesats for the maiden flight plus two backups will be decided jointly by the Director of Legal Affairs and External Relations (D/LEX) and the Director of Launchers (D/LAU), based upon a recommendation of the Selection Board.

The selection criteria will include, amongst others:

- the educational content, technical maturity and project objectives of the proposals,
- letters of commitment by the funding bodies (institutions and/or industry)
- compliance of the development schedules with the Vega Maiden Flight schedule,
- signing of relevant agreements between the educational institutions (universities) and the Education Office.

13 Backup CubeSats

From the proposals received, in addition to the six selected for flight, two backup CubeSats will be selected and treated by the Education Office in the same way as the selected flight units, i.e. they will follow the same schedule and participate in the integration and test campaign. During the launch campaign they are on stand-by. In this way, they can replace the selected flight CubeSats at any time should an unresolvable problem occur with any of the flight CubeSats or should any of them not be ready in time. If everything goes as planned with the flight CubeSats then backup CubeSats will have the highest priority for flight on the next launch opportunity which becomes available to the Education Office.