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ARES EVE5: AN OCTAVE'S EXPERIMENTAL ROCKET FOR PERSEUS PROJECT

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OCTAVE association was founded in 2009 into the University of Evry. It gathers students, professionals, or people interested in aeronautics and space from Evry to design and experiment in those fields.

In this purpose, OCTAVE takes part of PERSEUS project (initiated by CNES in 2005 at the International Paris Air Show). We have designed rockets, test benches, and a lot of electrical and mechanical stuff. These activities in PERSEUS project must respect CNES and Planète Sciences (French association promoting sciences) specifications.

This document presents our work on our sixth experimental flight demonstrator, called EVE5. Thanks to it, we won the innovation prize from CNES.

EVE5 is a high power rocket demonstrator designed and built by OCTAVE according to the ARES rocket specifications of PERSEUS project. Meaning the electrical architecture is composed of several electronic modules which are the electronic core of the system. The mechanical structure is made of composite fiber with hybrid foam sandwich tubes, and mechanical rings (between tubes) which are made of aluminum. The nose cone, with Von Karman geometry, is made of Kevlar carbon composite, and was studied for a supersonic flight. The rocket use a double parachutes system for descent and it is propelled with a classical Cesaroni engine Pro75-3G.

Each rocket design in the fame of PERSEUS project has to be an upgrade of the previous one: more powerful, more sophisticated. In this context, the main objective for EVE5 was a new nose tip, made with an alternative kind of manufacturing technique: selective laser melting. This nose allowed us to substitute the new nose to the Pitot tube. It incorporates 5 holes used for pressure sensors. We also design the interface to get measures from this nose and a real time video transmission system.

There were ten students members of OCTAVE working on this project with the help of teachers of the University of Evry. We chose to build three teams according to our skills: the first was responsible for mechanical designs (design, structure optimization), the second was responsible for the electrical systems (design, integration) and the third was responsible for developing embedded software.

The final prototype has been launched during the C'SPACE 2013, organized by CNES, in the military site of DGA EM (Biscarrosse, France), the last week of august 2013.

I. INTRODUCTION

Since 2009, every year the OCTAVE association designs at least one experimental rocket demonstrator for the PERSEUS project. One of these demonstrators was made in collaboration with the Dutch club DARE.

The demonstrator which gave us the opportunity to write this paper is called EVE[*]5 (the fifth rocket entirely made by Evry students).

I.I Team

The team behind the experimental rocket EVE5 is composed exclusively of students with multidisciplinary knowledge in rocket design.

Organization

For each project, the OCTAVE association makes a team responsible of its accomplishment. The EVE5 team can be divided in three sub-teams coordinated by the project chief: Jérémy KORWIN-ZMIJOWSKI. The members repartition is assumed according to their skill fields.

The mechanical sub-team is composed of Quentin LE JONCOUR and Benoît ESPERAT. The electrical team is composed of Léo GIRARD and Jérémy KORWIN-ZMIJOWSKI. And finally, Benoît HUGUES and Xavier REGIDOR (an ERASMUS Spanish student) are the computer scientist team of the project.

Each sub-team has its own tasks but it should work considering the other sub-team duty.

[*] EVE : Evry Val d'Essonne

The University of Evry-Val d'Essonne has brought a crucial support with the help of Shehzaad CALLACHAND as an operational technics director.

II. UNIVERSITY OF EVRY

The University of Evry-Val d'Essonne (UEVE) was created in 1991 as part of the development of higher education in the Ile-de-France region.

Situated in a growing agglomeration, the university has been multidisciplinary from the start and has developed work-oriented education in order to meet the demands of its local social and economic environment.

There are more than 160 curricula, over half of which are professionally-oriented. The University offers courses in Science, Technology, Law, Economics, Management and the Social Sciences.

The University of Evry has built a reputation as a dynamic local institution, one whose students find work rapidly. Today, the university counts more than 10 000 students (data from April 2008) in both initial and ongoing training.

Thanks to 18 laboratories and 3 doctoral schools, the university is also a significant research center developing major projects, in particular those concerning Biology in conjunction with the Genopole.

The University of Evry is composed of 5 Faculties and it includes a very dynamic Institute for Technology and the ENSIIE (National School of Computer Science for Industry and Business), a well-known Engineering School.

OCTAVE association is hosted in the University of Evry-Val d'Essonne, into the Sciences and Technologies Faculty, where an aeronautics cluster is born. It is now under the direction of Mr Saïd MAMMAR, Mrs Claire VASILJEVIC and Gerard PORCHER.

III. PERSEUS PROJECT

The “Projet Etudiant de Recherche Spatial Européen Universitaire et Scientifique” (PERSEUS) is an european and scientific student project for spatial research. This project is an initiative of the Launcher Directorate of the Centre National d’Etudes Spatial (CNES). It is part of the preparation of the future and aims to promote the emergence of innovative technical solutions from space projects for industrial and educational value, all made by college students.

The project has three main objectives, in order of priority:

- Innovation research and promising technologies development in purpose to be applicable to space transportation systems;
- The implementation by students in an academic and associative framework to develop their motivation and interest for space careers;
- The development of a set of ground and flight demonstrators to establish comprehensive draft report about a nanosatellite launch system.

ARES Macro-Project

To allow students to more easily address the problematic development of a launcher, the PERSEUS project is divided in sub-projects, called macro-projects.

Each macro-projet is related to a system discipline. It gathers all the students or partners activities around the system discipline associate to the macro-project.

The ARES (for Advanced Rocket for Experimental Studies) macro-project aims to design experimental rockets. The purpose is to develop flying test-benches for technologies from others macro-projects. EVE5 experimental rocket is part of ARES macro-project.

IV. EVE5 AN ARES EXPERIMENTAL ROCKET DEMONSTRATOR

IV.I Specifications

EVE5 respect the ARES standards regarding the mechanical architecture and electrical systems.

Mechanical specifications

- Mass of mechanical structure: 4.5kg;
- Electrical core (avionics): 3,5kg;
- Recovery system: 2kg;
- Equipment: 1kg;
- Experiences: 1kg;
- Cesaroni Pro75-3G propulsion;
- Handle high vibrations environment;
- Tubes diameter: 160mm;

Electrical specifications

To embed the following modules:
- SYSTAR, from SYSNAV;
- ESIEE-SPACE, from ESIEE School;
- XSens base system, from IPSA School;
- Time measurement, from GAREF Association;

- On Board Computer (OBC), from GAREF Association;
- Radio emitter, from GAREF Association;
- Power distribution, from GAREF Association;
- Battery pack, from GAREF Association;

Global PERSEUS specifications

- PERSEUS Launchpad;
- To embed scientific and technic experiences;
- PERSEUS management guidelines;
- Redaction of a report based on tests and flight results to submit to the CNES.

IV.II EVE5 Presentation

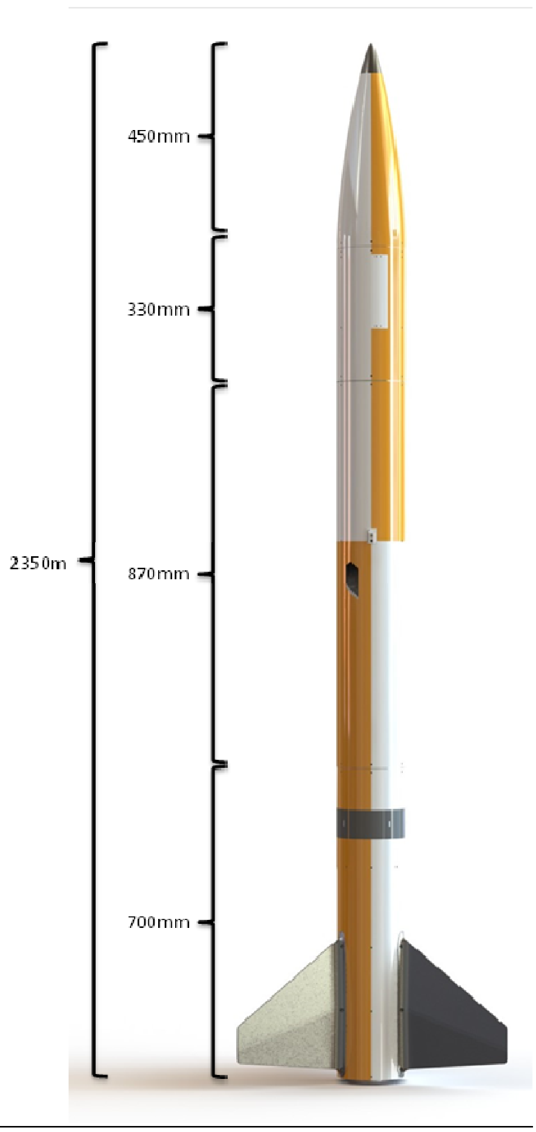

Fig. I: General view of EVE5, with parts sized.

All tubes are manufactured and supplied by the French engineering school IPSA (mass per unit length: 900g/m).

Tubes are qualified (for compression stresses and arrow deformation) with a test-bench designed especially for ARES demonstrators. This test-bench is another realization from University of Evry Val d'Essonne students.

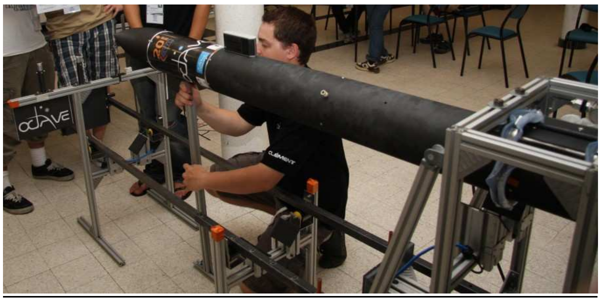

Fig. II: Test-bench designed by the University of Evry Val d'Essonne students with the EVE3 rocket

EVE5 is a four-part assembly. From bottom to top, the first is the propellant tube where fins are attached to; the second is the avionics and recovery tube; the third is the payload compartment; finally, the last part is the nose cone equipped with pressure sensors.

IV.III EVE5 Parts decomposition

Propellant tube

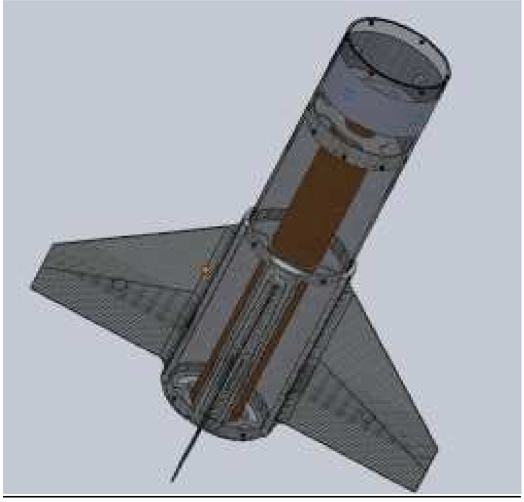

Fig. III: Propellant tube

The propellant tube is composed of three rings: one base ring, one centering ring and one thrust ring. Fins are fixed on the base ring plus the centered ring.

Inside the tube, over the propellant, there are all the radio emitter equipment: a power divider and the emitter. Around the top of the propellant tube, a patch antenna is circled.

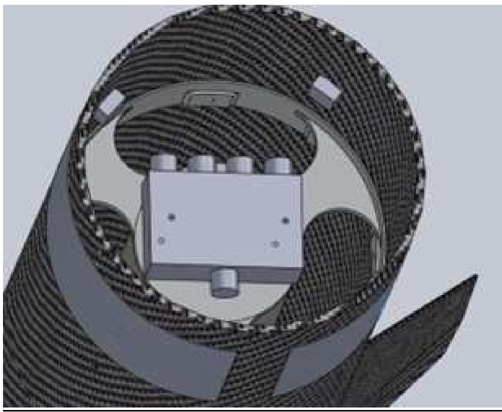

Fig. IV: GAREF’s patch antenna around the propellant tube

Avionics and recovery tube

Avionics rack and recovery system are placed in the same tube. The avionics rack is in the lower part of the tube, the nearest position from the gravity center; on the upper part, there is the recovery system housing.

Avionics part

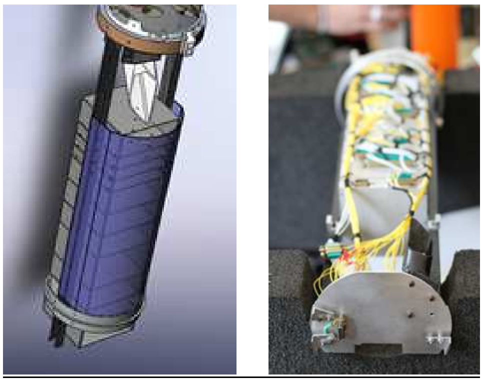

Fig. V: Avionics rack

The avionics rack is composed of the following modules plus the modules required in specifications:

- IMU measurement board, from OCTAVE;
- Pressure measurement board, from OCTAVE;
- Sequencer, from OCTAVE;

Recovery part

The recovery system is composed of a mechanism able to operate the axial separation of the rocket and to ensure the parachutes extraction.

Fig. VI: Recovery system deployed on DAVE rocket (the rocket launched in Netherlands with contributions from the Dutch club DARE)

Payload tube

The payload tube hosts the casing of payloads and the mechanism responsible for their ejection.

Fig. VII: Payloads tube and mechanism

Nose cone

The nose cone is a glass fiber manufactured in one piece by the mechanical sub-team of OCTAVE. The final part of the nose cone is an aluminum cone manufactured by selective laser melting. A specific fabrication technic that allow us to instrument the cone with pressure sensors.

Fig. VIII: Nose cone and nose tip

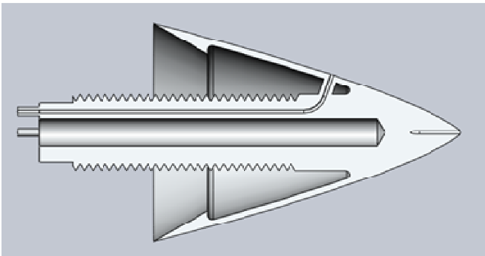

Fig. IX: Nose tip

V. MAIN STUFF

Each rocket developed by OCTAVE has to be improved in terms of sophistication and innovation. In this purpose, OCTAVE has developed four new systems for EVE5 and improves previous systems.

V.I Video stream transmitter

This is a module based on Raspberry Pi board able to forward a video stream from a HD camera to the ground and to ensure the stream saving on an SD card. The video stream is transferred to the GAREF OBC via USB bus.

V.II Instrumented nose cone

The objectives of the nose cone are to handle a supersonic environment and to allow in situ measurements. This is possible thanks to the manufacturing technique.

The manufacturing technique behind the nose cone is the selective laser melting of aluminum. The one-piece-shape incorporates 5 holes, connected to pressure sensors. All the data from the nose cone are coupled with the ones from inertial units to provide attitude, orientation, spin and speed.

V.III Real time apogee detection

This is an experimental function added to the IMU measurement board to determine the reach time of the rocket apogee.

V.IV CANSAT Ejector

The system consists of a central structure fixed to the launcher body. The central structure is surrounded by three triplicate articulated elements.

The system is composed of two aluminum disks attached to the body of the rocket. To stiffen the structure, the two disks are connected by three aluminum cylindrical pillar. These pillar help to support the additional stresses caused by door (rocket skin part) opening and closing. The moving part is driven by a servomotor which got his order from an external sequencer.

To avoid any synchronization issue, the door opening and closing is driven by the same actuator. The ejection is effective only when the doors are totally open. The doors are made of glass fiber in order to allow the transmission of telemetry CanSats and are reinforced by steel elements to the fixings.

The opening kinematic is divided in two steps: the doors are remote away from the rocket skin, and then they are shifted on the side to avoid the CanSat ejection axis.

CanSats stand on an aluminum plate. To reduce the frictional stresses, the plate is recovered with Teflon.

To avoid entanglement with parachute and shroud lines, all is placed into a deployment bag. The bag with the CanSat is place in a semi-cylindrical housing, acting like a separation casing with the rest of the system.

V.V Ground station

The purpose of the ground station is to display a sum up of the diagnostic of the rocket, in real time. It decodes a signal sent by the rocket to get three kinds of information:

- Mechanical states of mechanisms (separation, ejection, open, close)
- Power state of electrical modules (ON/OFF)
- Data from measurements
- Optionally: the battery load and time remaining.

OCTAVE has developed an extension (add-on) for GAREF ground station for its own modules.

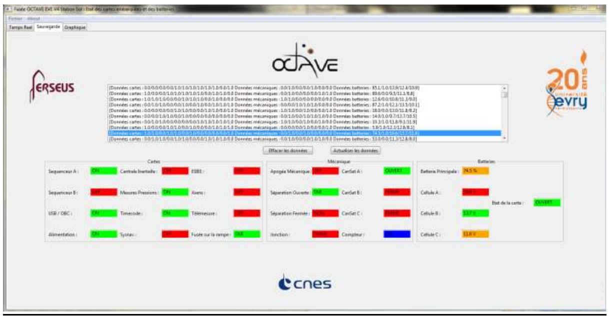

Fig. X: One view of the ground station software

VI. LAUNCH CAMPAIGN

VI.I Chronology establishment

The chronology is the to-do list of the team. It is composed of every task we need to accomplish to launch the rocket in good conditions. All the tasks are listed in chronological order.

VI.II Operations

For one week, all the team is living immersed in a military base. For the C'SPACE campaign of year 2013, the host was the DGA's launch site for the test of military rockets (Biscarrosse, France).

Some barracks was dedicated for students to sleep or to work.

On the 29th of august we finally launch the EVE5 rocket; it was a nominal fly (the 6th for OCTAVE)

Fig. XI: EVE5 Take-off

VI.III Exploitation

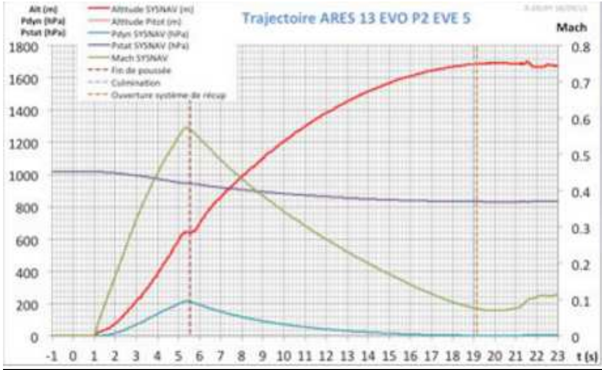

Fig. XII: Exploitation graphics sample

After the campaign, the last mission for the team is to analyse all the data we got to write an exploitation report for the CNES. It gathers all the estimations, all the results and all the interpretation of differences between what we were expected and what we got. This report is the base for further experimentations on future rockets.

On the figure XII, we can see a result of pressure and acceleration data processing.

- Estimated culmination: 1483 m
- Actual rocket culmination: 1704 m
- Estimated maximum speed: 0.56 Mach
- Actual rocket maximum speed: 0.57 Mach

VII. NEXT STEP

Year 2013 was full of innovations and experimentations: selective laser melting nose cone, payload ejection and video stream transmission. The launch campaign was a success. Moreover, this first try of selective laser melting in our astronautical applications opens us a lot of new purposes.

On May 2014, we took part of the SERA 1 launch campaign at Esrange (Sweden): the first supersonic rocket designed by French students.

More recently, in August, we launch with success our seventh rocket: EVE5 Reloaded: a rocket based on EVE5's architecture, which has embedded three instrumentable fins made by selective laser melting.

Now, we are preparing the future for 2015…