CNES and French university satellites: a successful experience and objectives for the future

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Abstract

The CNES (French Space Agency) has always had a policy of interaction with young people. In this context the CNES launched in 2006 a call for proposal « EXPRESSO » (EXpérimentations et PRojets Etudiants dans le domaine des SystèmeS Orbitaux et ballons stratosphériques) towards French universities and high schools. Montpellier University proposed the conception and realization of a satellite named "Robusta" (Radiation On Bipolar University Satellite Test Application). This cubesat- standard satellite is endowed with a real scientific mission consisting in measurements during flight of key degradation parameters on bipolar-transistor-based electronic devices subject to space radiations. Results delivered to the ground station mounted on the campus will be compared to those obtained by means of ground-based tests. Young people stem from various Montpellier University schools: the Institute of Technology (IUT), classic Master's degree in the Electronics domain, and the High University School of engineering Polytech' Montpellier. They all mingle along giving rise to constructive exchanges. An interesting feature is the fact that students with second-year university levels up to the doctorate degree are involved in Robusta. Thanks to work processes proposed by the CNES, students are shortly confronted with the professional constraints of the spatial domain. This professional background is really new in such a university project. The scientific mission and the possibility of in-situ measurements, for example on battery or solar cells, entice a large number of companies. Robusta is now entering the phase of flat sat tests. During the conception, partnerships for student exchanges have been established with the University of Heidelberg (Germany). Considering the ground station, links have been settled with the University of Arizona (USA) and the University of Würzburg (Germany) to use them as relays for transmitted data when satellite not visible from Montpellier. Hence Robusta is a good example of a complete spatial project being driven by students in a university, project giving rise to international exchanges.

Following this successful experience, CNES has decided to launch an ambitious program named RISTRETTO (French acronym for International Network of Students satellites Projects based on Technical Development in open source). RISTRETTO will extend the concept Cubesat to a larger size of satellites of 30l, 30w, 30kg to enlarge the possibility of the embedded targets.

The main guidelines used for RISTRETTO specifications are :

to develop a generic bus for a family of small satellites which should be able to perform the largest range of mission

with high payload capacity to allow ambitious missions

The development has to be done under a cooperation between French and Foreign universities and thus in an open source concept applied as a minimum to the bus

This new concept of nanosatellites could be of a great interest for scientific communities or used as demonstrator for validating new technologies

1. Introduction

The CNES (French Space Agency) has always had a policy of interaction with young people. In this context the CNES launched in 2006 a call for proposal « EXPRESSO » (EXpérimentations et PRojets Etudiants dans le domaine des SystèmeS Orbitaux et ballons stratosphériques) towards French universities and high schools. Out of eight answers, three were selected amongst which Montpellier University for its Robusta project. This large educational program consists in the conception and realization of a satellite named "Robusta" (Radiation On Bipolar University Satellite Test Application) and of a ground station mounted on Montpellier University campus. The originality of the project stands in two elements: the variety of students implied and the payload. Though not yet finished, Robusta is already considered a success for all the spatial culture and hands-on training it has procured. Additionally, though entirely undertaken by students, this still-going on project promises to be achieved. The satellite enters the phase of flat-sat tests and the ground

segment should be operational beginning of March 2010. Enthusiasm and motivation are unmoved both between students and teaching staff.

2. The Robusta project

The cubesat - standard satellite in itself consists of a mechanical structure, and inside a payload, a radio board, a power management board, a controller board. All four boards are connected to a mother board. Antennas must be added as well as all switches and electrical pins rendering it compatible with a p-pod system for launch. The ground station includes appropriate antennas, transceiver and software. It is mounted onMontpellier University campus. The Robusta satellite has been selected in January 2008 for launch on the Vega Maiden Flight [1] with other cubesat projects: UNICubeSAT [2] (Italy), est@r [Reference 3] (Italy), AtmoCube [Reference 4] (Italy), Swisscube [Reference 5] (Switzerland), Xatcobeo [Reference 6] (Spain), OUFTI-1 [Reference 7] (Belgium), PWsat [Reference 8] (Poland), Goliat [Reference 9] (Romania) and two back-ups UWE-3 [Reference 10] (Germany) and HiNCube [Reference 11] (Norway). The orbit proposed by Vega is unusual for a cubesat: it's an elliptic orbit with 350 km for perigee altitude, 1774 km altitude for apogee altitude and 71° for inclination. The high perigee altitude in particular will lead to a drastic exposure to space radiations, rendering the satellite's mission all the more interesting.

Young people involved in Robusta stem from various Montpellier University schools dispatched in the cities of Nîmes and Montpellier separated from 50 km from each other: the Institute of Technology (IUT) in Nîmes [Reference 12], and the classic Master's degree in the Electronics domain [Reference 13], and the High University School of engineering Polytech' Montpellier [Reference 14] both located in Montpellier. Students have university levels ranging from the 2nd-university year to the PhD diploma. Each school department has its own specific field of study which enables all parts of Robusta to be designed and manufactured. The IUT is in charge of the mechanical structure and of the power management with solar cells and battery through the department of Mechanics and Electrical Engineering. Polytech'Montpellier is involved in the controller board and all needed software programs. The Master's degrees in electronics are concerned with the payload, radio board, as well as with the ground station. PhD students help in the management and system engineering team. They are also particularly concerned by the payload. Under guidance of faculty members, students all mingle along giving rise to constructive exchanges. They are faced with interface problems and cubesat or launcher requirements to follow. They cannot, whatever their university degree, ignore other teams working on the project. Thanks to work processes proposed by the CNES [Reference 15] students are shortly confronted with the professional constraints of the spatial domain. Regular quarterly meetings are held with CNES experts.

Hence Robusta is taken as an opportunity not only to try one's specific technical skills but also acquire a whole system engineering knowledge. The professional background is of true importance for a university project. It is considered being a real added value to classical diplomas.

The other point contributing to the success of Robusta is that the satellite is endowed with a real scientific mission. It consists in measuring during flight key degradation parameters on bipolar-transistor-based electronic devices subject to space radiations. Results delivered to the ground station will be compared to those obtained by means of ground-based tests. The scientific context is the following. In 1991, some bipolar devices exhibited much higher current gain degradation induced by a given TID (Total Ionizing Dose) if the dose was deposited slowly (low dose rate) [Reference 16]. This phenomenon has an important impact on the hardness assurance of space systems. Indeed ground-based tests are typically performed at high dose rates on a short time. Therefore they may underestimate the real low dose rate degradation occurring during the mission lifetime encountered in actual space missions.

A Montpellier University research team, Radiac (Radiation & Components) from the laboratory Institut d'Electronique du Sud (IES), has proposed a new test method for bipolar devices [Reference 17]. Physical effects at play during this test are closer to those encountered in a space mission, hence leading to very promising preliminary results. This ground-test is based on a two step experimental procedure: device under test is subject first to a high dose rate irradiation and then to a low dose rate irradiation. The whole procedure and the associated model are described in [Reference 17] and [Reference 18]. Of course this method must be of use to satellite manufacturers. Therefore in order to validate it, a large amount of experimental data is needed, for a large variety of devices. Hence Robusta's mission will allow collecting flight data in a rather short time, two years and a half. This data, confronted to results obtained by ground – based tests, should help validate the latter.

The Robusta payload consists in two different analog Integrated Circuits, the voltage comparator LM139 and the voltage amplifier LM124. These devices are often used in space and astronautic applications. They are both known to suffer strong current gain degradation from Enhanced Low Dose Rate Sensitivity (ELDRS). Both devices will be biased in two different conditions. Input and output current and voltage will be measured, as well as the temperature and dose received. Device manufacturers like Texas Instrument [Reference 19] and Intersil [Reference 20] who are interested in such a methodology have offered to provide some components. Besides this scientific mission, the possibility of in-situ measurements, for example on battery or solar cells, entices a large number of companies. The professional environment and low cost of the project are hence reinforced around Robusta.

3. Robusta benefits for Montpellier 2 University

Today, regarding the technical part, Robusta is entering the phase of flat sat tests. But Robusta is more than a technical challenge. It's also a large communication plan, in and out of France, with an associated website [Reference 21]. Nationally, items in journal and interviews for radios or television programs have been edited[Reference 22][Reference 23][Reference 24]. Out of France, students have already participated in several workshops [Reference 1][Reference 25][Reference 26]. From the pedagogic point of view, these conferences force them to polish their communication skills. Beyond the educational aspect of Robusta, communication on this project toward the academic and scientific community has begun to open doors for other relationships. Partnerships with other universities have been engaged. Erasmus agreements for student exchanges have been established with the Hochschule of Heidelberg (Germany). This university is also involved in the realization of a cubesat satellite, Heidelsat [Reference 27]. Methods and point of views can be swapped, enriching student's knowledge and practical proficiency. Some Montpellier students have also gone for practical trainings in Aalborg. Working on Aausat II [reference 28] has motivated them to work on Robusta once returned to France. Considering the ground station, links have been settled with the University of Würzburg (Germany) during the first ESA workshop. A connection has also been established with the University of Arizona (USA). These universities are to be used with their consent as secondary ground segments. Their reception frequencies are close to 433MHz, like for Robusta. They should receive the experimental data when the satellite Robusta is not visible from Montpellier and transfer them to Montpellier. Partnerships with Bauman Moscow State University (Russian Federation) and Vanderbilt University (USA) are yet to come.

Hence Robusta is a good example of a complete spatial project being driven by students in a university, project giving rise to international exchanges.

4. The RISTRETTO program

Following this successful experience, CNES has decided to launch an ambitious program named RISTRETTO (French acronym for International Network of Students satellites Projects based on Technical Development in open source). The idea is to go further with a

similar concept called RISTRETTO to set up a new family of student's satellites done in international cooperation, with higher ambition as regards technical performances in order to allow more technical, scientific and application missions

The initial target defined for RISTRETTO satellites is a size around 30 cm fro the edges, an electrical power of about 30 watts and a weight of approximately 30 kg. The RISTRETTO satellites bus must be compatible with several kinds of launchers by the way of a standard interface. They have to be developed under a low cost and reduced time using COTS. And we would like RISTRETTO satellites to be studied and developed via an OPEN SOURCE concept by an international student community in some ways similar to what is being done for the GENSO project (student's ground segment currently in development)

Feasibility analysis have been performed by CNES on missions, technical solutions and program organization

Before launching this ambitious program, the CNES is currently performing an internal study on its feasibility on 3 aspects, the type of payloads compatible with such satellite bus, a technical analysis of the bus with a specification of the performance limits, and the programmatic aspects (organization, planning, open source …).

The orbits considered for RISTRETTO are LEO and GTO, i.e. orbits compatible with most launches as auxiliary passengers

Mission analysis shows that there are potential interested missions for a family of satellites in the range of (30 kg, 30 W, 30 l) on the different domains. The RISTRETTO concept could be used as a demonstrator to qualify new technical solutions at component level as well as equipment or subsystems. Some scientific missions (astronomy, earth study, …) could also be performed using RISTRETTO bus. And applications missions such as telecommunications (data collection, localization of mobiles, …) or earth observation (ground surface, atmosphere, waters …) are also possible. Those missions would be feasible in about 3 years in university s with a quite low cost, as a first estimation, the bus will cost 400 k€ including margins.

Technical feasibility analysis allows showing that there are technical solutions for a bus to allow the type of missions above listed. Some preliminary specifications or olutions have been drawn-up from those studies.

Mainly, the satellite mass is around 30 kg with at least 5 kg for the payload, the volume is about 30 liters and the total electrical power is about 30 W with at least 5 W allocated to the payload. This power capacity could be obtained using 2 deployable oriented solar array (using SADM). The satellite could be 3 axes stabilized, and will have an attitude control capability using star tracker and reaction wheels for high pointing accuracy. The propulsion system based on liquefied butane will allow injection orbit correction and end of life de-orbitation. The Telemetry and Command system will be based on the use of S-band frequencies with patch antennas on board.

These technical solutions have been validated through various studies but remains to be decided with partners ready to contribute to the design and development of RISTRETTO

About RISTRETTO program organization and management, the study is on-going through contacts with universities, laboratories, industrials potentially interested. However based on the assumption that the RISTRETTO bus will be available in open source from the team that has developped it and assuming that the study and development could be conducted in an international university frame, one of the ideas is to establish a central project team in Toulouse with representatives from universities (for instance one for each university in charge of major subsystems).

Administratively speaking this team could be organized under the French association law which seems by far the easiest and more flexible solution. Any partners would be essentially “committed” through “a best effort clause” to study and provide one equipment, subsystem, software or service.

Considered the existing lines of product (for instance the Cubesats), the various possible missions in the university satellite range, and the need to remain cheap and feasible in less than 3 years in universities, we concluded that there is a need for nanosatellites in the 30 kg, 30 W, 30 cm ranges.

This new concept of nanosatellites could be used by students themselves but we can imagine that it could be also of a great interest for scientific communities or could be used as a demonstrator for validating new technologies at a low cost for industries

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