ABSTRACT

Robusta is the first French university cubesat designed with the support of CNES. The aim of the payload experiment is to measure the radiation induced degradation of electronic devices. Flight data will be compared to the results of a novel prediction method taking into account the Enhanced Low Dose Rate Sensitivity. The second interesting point of this project is that it's a real educational project. The organization and derived implications are presented. This paper should highlight the interest of a cubesat-type satellite from the scientific and educational point of view.

1. INTRODUCTION

Small satellites are exceptional interdisciplinary vector apprenticeships for system design and integration. The conception of cubesat was delivered by professor R. Twiggs in the 2000s in the United States, and set up at the polytechnic university of California (Calpoly). R. Twiggs showed that a small satellite provided with a true scientific mission, can be very helpful as a "hands-on" project for a complete educational program due to its relative simplicity and moderate cost with regard to the big spatial systems.

Robusta (Radiation on Bipolar University Satellite Test Application) is the only French cubesat entirely designed by students within a French university. Robusta is the joint response of five schools of University Montpellier 2 to the call for proposal for student projects in the spatial field, EXPRESSO, issued by the Centre National d'Etudes Spatiales (CNES) in 2006. It is a mile stone in long term cooperation between ESA (European Space Agency), CNES and University Montpellier 2 on onboard electronics reliability, and more specifically radiation effects on devices. The Cubesat proposed by University Montpellier 2, named Robusta, is entirely designed and built by Montpellier University students with the support of the CNES and key sponsors such as Intersil Texas Instrument, Trad, Cofidur and Farnell. The payload itself will contribute to validate a radiation testing methodology currently evaluated by ESA and a consortium (CNES, TAS, EADS-ASTRIUM, ESNIS). It is strongly supported by the University and the local authorities and benefits from an enthusiastic coverage in French media.

The idea of a conception of a cubesat by Montpellier University students comes from the history of another cubesat, Sacred, initiated by Thalès Alenia Space in 2000. The story of Sacred is hence briefly presented in section 2. Follows section 3 devoted to the context of the scientific mission of Robusta and the implications expected. The organization of this large-scale project is given in section 4, and the state of the art of the various sub-systems in section 5. Section 6 is devoted to the communication surrounding the project, and section 7 is a review of the different sponsors implicated in Robusta.

This paper will highlight the interest of a cubesat-type satellite from the scientific and educational point of view.
2. PREVIOUS CUBESAT EXPERIENCE

In 2000, Alcatel Space (Now TAS), acquired a picosatellite, named SACRED, from the University of Arizona, the aim of which was to study radiation effect on MOS power devices. The payload was entirely designed and built by University Montpellier 2 students, some of which during their Ph.D. program. The payload was delivered on time. Montpellier students were sent to Arizona to participate in the assembly and testing of the satellite. SACRED passed all the qualification tests. Unfortunately, the DNEPR -1 launch vehicle failed and SACRED was lost on the 26th of July 2006. Nevertheless, from this preliminary experience, several conclusions were drawn. First, all the knowledge and expertise required to design and build a picosatellite, are available on the University of Montpellier, provided that all the schools work together. Second, space related projects are a drive for highly motivated and skilled students. Finally but none the less, picosatellites are a fantastic tool for scientists of many different fields for an access to space and new experiments.

The long term collaboration between the radiation effects group from the university research lab IES and the CNES provided a few very interesting ideas for science applications. As a consequence, the Montpellier team decided to respond to the EXPRESSO call for proposal, with a picosatellite carrying a payload devoted to the study of one of the major current concerns for hardness assurance that is Enhanced Low Dose Rate Sensitivity (ELDRS) on bipolar technologies. EXPRESSO "Expérimentations et PRojets Etudiants dans le domaine des SystèmeS Orbitaux et ballons stratosphériques" is a call for proposal launched by the CNES Toulouse Space Centre in order to promote space science and technology and draw students into these careers. In 2006, a jury of experts selected 3 projects out of 8 responses for the EXPRESSO call for proposals, amongst which the University Montpellier 2's picosatellite ROBUSTA.

3. PAYLOAD EXPERIMENT AND MISSION

3.1 Context of the mission

The earth’s natural radiation environment consists of electrons, protons and heavy ions. These particles can cause severe radiation damage to electronic components, solar cells and materials. They can easily penetrate satellite walls and deposit total dose during mission. The concern of radiation-induced degradation on bipolar transistors and integrated circuits was raised in the 60s. Early studies focused on gain degradation due to neutron irradiation. Indeed in 1958 G.C. Messenger published the first results of degradation of electronic components subject to irradiations. It concerned neutron irradiation on germanium bipolar transistors. In 1962, Wallmark and Marcus predicted the possibility of flight errors because of singular effects. Their predictions already mentioned temporal effects and permanent failures due to cosmic radiations. The first abnormal phenomena detected during flight took place on a satellite, i.e. Intelsat IV, in 1975. From this date, the studies on device reliability and electronic systems subject to a radiative environment began. More recently, attention was paid to the gain degradation due to Total Ionizing Dose (TID). Therefore, developing hardness-assurance and test methods addressing the concern of ELDRS has constituted a major challenge during the last few years. The aim is to predict at ground level, in a short time (at least one month), the behavior of a device, which will be for 15 years on-board. Although accelerated test methods have been proposed (Elevated Temperature Irradiation in the 1019.6 standards of the American Department Of Defence), low dose rate testing is still advisable in critical applications. Current standards, while putting a harsh constraint on manufacturers, are not suitable to take into account ELDRS, or even based on acceptable physical models.

3.2 A new approach for bipolar devices testing

In 1991, the first report of enhanced low dose rate sensitivity (ELDRS) on irradiated bipolar transistors was published. It was found that in some bipolar devices, the current gain degradation induced by a given TID was much higher if the dose was deposited slowly (low dose rate) than quickly (high dose rate). This phenomenon has an important impact on the hardness assurance of space systems, since ground-based testing, typically performed at high dose rates, may underestimate the real low dose rate degradation on the mission lifetime encountered in actual missions. An example of the phenomenon is shown in Figure 1.

![Figure 1](image)

Figure 1 : Experimental results of degradation of the base current of NPN and PNP bipolar transistors irradiated at 20 and 30 krad(SiO2).

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In both curves, the grey highlighted regions correspond to test standard specifications. The electrical parameter decreases at low dose rates, approaching those encountered in space. The higher dose rates, corresponding to test range at ground, underestimates the degradation. Note that the “inversed S-shape curve” obtained, characteristic of the degradation versus dose rate, is obtained for both NPN and PNP devices.

The Montpellier Radiac (Radiation & Components) research group has proposed a new approach for bipolar devices testing. This new approach is closer to physical effects at play during a space mission, and the preliminary results obtained are very promising. It is based on a “switching experiment” that correspond to a two step experimental procedure: first a high dose rate irradiation and second a low dose rate irradiation. The whole procedure and the associated model are described in and . In order to propose a new testing method that can be used by satellite manufacturers a large amount of experimental data is needed for a large variety of devices. ESA and CNES have initiated a 36 months experimental campaign, ran by Austrian Research Centers GmbH – ARC Research Center, 2444 Seibersdorf and directly supported by ESA. The ROBUSTA project aims a collecting flight data in order to contribute to validate the method.

3.3 The experiment on-board

The experiment proposed with Robusta, though very simple, should provide very interesting data. It consists of flying two different analog Integrated Circuits, the voltage comparator LM139 and the voltage amplifier LM124, both with date codes known to exhibit ELDRS and very strong degradation. Both devices will be biased in two different conditions. The degradation of key parameters will be recorded on an hourly basis and compared to the prediction issued from the testing performed at ground level, using the new methodology. A good agreement between values would be a step forward on the path to validation. Otherwise, actions will be taken to update the models and procedure. The scientific aspect of this project is therefore not negligible. Two Ph.D students are currently working on the research aspect of the payload. Device manufacturers like Texas Instrument and Intersil who are interested in such a methodology have offered to provide some components.

4. PROJECT ORGANIZATION

The satellite fits the cubesat standards: it is a cube of 10cm aside, weight 1kg, maximum consumption 1W. The project is jointly led by the University Montpellier 2 and the CNES project managers. It is meant for a three-year flight.

4.1 Sub-systems and schools involved

Basically, the cubesat can be split into 8 main parts: Overall management, Mechanical structure, Power supply and power management sub-system, Radio communication sub-system, Controller sub-system, Payload sub-system, Ground station sub-system, public communication and value of the project.

The Robusta project on the whole groups the following four schools, all part of Montpellier University: the master in Electronics, Electrical Engineering and Automatics of the University school of science, Electronics and Robotics (ERII) department High School of engineering Polytech’ Montpellier, the department of Electrical Engineering of the Institute of Technology of Nîmes and the department of Mechanical Engineering of the Institute of Technology of Nîmes. Each of these schools brings an expertise and a specific contribution in a different field. Each task is attributed to a given school under the control of faculty members, recognized for their experience. A schematic of the different university schools associated with the sub-system they develop is given on Figure 2.

![Figure 2: ground station and satellite sub-systems and associated schools.](image-url)
in electronics section more specialized in electronic components.

4.2 Organization throughout the different levels of university studies

From the organizational point of view, three generations of students work on each task at the same time. The senior students are in charge of the project management. They are responsible for the technical survey of the whole satellite realization. They also supervise tests procedures and write the associated documentation according to the CNES standard guide procedures. Senior students are assisted by the junior students, who therefore learn from the senior. After the senior graduate and leave, the junior will be in charge of the specific task. The Experts are former senior students who graduated the year before. Previously in charge of the task, they have accumulated experience. Some of them have found jobs in the industry but still act as consultants for the Robusta project. This way of working ensures that no information is lost when students leave the project. It also gives them the vision of a whole industrial project, that they must manage taking into account all the constraints encountered in project management found in companies.

The whole project plays a role in making electrical engineering and space sciences more attractive for students, the results being an increase in the number of applicants in the above educational programs.

4.3 Common knowledge

A platform of common knowledge sets up regarding electronic components. For example, the spatial radiative environment, which is at the heart of the Robusta’s mission, must be perfectly acknowledged and understood by all the actors of the project. Indeed devices chosen for the conception of the different sub-systems, other than devices under tests, must be able to resist radiations as a minimum. Therefore students must be informed about spatial problems, and concerned in their choice of devices and shielding. This led for example in the implementation of an anti-latch circuitry associated with the PICs (Peripheral Interface Controller) of several subsystems.

The need for a very compact design associated with restricted power supply also has an influence over the choice of all components.

Finally the supply of electronic components is never that simple and the students have the opportunity to discover it. First of all they must get acquainted with the electronic manufacturers or the specific distributors for either specific software or components. As an example they have become familiar with OMERE software for the calculation of radiative doses, or the suppliers Mini-circuits or Hittite for specific radio frequency components.

In the same time they get concerned about a clean environment and sustainable development by discovering and choosing preferentially RoHS components (Restriction of the use of certain Hazardous Substances). They can also directly approach advanced technologies like radiofrequency SMT (Surface-mount Technology) devices and double-sided circuits to answer the constraints of weight and size.

From the management point of view, they are subject to true technical meetings, and to the writing of reports. They therefore become familiar with documentary management, such as those encountered in societies, and handling up-to-date information on the devoted website.

It must be remarked that in the classical practical projects proposed at the university, all these constraints are rarely taken into account.

4.4 Launch

In January 2007, the Robusta team took part in the 1st workshop on small satellites at ESTEC (ESA) in Noordwijk, Netherlands, amongst 22 other participants. The purpose was to present the project to the European community. Robusta was selected with 8 other cubesats: SwissCube (Ecole Polytechnique Fédérale de Lausanne, Switzerland), Xatcobeo (University of Vigo and INTA, Spain), UNICubeSAT (University of Rome, Italy); AtmoCube (University of Trieste, Italy); e-st@r (Politecnico di Torino, Italy), OUFTI (University of Liege, Belgium), Goliat (University of Bucharest, Romania), PW-Sat (Warsaw University of Technology, Poland). All these cubesats have won a free launch on the new European launcher Vega during its maiden flight.

Now the overall of the project has been clarified, the different sub-systems are described hereafter.

5. SUB-SYSTEMS

5.1 The mechanical structure

The mechanical structure will be machined in the mass. The mass is estimated to 160g. The structure comprises the metallic cube, and the mother-board on which all sub-systems will be connected. Connectors permit the electrical and mechanical link between the
power sub-system and the mother-board. The models are connectors from the DATAMATE series from the Harwin society. The satellite uses two switches for the separation of cubesats when ejected by the p-pod. These switches are given on Figure 3. They allow the launch of the satellite with inactive electronics, and once ejected permits the electrical activation of the satellite. The integrated micro-switches are purchased from the Harwin Company.

Figure 3: switch design.

The whole mechanical structure has been designed with a CAD software. Examples are given on Figure 4.

Figure 4: Mechanical structure and sub-system assembly.

On Figure 4 we see the armature of the structure and the subsystems inside. In the complete structure, aluminium panels on which solar cells will be glued upon will close the structure, except for the hole above the DUT’s. Design of the boards for all sub-systems has also been done. An example for the mother-board is given on Figure 5.

Figure 5: design of the mother board.

We see on the figure above the connectors ready to receive the four-subsystems. In the middle of the mother board there is an open space left for the battery. Finally the reverse side of the mother board shows all the electrical tracks.

5.2. The Payload

The payload comprises several sub-systems, as shown on Figure 6.

Figure 6: Synoptic of the different parts of the payload.

The command part (yellow) comprises the microcontroller and switches.

The metrology part (green) comprises temperature sensors, plus a dose-meter OSL conceived in the Radiac group from the IES research lab, and finally measurement systems for currents and voltages.

The Experience part is in blue. The devices under tests (DUT) are two LM124 (4 operational amplifiers per DIL14 package) and two LM139 (4 voltage comparators per DIL14 package).

The DUTs are placed beneath a 60x12mm² hole in the metallic shielding, as shown on Figure 7. This way the DUTs are in direct exposure to radiations.

Figure 7: Satellite CAD model with DUTs under the hole in the metallic structure.

The key parameters to be measured when DUTs are subject to radiation are the following: the input current, the output voltage and the positive and negative supply currents. Measurement precision will be respectively 10 nA, 5 µV, 50 mA. To these measured data one must add the temperature in the vicinity of the operational amplifiers tested. Each current and voltage data will be measured on a 12h-basis. Temperature
measurements will be performed every 6 mn with a 3° precision. The temperature mean value and mean square value will be calculated and transmitted to ground with the other data. All these measurement precisions take into account all effects arising during a three-year life in orbit: measurement discrepancy, noise, temperature variations during flight, aging effects.

The environmental metrology will be performed with the help of an OSL dosimeter\(^\text{27}\) and two temperature sensors. This dosimeter is conceived in the Radiac group of the IES lab. It has already been implemented on experiences such as CARMEN 2 (CNES) on-board JASON2, and DIME of the university of CLEMSON on-board SET-1 (NASA). This OSL dosimeter needs a specific circuit named DIME because initially developed for the same-named experience. DIME serves as a bias circuit and assures a first data processing of the measurements. The dose rate will be measured every 90 mn with a precision of 10%. This precision is the most precise value achieved for this type of sensors. Each measurement is transmitted to the controller sub-system which adds it to the previous value, hence giving the total cumulated dose between two experiments. A last dose-rate measurement is transmitted toward the ground station every 12h.

A microcontroller collects all data issued from the OSL, from the temperature sensors and from measurements issued from the DUTs. It will also manage the communication with the controller sub-system. The experience has a need for tracking dose variations and device degradation versus time, regarding an initial instant corresponding to the beginning of the experience. Date on-board will be performed by the controller sub-system with a real-time clock.

The command system of the payload comprises a PIC microcontroller and ADG714 integrated switches\(^\text{28}\). The micro-controller will communicate with the other sub-systems via a CAN (Controller Area Network) bus, manage switches and temperature sensors with a SPI (Serial Peripheral Interface) bus and collect measurement data with the help of integrated analog-digital converters. The micro-controller chosen is a PIC18F4580, as it permits 11 inputs on the analog-digital converter, thus minimizing multiplex functions. The oscillation frequency of the PIC is lowered from 20 MHz to 4 MHz for lower current consumption: it goes from 12 mA to 4 mA, hence leading to a reduction of 40 mW.

Regarding switches, each package comprises 8 switches commanded by a SPI (Serial Peripheal Interface) bus. This bus comprises 3 lines: one for the data, one for a clock and one for synchronization. Only the part receiving a synchronization order takes into account the received data on its input. Switches are mounted in a daisy-chained configuration such as that on Figure 8.

![Figure 8: ADG714 mounted in a Daisy chained configuration.](image)

The output of the command register of a package is linked to the input of the following package. The information is passed on when the register is full. This type of configuration allows having only a single synchronization line. The whole assembly is then dependent on the degradation of the switch packages but it was shown\(^\text{29}\) within the framework of the Robusta experiment, that they should only slightly degrade themselves. They must remain functional during the whole mission duration, and their use has been validated for flight.

Simulations of the dose affecting the satellite have been performed, issuing initial gain regulations on the measurement chain. Nevertheless, the spatial environment being extremely versatile, a remote control allowing modification of the sensibility OSL system is planned.

### 5.3 Power Supply and power management Board

The power sub-system will convert the solar energy issued from the solar cells for the charging of a battery and supply the other sub-systems. A synoptic is given on Figure 9. The management of power is probably the key point of the satellite. The energy available, 1W does not make possible to supply all of the four sub-systems on-board at the same time. The power board also comprises the system for supplying the nichrome wire meant to act in the deployment of the antenna.

![Figure 9: Synoptic of the power sub-system.](image)
The key choice privileges simplicity and reliability. For this reason, a single Boost DC converter will be used to convert the energy issued from all the six solar panels.

Solar cells are placed on the six faces of the cubesat. There are 2 solar cells mounted in series on each cubesat face. Solar cells are triple junction GaInP/GaAs/Ge on Ge substrate from AzurSpace (cf. Figure 10). Integrated Solar Cells with coverglass and connectors have been ordered from Selex Galileo Avionica. The position of the interconnectors was defined with Selex and approved by CNES.

The battery is a Lithium-ion one from Saft\(^{30}\), as shown on Figure 11. The depth of charge of the battery will be included in the telemetries sent to ground with a precision of 2%. The nominal energy is 10 Wh, nominal voltage: 3.75 V at 20° with 0.5A.

Sub-systems are supplied with + or -5 Volts, except the radio-communication board which needs 7.5V.

The role of this subsystem is to manage the different tasks to be performed by all the other sub-systems in order to optimize the power consumption.

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**Figure 9:** Synoptic of the power sub-system.

**Figure 10:** Solar cells size and picture.

**Figure 11:** Battery and mounting of the battery.

**Figure 12:** Connecteur design

**Figure 13:** Schematics of the main controller board.
The controller sub-system activates the different measurements. The payload delivers the measurement data to the controller subsystem after each measurement. Every three last series of measurements will be stored in the controller sub-system before transmission toward the ground station. Every new series erases the most ancient data. Every 3 mn, the controller board tests the power subsystem for sufficient power for transmission. The controller board tests the power subsystem for sufficient power at least every 3 mn before each data transmission toward ground and before each task to be undergone during mission. If the battery level permits it, the data are then transferred to the radio communication subsystem. A timer sets up, synchronized on the beginning of data transmission. After 8s, the transmission of data is stopped, and the radio communication sub-system sends a message to the controller board to confirm the stop of the broadcast. No receipt acknowledgement from the ground station is planned.

The controller sub-system includes the following parts (cf. Figure 13): a CAN bus, a 18F4680 PIC, a real-Time Clock, an EEPROM and an anti-latch circuitry. The real time clock is independent from the microcontroller. It presents a precision of 10s over 4 days. It includes a date in the measured data stream and on the events stored in the journal of events. An example of the date stream is given on Figure 14.

It comprises a spare battery to keep being supplied in case of a power shortage from the main power sub-system. The PIC communicates with the RTC by means of a I2C bus protocol with two separate lines: SDA (Signal Data) and SCL (Signal Clock).

The CAN (Controller Area Network) bus lets the radio-communication, payload and controller subsystems to exchange data. It comprises a differential pair of lines: CAN high and CAN low linked together by two 120 Ω resistances. Its advantage is to resist electric perturbations: indeed to code a logic 0 or a logic 1, only the voltage difference between the two lines is taken into consideration. If a perturbation arises, the voltage of both lines evolves in the same way, hence the potential difference is kept fixed. A BUS stream can contain up to 8 data octets; it includes an identifier to acknowledge the type of message. A comparison between the CAN and an E-CAN bus was performed. The E-CAN bus is recommended for high data traffic, that is for up to 16 messages. In the case of Robusta the choice was made to use an E-CAN because of the different possible modes adaptable to traffic.

A task-oriented Petri net is considered for the controller sub-system. A real time operating system will be implemented in Robusta. Indeed programming with the help of an OS (Operating System) is comfortable because it’s an API (Application Programming Interface). A synoptic is given on Figure 15. This means that it supplies a set of tools enabling to access any stage without being obliged to pass through a lower stage. Once the OS implemented in the microcontroller, one will just have to work on the last application level. The µC/OS-II system has been chosen for its reliability and its portability to be implemented with a PIC18F4680. In parallel, a sequential programming solution has been developed. Both solutions will be tried on the prototype.

5.5 Radio communication subsystem

This subsystem is intended to transmit data (telemetries: TM) and receive data (telecommands TC) to and from the ground station. Chosen characteristics are the following: AX 25 protocol, AFSK (Audio Frequency Shift Keying) modulation, reception frequency on the satellite 145.95 MHz and 435,325 MHz for downlink. In normal operation TM will be broadcast every 3 minutes.

The whole subsystem comprises five parts: the emission part, the reception part, the PIC board, the general reset part, and the appropriate antennas. In the emission part a low frequency bloc amplifies the data to be emitted (Figure 16) followed by a synthesizer bloc in a classical PLL loop. A power amplifier bloc comprises passive elements for matching between amplifier and differential amplifier, and make sure the point of compression is not reached.
A classical radio reception architecture is chosen with a Low Noise Amplifier, frequency dividers and filters. It also reduces signal amplitude, so by keeping a peak to peak 400mV amplitude a sole binary transmission canal is used. The communication subsystem on the whole can be conceived with commercial off the shelf components except for the LNA and external crystal oscillator. Most of the components chosen have already flown on other Cubesats. An example of the prototype for the emission and reception parts is given on Figure 17.

Behavior of antennas has first been simulated with the help of an electromagnetic simulator program, CST Microwave Studio. The structure of the satellite is represented by a metallic cube. It showed that the length was appropriate for operation at the chosen frequencies. An example is seen on Figure 18 where the reflection coefficient is represented for the system antenna + cube. A peak is seen to occur around 140 MHz. In practice, measurements on the VNA lead to the optimization of the antenna length.
A balun is necessary for power supply and correct electromagnetic field radiation. A simple balun has been realized according to the design presented on Figure 20. It is conceived with discrete self and capacitors.

Simulations were again undergone, first on the balun only, with the help of a circuit simulation software ADS. Then simulations are performed incorporating the balun system with the antennas. Good radiating patterns were obtained. The system was then realized, as shown on Figure 21.

Measurements of the antenna-balun systems on the vector network analyzer were performed. They enabled the optimization of the antenna size for a good load matching and thus radiation at the required frequency. Then the radiation pattern was measured outdoors. The first non-optimized samples gave good results, as seen on Figure 22, where the Diagram pattern showed a nearly-omnidirectional radiation for the transmission antenna. The equivalent was observed for the reception antenna.

Deployment system is based on a classical mechanism. Antennas are rolled up and held by a nylon thread. A nichrome wire heats up with the passage of a current and melts the wire, releasing the antennas. Nichrome is purchased from Goodfellow. Tests were performed both at ambient pressure and under 0.1 bar pressure.

5.6 Ground Station

The main ground station will be based on the Montpellier University campus using low cost amateur radio hardware. It is meant to send commands or receive data. It will store the received data and processes them. The Robusta project joined GENSO (Satellite Global Educational Network for Operations) in February 2009. GENSO is a project initialized by the ISEB (International Space Education Board). The ISEB includes the educational departments of the (French Broadcasting Authority, the Canadian Space Agency, of the CNES, the ESA (European Space Agency), of the JAXA (Japan Aerospace Exploration Agency) also the NASA (National Aeronautics and Space Administration). GENSO is managed by a division of the educational projects of the ESA. Montpellier University is currently involved in the survey of new modulation techniques to be implemented on GENSO.

The architecture and hardware are detailed below (cf. Figure 23 and Figure 24). It comprises two commercial cross-Yagi antennas (cf. Figure 25), one with 2x19 elements, one with 2x9 elements. They are cross-polarized operational, and include two polarization coax switches.

Antennas are mobile through two Yaesu rotors. The rotor Command interface is a GS232 system. For rotor command: Orbitron software is used. It leads to the tracking of the satellite, with the help of an ephemeris table at the input, regularly updated with online data base. The transceiver is compatible with Genso standards, it's an Icom 910H.
Transceiver reception operates on audio frequencies only with the 1200 bit/s rate, hence the input is on the audio card and data decoding take place here. The AGPWE program (Application Gateway packet engine: traffic) turns AFSK-coded data to binary data. Binary data are stored in a data base. A PhP home-made program decodes the AX25 frames and stores data in a data base such that they are in the correct display form, with sections devoted to experience data, battery and solar cells-related data, events-related data. The display program also lets the CSV data to be stored. These data will be available from the university network.

6. ROBUSTA, A COMMUNICATION VECTOR

For the Robusta project, several different schools work together. These schools are based in Nimes or in Montpellier. Therefore, the communication between them is essential for the progress and outcome of the project. In particular a perfect timing and technical status between the various parts of the satellite is needed. The students regularly work on the diverse meetings to prepare them, and after meetings they are bound to make a synthesis for everyone. Meeting reports follow a normative guide edited by the CNES. The students thus have to conform to these guides, quite as they would do if in a big company. Also, the discussions which follow the presentation of results or choices made must be understood by all, even people which are non-specialists of the technical theme discussed during the meeting. Students must therefore make quite naturally an effort to have a wide vision of the project. They are sharp on their subject of the concerned training course, but quickly acquire in a autonomous way basic knowledge in the other fields.

Because in France this whole project is quite original, it benefits from wide media coverage. Students are regularly interviewed by the journalists for broadcast reports or written articles in the regional newspapers 38, 39, 40, 41. This playful way of presenting science has for consequence the arouse of interest in a number of high school students and other young people, susceptible to be later enticed towards the diverse university education. Besides Robusta-implicated students have to adapt their technical language to every kind of public and venture on the scientific popularization field.

We notice another key point of the Robusta project. It allows the students to learn to communicate technical and scientific results, to acquire a know-how in oral presentation.

7. A WIDELY SPONSORED PROJECT

Numerous companies sponsor the Robusta project. Indeed, for them, Robusta is above all an excellent communication vector towards a large public. They are also interested to engage students in Sciences for the Engineer well trained in their specific field. For some of the companies directly involved in spatial electronics, it is a way of supporting the development of the method of qualification of their devices. It is the case of the Intersil, which supplies to Robusta hardened devices. Texas Instrument 43 supplies commercial components and has given about ten development kits for Microcontrollers. TRAD company, located at Labège next to Toulouse, has supplied several licensees for their FASTRAD software dedicated to the simulation of dose-rate received by each component of the satellite. An example of such simulations is given on Figure 26.

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Figure 23: synoptic of the ground station.

Figure 24: software for the ground station.

Figure 25: example of one of the ground station antennas

Figure 26: Example of model for the calculation of the absorbed dose by a Robusta component with the FASTRAD software.
The SAFT company supplies the Li-Ion batteries, in exchange for data on their behavior during flight. Voltage follow-up measurements of the battery will be undertaken during the mission. The Cofidur group will supply the flight model of the sub-systems. It also proposed that student designers attend the process of birth of the prototypes. Finally, Farnell provides direct sponsoring to the project, contributing to device procurement.

CONCLUSION

The Robusta project aims at conceiving a picosatellite with a scientific mission dedicated to the measurements of damages of bipolar components under ionizing radiation. Data measured during three years of flight will be compared with those obtained by a test method performed on ground. Under university professor and researchers supervision, about 120 students of Montpellier University, both undergraduate, graduate and post graduate, are strongly implicated in the Robusta project through training periods courses integrated in their educational program.

Besides the necessary knowledge about space and its constraints, various technical fields are approached, as energy management, radio communications or micro-controller programming. The interest of such a hands-on project, with a real scientific vocation, is to allow students to conceive and realize prototypes, and in the mean time acquire a whole system vision, without forgetting to communicate on the project in various manners.

It appears that such a large-scale interdisciplinary project can be completely led within a university if skills are put together. Moreover, if the project presents a major scientific interest for the scientific community and companies it can obtain additional funding.

Today, from a pedagogic point of view Robusta is already a success. We now await with impatience the launch and data collection to complete this success from the scientific point of view.

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33. Website: http://www.rfic.co.uk
34. Advanced Design System (Agilent Technologies®, Inc.).
35. Website : www.goodfellow.co
36. Website: http://www.genso.org/
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