IniSat: Pedagogical platform for learning cubesat's missions

Frédéric Giamarchi (1), Eric Nativel (1), Thierry Fiol (1), Nabil Boureghda (1), Hubert Diez (2), Laurent Deroin (2), Laurent Dusseau (1,3)

(1) University of Montpellier - University Space Center - CC06-001 - 34095 Montpellier, France, + 33 4 67 14 49 45, frederic.giamarchi@umontpellier.fr,
(1) University of Montpellier - University Space Center - CC06-001 - 34095 Montpellier, France, + 33 4 67 14 49 45, eric.nativel@umontpellier.fr,
(1) University of Montpellier - University Space Center - CC06-001 - 34095 Montpellier, France, + 33 4 67 14 49 45, thierry.fiol@umontpellier.fr,
(1) University of Montpellier - University Space Center - CC06-001 - 34095 Montpellier, France, + 33 4 67 14 49 45, nabil.boureghda@umontpellier.fr,
(2) CNES – DIA/AE Anticipation & Emergence - 18 Avenue Edouard Belin, 31401 Toulouse, France, + 33 7 86 27 67 58, laurent.deroin@cnes.fr
(3) University of Montpellier – Institut d'Electronique du Sud UMR CNRS 5214 - 34095 Montpellier, France, + 33 4 67 14 40 50, laurent.dusseau @umontpellier.fr

PAPER

Cubesat-type structures allow students of the University of Montpellier to study and learn how to design space systems. In the first part, we will recall the importance of attracting students to careers in space engineering.
Secondly, we will present a cubesat-type educational platform called Inisat. Teachers and students have developed it and we use it in our courses. It consists of a 3D printed cubesat-type structure that supports 3 electronic boards and 2 solar panels. This educational tool has been developped in partnership with the French Space Agency, CNES. This structure includes all the fundamental elements of a real satellite. We used the experience gained from the study and design of our ROBUSTA cubesats to design this platform. We will present how each part is used to teach the basic functions of electronics to undergraduate electrical engineering students.
Thirdly, we will present how this platform can be used to imagine missions of increasing complexity. We have equipped it with various sensors (GPS, Inertial Center, Camera and possible extensions) and an RF link using XBee protocol to communicate with a station.

1 INTRODUCTION

CubeSats or other small satellite formats are powerful tools for education, R&D and technology demonstration. Such projects should have a clear role in every national space program, but they can be difficult to explain to decision makers, because results will be seen in five plus years. Educational projects have a clear effect on the creation of tech startups and in addition the industry will receive well educated employees.
At the university of Montpellier, students have had the opportunity to study, build and launch Cubesat standard satellites since 2006. 3 1U cubesats were launched in 2012, 2017 and 2019. Others are in preparation, including a 3U model. The University of Montpellier has shown that it is not necessary to come from a famous school to make a small satellite [1], [2]. But in general the skills to tackle these projects are not taught in academic structures. The University of Montpellier, being well aware of this, offer an advanced master in Space System engineering, and at Bachelor year 3 level.
Moreover, space careers are rarely considered by science students. The academic path to these careers is not known to guidance counsellors and the university open days show too few courses related to space.

However, space engineering companies need not only engineers, but also technicians who are trained for the assembly, integration and testing of space systems.
On the other hand, the age pyramid shows that it is essential to train the next generation, so that France remains a nation that has a prominent role in space train.
These observations are shared by many academics in France who have founded student space centers (CSE) or university space centers (CSU). Meetings between these structures made it possible to define a charter carried out by CNES. It is from these meetings that the idea to propose educational platforms to introduce students to the study of CubeSats was born. Hubert Diez, the head of university relations at CNES, initiated this whole process. When he retired, Laurent Deroin take over the task.
Montpellier University and its Nîmes unit tested an existing platform for its teaching [3], since the result did not correspond to the demand, teachers proposed to their students to develop a new platform which would be more in line with their experience of the teaching needs and the types of cubesat launched [4],[5].
The result of all these actions is a first educational platform called IniSat, for Initiation to Satellite engineering.

Figure 1. IniSat, Satellite for Initiation

2 INISAT

The IniSat is a 1U type educational platform. This is a 10cm cube using various hardware resources associated with embedded systems similar to that can be found in a small CubeSat satellite. A ground station completes the set.
Space systems use power regulation and distribution systems, microprocessor control, data conversion and signal processing, environmental sensors and control and RF communications.
All these hardware and software resources are studied on other systems, but with IniSats they are combined in a small device with implementation criteria specific to space systems, which are related to earth and space science.

2.1 Structure

The structure of our educational platform is a 3D printed platform that supports electronic cards connected to each other by an inter-card connector. Two solar panels are arranged on two adjacent sides. The Man Machine Interface (HMI) includes switches (Selection, Pin, End of Travel), light indicators and connectors to program the processor board and recharge the accumulator. The heart of

the systsem is a STM32 microcontroller. The various sensors proposed are a temperature sensor, a GPS, a camera and an 9 axis motion tracking device. It is even possible to add your own sensor, since a free zone is available with standard connections (Power, GPIO and I2C).
The ground station allows dialogue with the structure. The dialogue process is wireless at 2.4GHz (XBee).

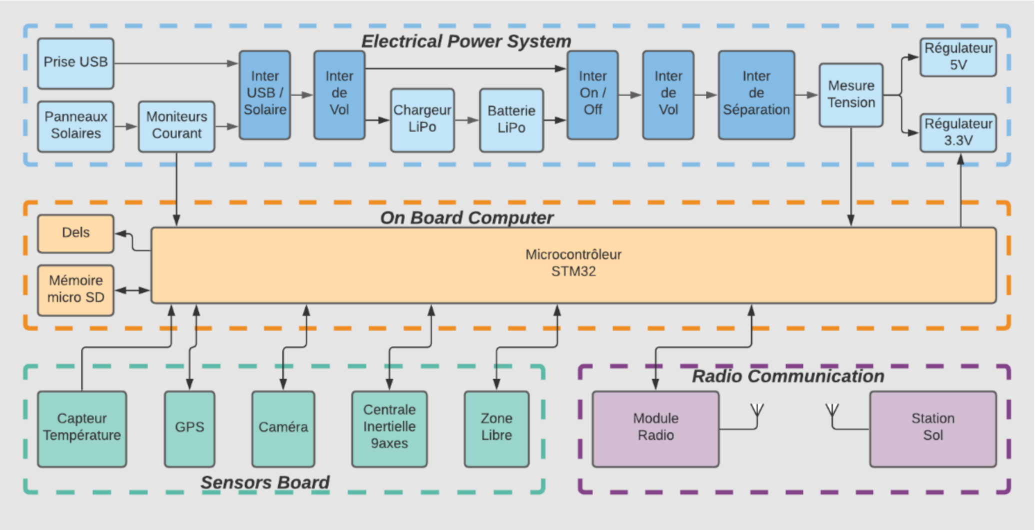

Figure 2. Satellite Bus System Architecture

This concept offers an educational framework that allows 3 year students, to explore the subsystems at their own pace. There are several associated courses for this level.

2.2 Assembly Integration and Tests

The objective of our professional bachelor is to train senior technicians who are proficient in the assembly, integration, functional and environmental testing procedures of the space industry.
Graduates will join a project team that can work on assembling or qualifying a satellite, launcher or ground segment, in an equipment manufacturer or a space agency.

Figure 3. Assembly of EPS and CPU boards

2.3 Electrical Power System

The study of the electrical power system (EPS) makes it possible to understand several basic electronics concepts. It is necessary to collect the needs of the various subsystems in order to choose the necessary voltages and currents as well as their management, and distribution over time. A power balance must be made between the battery’s needs and capacity. It is necessary to study the charging and discharging cycles of the battery from the solar cells, as well as current measurements and voltages.

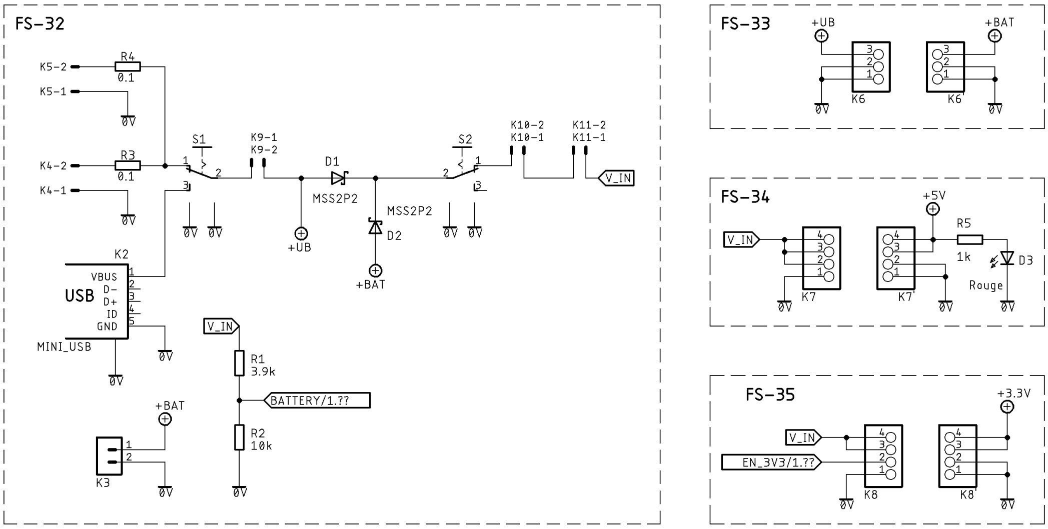

Figure 4. Electrical Power System Design

The EPS (Electronic Power System) board includes a set of functions for resource management to generate voltages to other boards. There is a LiPo battery charger (FS-33) from the solar cells or an outside connection, the contact and safety switches (K9, K10 and K11) (specific to the CubeSat standard) as well as 5Volts voltage regulators (FS-34) and 3.3Volts (FS-35).

2.4 On Board Computer

The electrical interface groups the various signals together so that the structural elements can function properly. In addition to the +5V, +3.3V and 0V power signals, there are I2C and SPI buses. The other lines are digital and/or analog inputs or outputs. Free lines (USER_X) allow you to add other features. If some functions are not used, it is possible to release more lines.

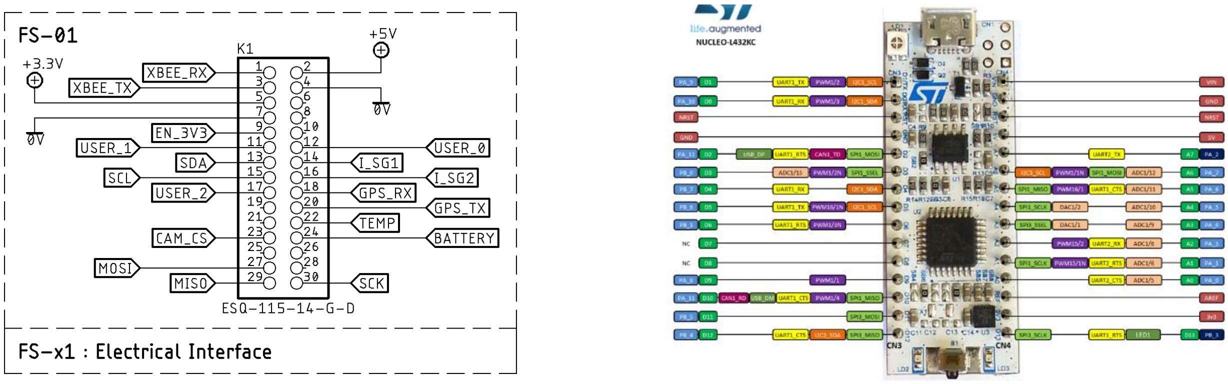

Figure 5. Electrical Interface and Nucleo 32 board

The Core of the system is a Nucleo 32 card. This development board uses an ARM Cortex-M4 processor of STM32 (STM32L432KC) type with an 80MHz clock and offers 256kB of Flash and 64kB of RAM. In addition, this chip has many dialogs interface devices (UART, I2C, SPI, CAN) as well as digital and analog input lines. These small form factor cards are very popular with universities. They are inexpensive and perfectly suited for experimentation.
The Mbed online development environment (IDE) is free and offers access to many library, projects and allows the storage of one's own projects. In addition, the community has been operational for

several years. Even if this is not the only development environment possible, Mbed by its online aspect allows sharing, pooling, management by teams and the easy access to the latest updates.

2.5 Radio CommunicationC

We use two XBee™ modules for communication between the platform and a PC. One XBee module is installed on the EPS board and has a patch antenna with U.FL connector. The ground station is equipped with the second module, but with a conventional antenna on RPSMA connector and an adapter board with a mini USB connector.

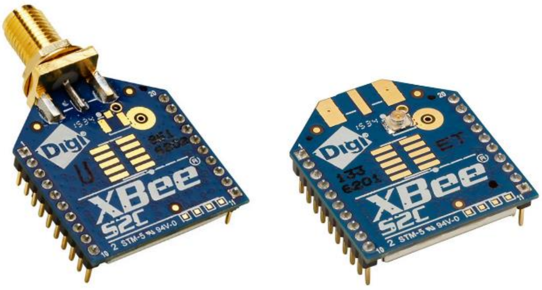

Figure 6. S2C XBee™ modules

3 MISSIONS

The most important point in the design of a satellite is the mission. This aspect is often left out of in educational projects, for which the method is often more important than the result. The Cubesat platform approaches projects the opposite way. We define the need and adapt the payload to the structure. Thus, in the case of a CubeSat project, the challenge may be to develop a payload that fits into a CubeSat and uses already existing subsystems (off the shelf platform).

Our Inisat platform helps develop such a payload for an educational mission. By developing the payload and trying to improve it, we will create better experts and spin-off missions. It is also by focusing on payloads that we will motivate future students to choose to these exciting careers.

3.1 Eps Mission

Before developing an original payload, the system allows to test the operation of the electrical power system by simulating the light and dark phases of the rotation of a satellite around the Earth. When combined with a rotating base, the current of the solar cells can be measured according to the irradiation angle. We use a Cubesat rotation system in combination with a simple artificial sun.

3.2 Camera Mission

The platform has a fixed or mobile 2 Mpixels camera on two axes. It is possible to make videos at 15 frames/second. The images are in JPEG format.
A camera on a CubeSat is an imaging payload that can be used for a variety of applications, including Earth Observation (EO).

3.3 Drone Mission

The passage of a satellite over the ground station can be simulated with a flying drone. The data collected during missions is stored on a 4GB SDcard. We simulate the time window to receive this data.

3.4 Other Missions

The platform has a temperature sensor, a GPS and a 9-axis motion tracking device, as well as a free slot to insert another sensor. A standard educational mission will use a GPS and weather balloon.

4 CONCLUSION

Our educational platform allows a first approach to space missions at a reduced cost compared to other systems on the market. The team is thinking about other actions to boost the platform. One of them would be to propose a 1-axis inertia wheel.

5 ACKNOWLEDGEMENTS

The authors would like to thank the technical and administrative staff who helped developed this platform in the complicated teaching environment of the last 2 years.

6 REFERENCES

[1] Giamarchi F. and Gervois G., *Robusta 1B: First feedback from in-flight telemetry on the power system*, 4S, Malta, 2016.

[1] Giamarchi F. and Gervois G., *Robusta 1B: Return of Experience from the energy power system in-flight telemetry*, 4S, Sorrento, 2018.

[3] Yamazaki M. and Zengo T. , *HEPTA-Sat Training Program : International Knowledge Transfer Using Hands-on Type CubeSat Education*, 32^{nd} Annual AIAA/USU Conference on Small Satellites

[4] Laurand X., *Lessons learnt during commissioning and one year of operation of the ROBUSTA-1B 1U Cubesate*, 4S, Sorrento, 2018.

[5] Bernard M., *Is ionizing dose a concern for CubeSats ? Robusta-1B A go and find out for yourself mission*, 4S, Sorrento, 2018.

Figure 7. Inisat logo