The CanSat Competition: PoulpySat II

Scientific article

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Contents

1 Introduction

From the perspective of creating an extraterrestrial probe, our objective was to pack as much technology as possible in the smallest probe. Therefore, *PoulpySat II* had to outclass technologically its predecessor while keeping a low profile.

To do so, *PoulpySat II* has been designed to perform the same tasks as *PoulpySat I* and much more:

- gathering and sending telemetry (position, speed, acceleration, temperature, etc.)
- video transmission
- ability to move
- ability to deploy an external probe in the ground
- ability to control the fall

To realise such a CanSat, we had to find or to create the most adapted components. As a result, we obtain a 0.57 l and less than 1 kg probe that responds to all our specification.

2 CanSat Team

2.1 The team

The *PoulpySat II* project has been carried out throughout this year by our team, *PoulpyEngineering*. It is exclusively made up of students from Grenoble-INP Esisar and is composed of five members:

- **Martin BOULIN**, Team Leader (third year student)
- **Éloi DONVAL**, electronics manager (third year student)
- **Nathan GARNIER**, mechanic manager (fourth year student)
- **Alexis MOYART**, RF manager (fourth year student)
- **Loïc SAVORNIN**, embedded programmer (third year student)

All the members of the PoulpyTeam are part of the *Club Robotique Esisar* (Esisar Robotic Club). The club was founded in 1995 and has for purpose to initiate students to robotic and to help them to give birth to their projects related to robotic, electronics and embedded systems.

2.2 The equipment

The team has access to the following equipment:

- FDM 3D Printer
- CNC
- Oscilloscope
- Laboratory power supply
- Logic analyzer
- Multimeter

3 CanSat Missions

3.1 Mandatory mission

The first objective is to send data from the CanSat to a ground station. Those data can be telemetry data, photos or video.

As explained before, *PoulpySat II* has to outclass *PoulpySat I*. Therefore we wanted to send more than telemetry data. *PoulpySat II* is now equipped with a 480p camera streaming to the ground station once the CanSat is falling.

Figure 1: BETAFPV A01 AIO Camera VTX

This camera has a 640×480 resolution and a field of view of 120° horizontally and 100° vertically. Its mass is 3.2 g, and it can stream data, thanks to its embedded PCB, on the 5.8 GHz ISM band. The output power is limited to 25 mW in accordance with the french regulations. The camera integrated circuit will stream the camera feed directly to the ground station.

Not to be undone, *PoulpySat II* will keep the same telemetry module than is predecessor: the SPSGRFC-868 from STMicroelectronics. This module, presented on the right, has several advantages for our use:

Figure 2: SPSGRFC-868, STMicroelectronics

• It has many options to configure the radio part and the data packing part. It allows the use of the following modulations: OOK, ASK, FSK, GFSK, MSK and GMSK. The data rate and the channel width are also adjustable and we can reach 500 kbps. The module integrates internally the checksum management, acknowledgement, re-transmission... This allows us to simplify its implementation.

• It is easily integrated on a PCB, being in the form of a System On Module with a compact footprint of 13.5×11.5×1.3 mm.

• Its communication interface being an SPI bus, it is easy to set up the communication with the micro controller. The module also has 4 programmable GPIOs. It is capable of delivering 11.6 dBm in frequency modulation and covers 863 to 870 MHz. In addition it has a µFL connector for external antenna and low power consumption.

3.2 Secondary missions

The CanSat Competition specifications asked for either controlling the fall or moving once the CanSat is on the ground. We elected to do both.

3.2.1 Controlling the fall

The easiest way to achieve it is to act on a parachute suspension. Therefore, we have developed a simple system with a servo motor and a spool. One of the four parachute suspension will be attached to this spool. When the servo motor turns in a way, the wire is lengthened or shortened leading to a instability of the parachute that makes it turning.

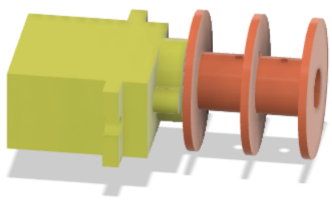


Figure 3: Servo motor and spool

The spool is a 3D piece and the servo motor has a 1.6 kg.cm torque and consume 2.64 W if fully loaded. However, we expect the consumption to be much lower than that as the servo motor won't be fully loaded. Moreover, the impact on the battery should be low as it will work only during the fall.

3.2.2 Moving on the ground

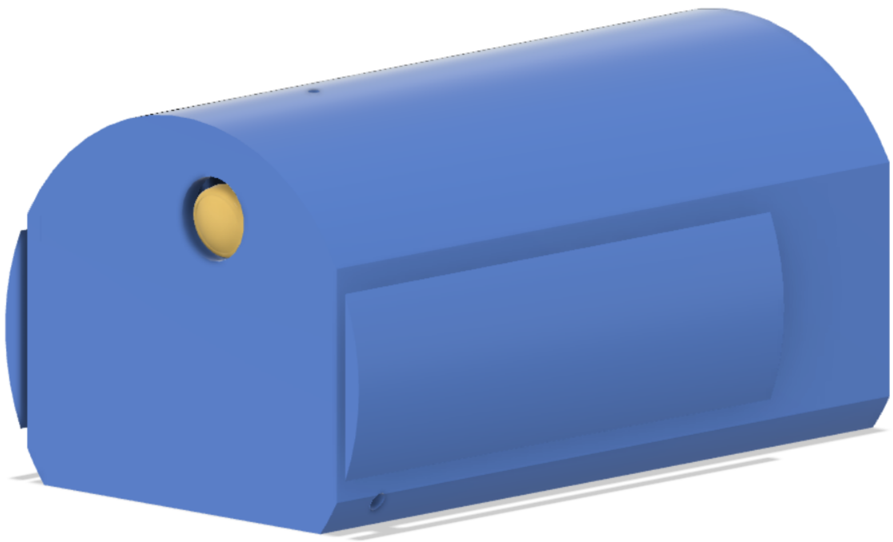


Figure 4: PoulpySat's Arms

In order to keep *PoulpySat II* as small as possible, we imagined an innovative system: two arms 3D printed and controlled by a servo motor each will make the CanSat to go forward or backward. Another main advantage of this system is that in the case the CanSat lands on the back, it will be possible, by moving only one arm, to flip the CanSat over.

Each arm is controlled by a servo motor with a 4.1 kg.cm torque and the servo motors are themselves controlled by the PCB developed by ourselves.

This system is clearly not the most stable or the most efficient but it assures us to have a compact CanSat and handles the turnaround as well as the movement while, by using a more conventional system, we would had to create two distinct solutions. Moreover, because of the size of the CanSat, we expect to have better result in a hostile environment (tall grass) than other solutions like tracks that would be inefficient because of the small size and the lack of torque.

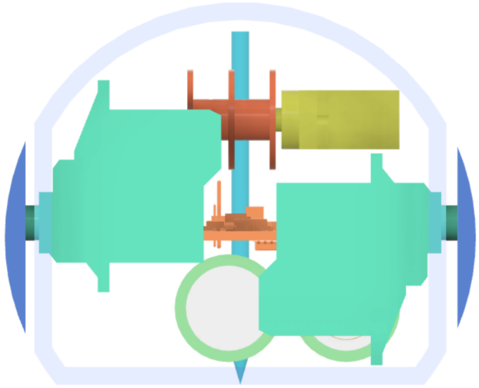


Figure 5: Servo motors controlling the arms

It is important to note that most of the energy consumption will be done by those 2 servo motors. Therefore, the battery has been designed to this matter.

3.3 Bonus mission

As the CanSat is an extraterrestrial probe, we wanted an external probe to get ground telemetry. In this context, we developed the *PoulpyProbe*. In our case, the probe is a thermometer.

The system is constituted of two parts, one is fix and the other (the one with the thermometer is mobile). The two parts are linked with elastic band and the mobile part is blocked by a system controlled by a servo motor (the pink part is what is blocking the mobile part of the probe). Once the mobile part is free, the elastic band pushes the probe into the ground.

This system has been created so the probe can be rearmed quickly and cannot be disturbed by any kind of perturbations (chock with the ground, unpredictable event during the drop, etc.).

Figure 6: PoulpyProbe

The servo motor is identical to the one used to control the parachute and the other parts, beside the thermometer, are made by a 3D printer.

Note that the blocking system might change in the future.

4 CanSat Design

4.1 CanSat material

The shell of *PoulpySat II* will be 3D printed. We are currently studying several materials to know which one will be more adapted to the CanSat and where (the material of the arm might not be the same that what we will use for the top). Therefore, the final mass of the CanSat is unknown.

4.2 CanSat layout

The design of *PoulpySat II* is relatively simple. We initially took the maximum volume possible, a 1 l cylinder with a diameter of 80 mm and 200 mm of length, then as we wanted a flat floor for the PoulpyProbe and for the stability when the CanSat is on the ground, we cut a part of the cylinder.

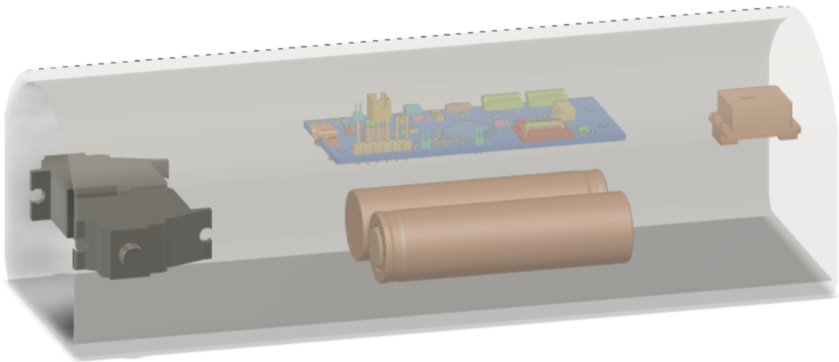


Figure 7: 3D representation of the first version of *PoulpySat II*

Once the maximum volume was delimited, we were able to place every component and we designed the arms directly in the volume to be sure to respect the specifications. Ultimately we placed everything so that the CanSat would be the smallest possible.

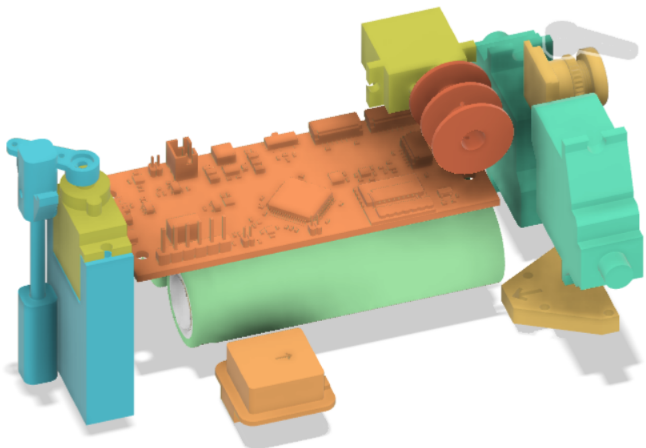


Figure 8: 3D representation of the second version of *PoulpySat II*

Afterwards, we designed the support for the components so we could fix them to the external shell then we designed all the necessary holes in the shell for screws and parachute suspensions and finally we decided to cut the CanSat in two following the longest side so that we can place easily each component.

Figure 9: Support of the PCB, the battery and the GPS

At the end, we obtained the following final result:

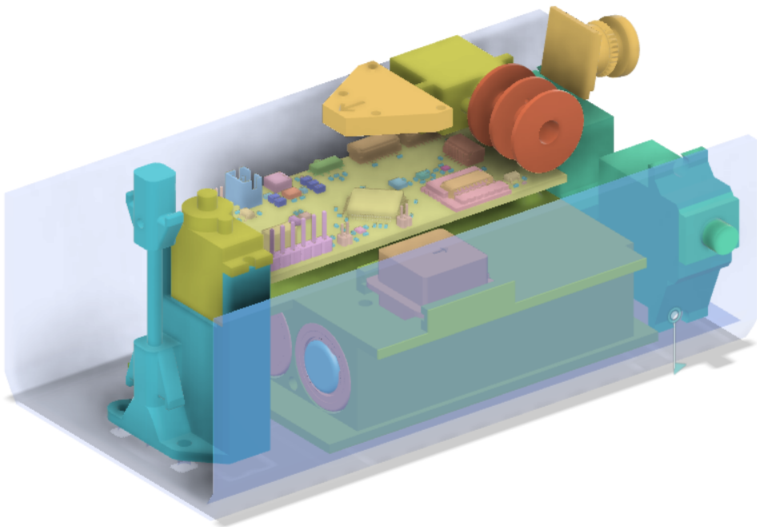


Figure 10: 3D representation of the inside of finale version of *PoulpySat II*

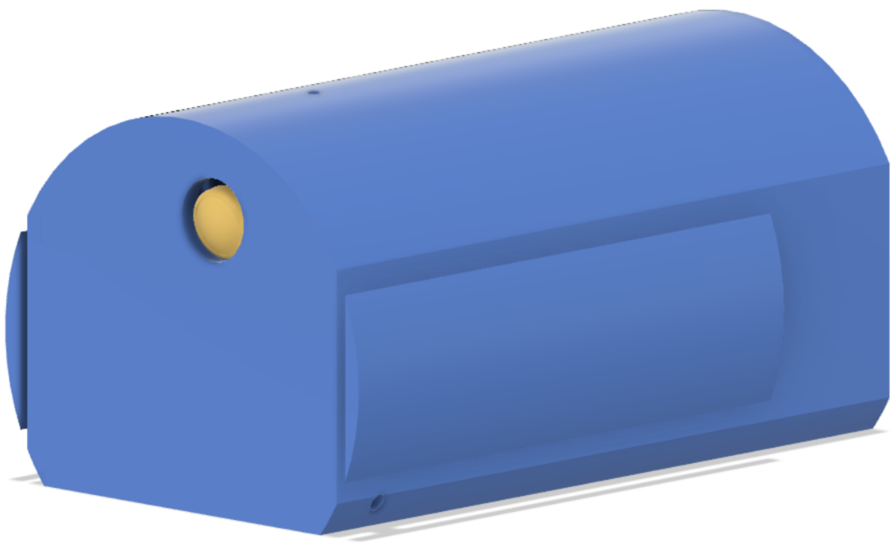


Figure 11: 3D representation of the outside of finale version of *PoulpySat II*

Please note that for the representation, we took an empty interior and we placed every component but in fact we plan to take a full interior and remove only the necessary matter to place everything. The objective is to reinforce the CanSat.

4.3 Electronics and PCB

The PCB has been designed with KiCAD. The board has 4 layers, 2 external for the logic lines and 2 internal for the power and ground planes. It is composed entirely of CMS parts and ICs (except the GPIO pad and extension interface). Notable elements on this board are:

- IC battery charger: LTC4065EDCTRMPBF (AD)
- USB micro-b Port / µSD Port
- µController: STM32F411RE (ST)
- IMU: LSM6DSL (ST)
- Barometer/thermometer: LPS22HB (ST)
- Hygrometer : HDC2010 (TI)
- RF Module: SPSGRFC-868 (ST)

This card has 4 expansion ports:

- Interface with 5 V, ground, I^2C, UART (GPS)
- Interface with 5 V, ground, 2 GPIO, UART (Ext.)
- Interface with 5 V, ground, 4 GPIO (Timer outputs)
- Interface with 3.3 V, ground, GPIO, 2 ADC
- Numeric RGB LED output (Timer 1)

A SMD switch on the side of the board allows the control of all the power supply buses. A JST terminal on the top of the board allows the management of the power supply bus of the RF module.

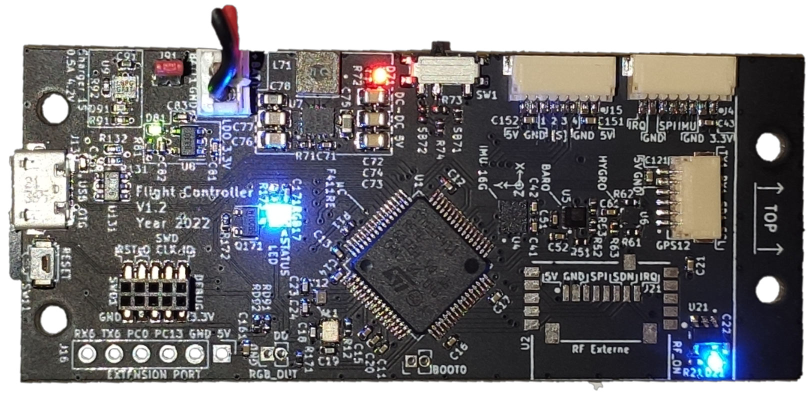


Figure 12: Face of the PCB

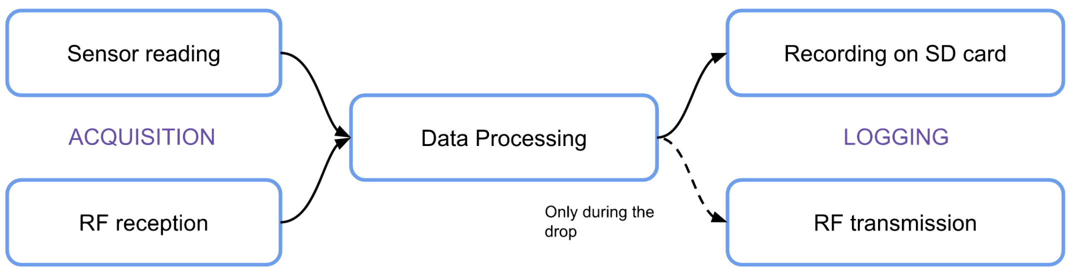
Several power supply modes are available:

- Via USB with battery charge
- Via USB without battery charge
- Via battery on the dedicated JST port

The battery is 2 Li-Ion cell Turnigy 18650 in series with a capacity of 2,000 mAh each.

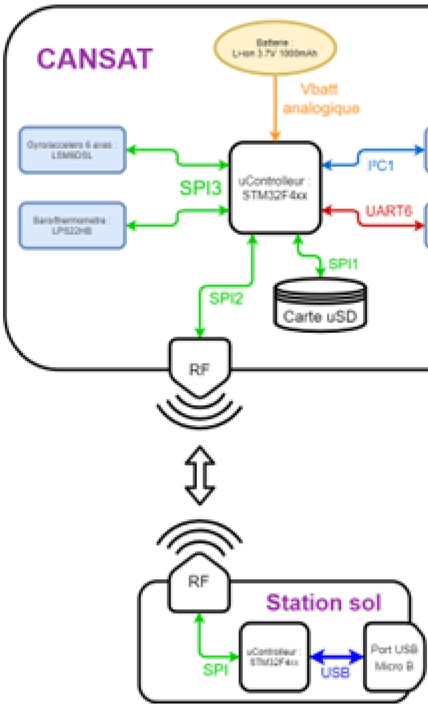
4.4 Embedded software

The µController being an STM32F411RE, we developed all drivers and mission programs in C. A simple scheduler is in place to ensure the flow of operations, below is a simplified diagram of a scheduler cycle:



Note that in order to get the best estimation of the altitude of the CanSat during its fall, the ground station sends the atmospheric pressure (at ground level) to the CanSat in flight until release.

We can thus decompose the CanSat by the synoptic diagram below, where we find the types of communication bus between each element and the simplified role of our ground station.



The ground station runs a python program that interfaces between the CanSat receiver and Grafana, which allows us to display the collected data in real time.

5 Conclusion

Despite the fact that the development phase is not finished yet, about 90 % of the CanSat is done. Even if some tweaks might happen before the launch day, we believe our CanSat will be able to perform all its tasks as expected.

This CanSat competition has been challenging for us, as we were developing two project at the same time, *PoulpySat II* and *PoulpyRocket*, we had less time than the last year to achieve it. Nevertheless, we believe our experience in the competition has lead us to build an improve version of *PoulpySat I* that meets perfectly to the specifications and much more.

Moreover, the CanSat developed this year has a good improvement capability as not all the volume has been used and the PCB has already shown its capabilities the last year. Therefore, we expect *PoulpySat III* to be an even better and more accomplished version. Next CanSat focus should be placed on improving current missions especially the arms and the *PoulpyProbe*, and the addition of a new mission.

6 Acknowledgement

We would like to thanks our two sponsors Elsys Design and SOTIC. The Esisar Robotic Club achieves more and more every year and it would obviously not be possible without their supports.