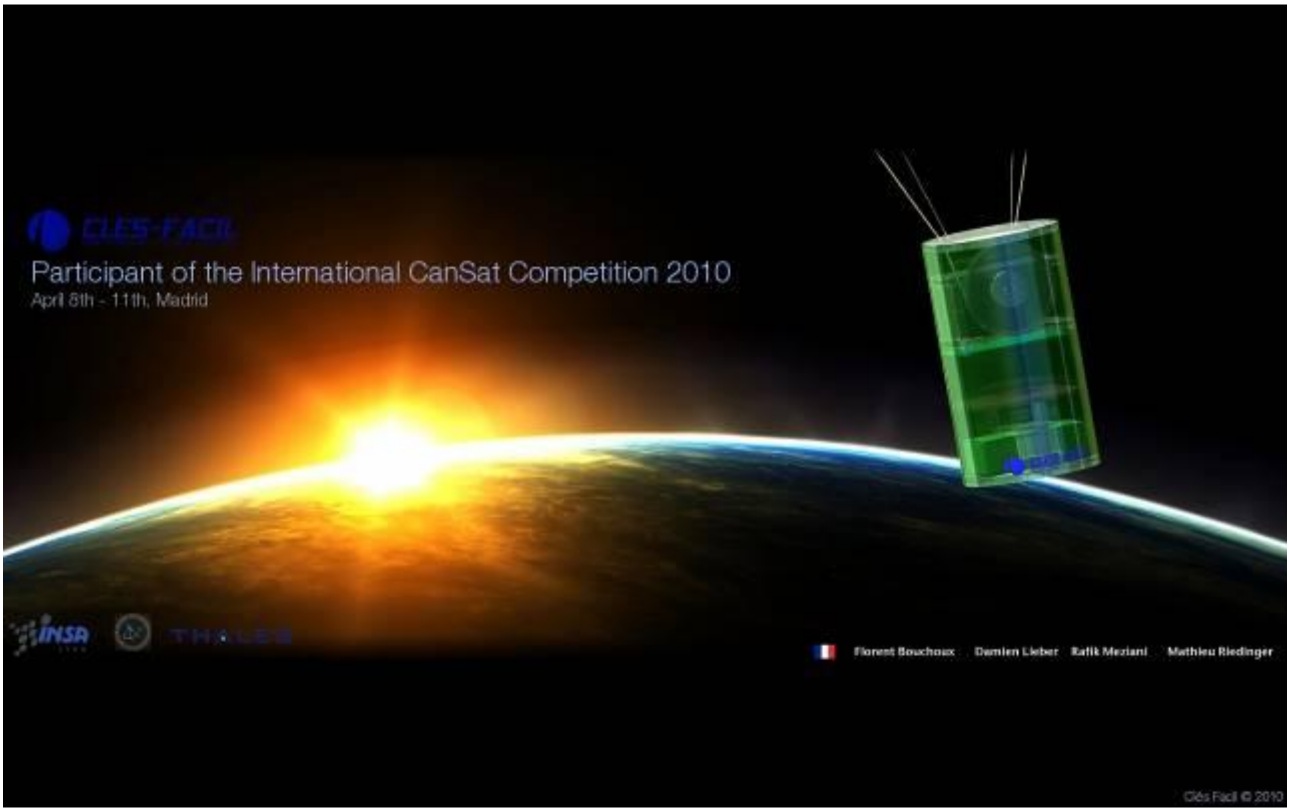
CDR – Critical Design Review

Project Altair II – CLES FACIL



CLES FACIL
2009-2010

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A. Introduction

1. Team members

This year, the CLES FACIL will be proud to present to you his fourth Cansat, *Altair*. This Cansat is our second in the International Class. Its predecessor, Yoda, made many nominal flights, but had problems which had to be solved. Altair is also an update, fixing all the previous problems we met in our last four Cansat experience years. We were many to register to the International Competition last year. The team has evolved, and is now constituted by:

- **Florent Bouchoux, Project Manager**
  - ➔ Florent.bouchoux@insa-lyon.fr
  - ➔ 22 years old, Engineer-Student in the fourth year in the Electrical Department of the INSA Lyon (France)
- **Mathieu Riedinger**
  - ➔ Mathieu.riedinger@insa-lyon.fr
  - ➔ 21 years old, Engineer-Student in the third year in the Electrical Department of the INSA Lyon (France)
- **Damien Lieber**
  - ➔ Damien.lieber@insa-lyon.fr
  - ➔ 20 years old, Engineer-Student in the second year of preparatory class in the INSA of Lyon (France)

We have an external support represented by:

- **Rafik Meziani**
  - ➔ Rafik.meziani@cpe.fr
  - ➔ 35 years old, engineering process technician, working by CPE Lyon, Engineer school

We all four will be present to the International CanSat Competition organized by ARLISS in Black Rock Desert from the 12th to 17th of September, 2010.

2. Mission objectives

Chosen category: Come Back

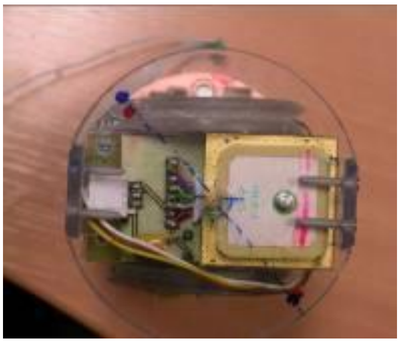
Modality: 350grams Cansat, International Class

Our Cansat will be launched from an experimental rocket. During its flight, it will have to use its components to control the wing it is flying under, in order to land on a precise point on the ground. During the whole mission, that is to say right before the rocket's launch, the Cansat will be autonomous. No direct or indirect action (using telemetry) will be performed by the team during the flight.

Before the launch, the target GPS coordinates will be sent using uplink telemetry to the Cansat, so that it will be able to drive its parafoil to the target. The direction is modified by two servomotors. That allows us to turn right or left and to go faster (by pulling both of the direction lines). All the GPS data is managed by an ATXMEGA microcontroller, and then sent to our homemade telemetry ground station.

During the flight, the Cansat will continuously be sending position, temperature, pressure, as well as batteries state information. When ejected, a jack cable, attached to the rocket's body, will disconnect and enable the trajectory calculation. The direction wheels are allowed to move after the parafoil has entirely deployed. The GPS data then allow the microcontroller to calculate the path of the Cansat and its moves (due to atmospheric conditions, wind...), in order to reach the predefined target on the ground.

See schedule: flight diagram



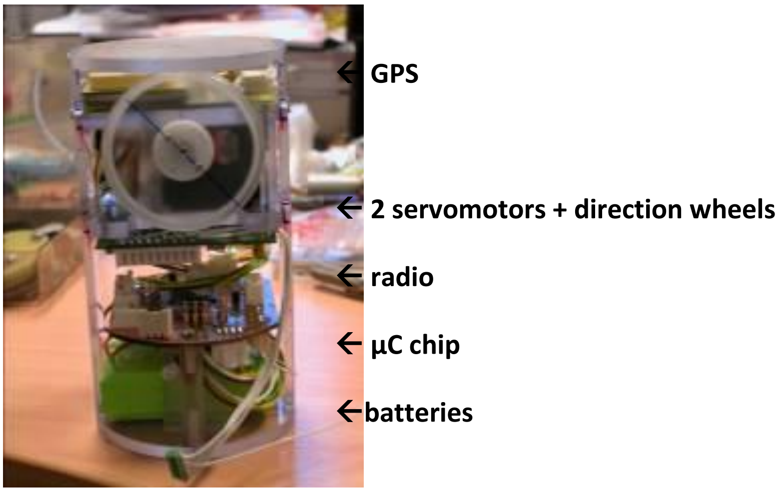
B. Cansat Subsystems

1. Structure

The structure is composed of transparent Plexiglas, which assures weightlessness, strength and design. There are no protruding parts to be declared.

The main structure dimensions are: diameter 66mm, height 115mm.

Structure composition:



a. Mass Budget

Designation	Reference	Mass
Mechanics		167.75 grams
- **Structure (all)**	Homemade	76.8 grams
- **Case**	Homemade	12.5 grams
- **Screw**	Farnell	12 grams
- **Wheels (x2)**	Homemade	22.65 grams
- **Servomotors (x2)**	Hitec	43.8 grams
Electronics		135.4 grams
- **GPS**	SiRF III GPS	21.5 grams
- **Radio**	HAC-LN-433 from HAC-TECH	15.1 grams
- **Pressure sensor**	MS-5534 (Selectronic)	21.8 grams
- **Microcontroller chip**	ATXMEGA 128A1	25 grams
- **Batteries**	Li-Po 1000mAh 2S 15C – Protronik Dimensions: 53 x 30 x 16 mm	52 grams
TOTAL MASS (< 350 grams)	**303.15 grams**	

See schedule file: radio datasheet

2. Recovery Subsystem

- **Chosen system: parafoil wing**

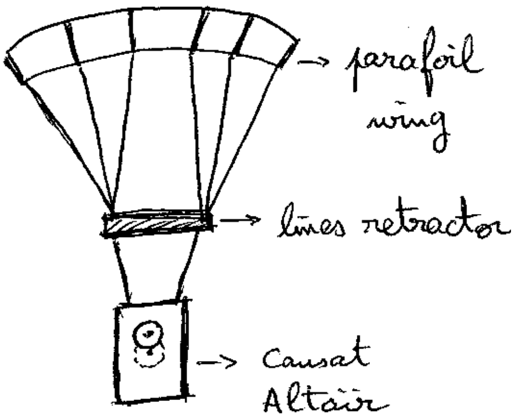
Main handmade parafoil wing dimensions: 350 x 600 mm

The Cansat is hanging up under a parafoil wing, which enables us to control the path of the module. The wing is tied to the Cansat with two main lines (fastening lines). Two other thinner lines allow changing the direction (direction lines). The microcontroller sends orders to two servomotors. On each servomotor is fixed a wheel, on which direction lines are attached. It enables to pull or release the line. That permits to go straight, right, left and faster (by pulling both of the direction lines at the same time, because each line is independent). That allows us to have high manoeuvrability, to forecast and react to different atmospheric conditions (wind, heat, air pockets...).

Our parafoil wing has been developed with the help of the Aerazur enterprise, specialized in military recovery systems. Our contact was a great help for the construction and development of the wing, but also gave us a lot of indications during our tests, of what was wrong, and what had to be changed. This part of the project, certainly the most important, is also the hardest to us. Instead designing a mathematical model of the wing, we choose to make many tests, and to rectify each seen problems, with the help of this expert.

- **Tests**

In order to test the parafoil elements (hooks, lines, nodes,...) we suspended a mass of 6 kg (20G * 300g) on the structure. Giving little shocks to simulate wind, we verified the good resistance of the structure and fixation points.

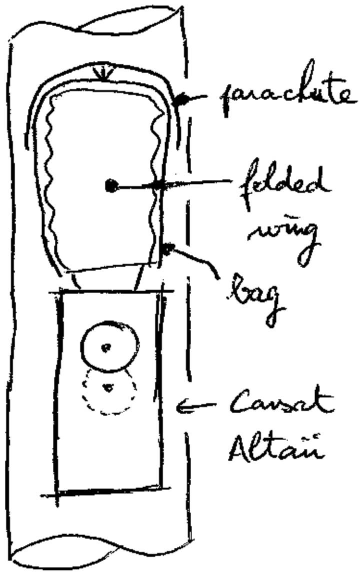


The Cansat and its parafoil wing

- **Parafoil in the Rocket Cargo Bay**

During the tests, we have chosen a wing folding, which enables fast deployment and stabilisation of the parafoil. In order to keep the parafoil folded like expected, we added an extractor. First, a parachute fixed to a line imprisoning the parafoil wing opens and stabilises the module. This will help us to reduce the fall speed of the Cansat after ejection from the RCB, in order to have no shock that destabilizes the parafoil wing. Once the system is stabilised to small speed, the parachute wing separates (flies away separately) and the parafoil wing opens at minimum speed. The flight algorithm then takes control of the parafoil wing in order to reach the aim on the ground.

Once the parafoil wing is folded, it will be inserted in a bag suspended to a small extractor parachute. The dimensions of the folded system are approximately the same as the Cansat ones that is to say: diameter 70mm, length 150mm.

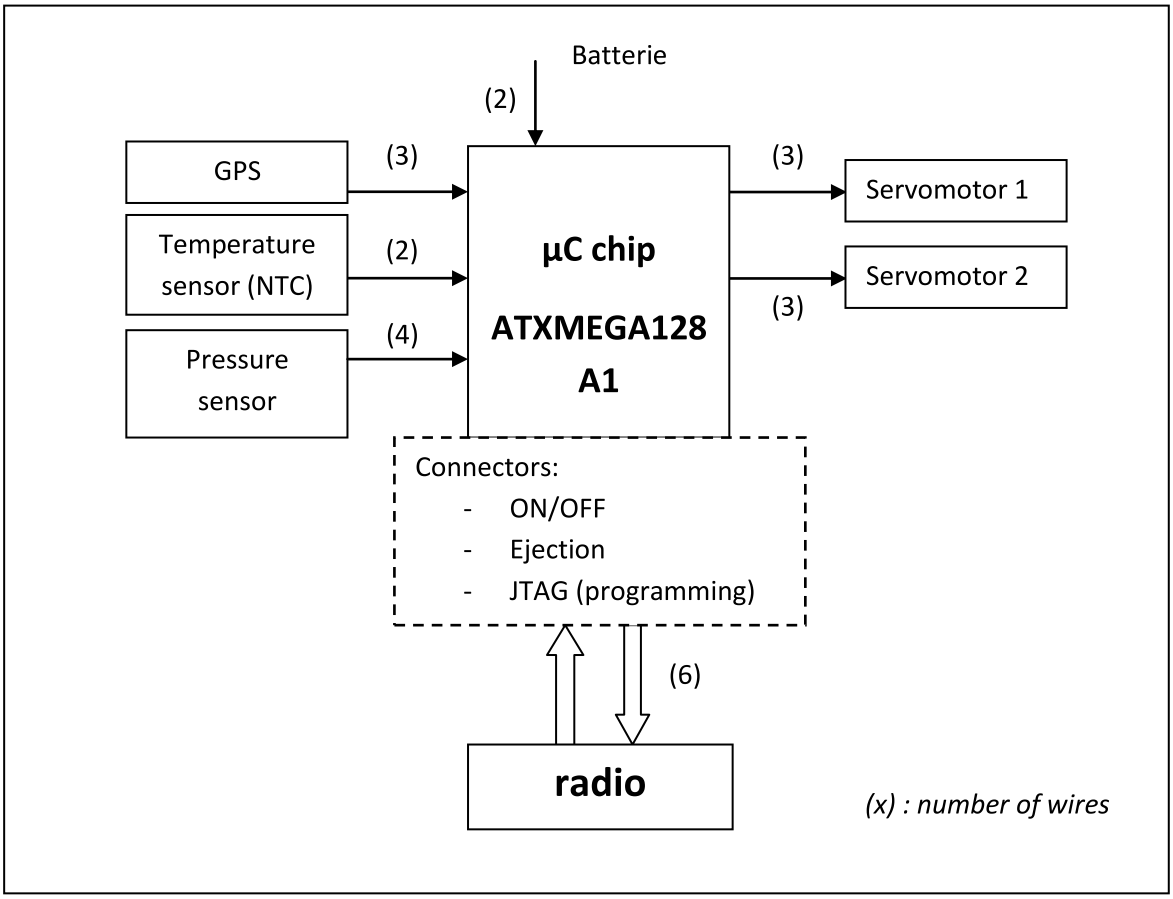


Cansat Altaïr in RCB

3. Electrical Subsystem

- Elements of the electrical subsystem

- Diagram of the components' interconnections



- Estimation of the power consumption – foreseen duration of the batteries (must be at least 1h power supply for all the equipments): the total current consumption is approximately 750mA. This consumption strongly depends on which subsystems are activated, for example disabling the radio transmitter considerably reduces the consumption.

- List description of the main components selected

    - **GPS**: gives the latitude, longitude and altitude of the module. It enables to locate the Cansat in the air, and to calculate its trajectory.

    - **Temperature sensor:** a NTC directly connected to the µC ADC gives us the temperature around the Cansat

    - **Pressure sensor**: gives a temperature compensated pressure. This data enables us, after conversion, to know precisely the Cansat's altitude.

    - **Radio module:** this bidirectional radio module can be used as well for data transmission or reception (the same modules are used aboard the Cansat and in the ground station).

    - **Servomotors**: the servomotors enable us to precisely know the angle of the wheel and its position, in order to have a perfectly controlled trajectory.

    - **Microcontroller chip:** the µC used and included in the Cansat structure is an AtXmega 128A microcontroller from ATMEL. This 16-bit microcontroller allows us to execute a consequent program, processing data from the sensors, and compute the flight algorithm.

This chip is the brain of the Cansat; it registers sensors data, controls the servomotors and communicates with the ground station via the radio.

4. Communication Subsystem

- Frequency used for data transmission/reception between the Cansat and the Ground Station:
  - 915 MHz (downlink and uplink)
- Maximum emission level (W)
  - 100 mW
- Maximum bandwidth (-6dB)
  - 25kHz
- Transmission protocol
  - GFSK modulation + proprietary protocol

5. Flight Software

- Flight software algorithm and programming language

The flight algorithm is implemented onboard the Cansat µC in the C language.

The main lines of the algorithm program are following:

- if there is not enough or just the time to reach the target : straight flight to the landing point
- if there is much time to reach the aim: following a virtual circle trajectory around the landing point, aka “Eagle Flight”.

The algorithm calculates all the possible trajectories to reach the same goal, after evaluation of the surrounding flight conditions (wind, pressure...). Then, it chooses one that has the less curves, in order to have no straight turns to perform, reducing the possibilities of destabilisation and gap between foreseen and real trajectory.

The two servomotors enable us to react to unforeseen weather inconveniences: heat holes, fast winds, etc. With the direction (turning right or left), we will be able to go faster by pulling on both lines or by releasing them in the same time.

During the mission, there is no data stored onboard the Cansat.

All the data is transmitted to the GSE with a radio downlink in real-time.

A proprietary frame is sent in real time to the GSE:

- Raw data collected by the sensors:

- GPS data: all the data is decoded onboard the Cansat, then sent to the GSE and used to calculate the trajectory.
- Temperature sensor: all the data is collected by the µC's ADC and then sent to the GSE by radio.
- Pressure sensor: the sensor gives us directly the digital pressure.

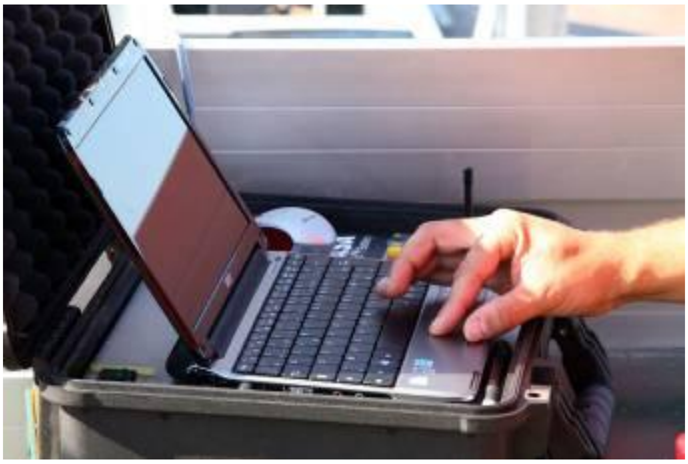
- Status information:
  - Ejection performed, sensors status, servomotors position

6. Ground Support Equipment (GSE)

The GSE has entirely been developed by the Cles Facil. All the components are settled in a military-like case. The main components are the following:

- Radio module: the same module as in the Cansat receives the sensors data (RX only during the flight) and sends orders given by joystick (used only during the test phase, disabled during the contest).
- A laptop computer: during the Cansat flight, it receives all the sensor data and saves it, in order to directly draw graphs, in order to have directly readable results. That allows us to verify the data correctness and magnitude in real time, during the flight. During the test phase, a joystick is connected, in order to control the Cansat from the ground and to test its flight possibilities.

The GSE is an autonomous system, all packed in a military-like case. It uses a proprietary technology developed for previous projects, including sounding rockets. It is quite complex in its conception, as it can be used for many projects. It includes a high-capacity battery that allows a complete autonomy above 5h of working.



7. Dangerous and Harmful material

No specifications for this section in our project.

C. Test & Certification Campaign

To perform our tests, we followed many different levels of testing our wing's flight:

1. Wing tests: the Cansat is thrown from a building (25 meters height), containing all of his components, but inert. The main goal of this test is to obtain a straight flight, when there is no wind. After this test, we are sure the parafoil is ideally positioned and fixed to the module.

   The same tests are then made with bad weather. Finally, we test and choose a wing folding, so it will be in the RCB. At this point, the wing is correctly integrated to the Cansat.

2. Flight tests: in order to check out our direction system, we drive the Cansat with our GSE Joystick (drive algorithm disabled). That allows us to look if the Cansat is acting like we want him to, with enough flexibility and in the good conditions.

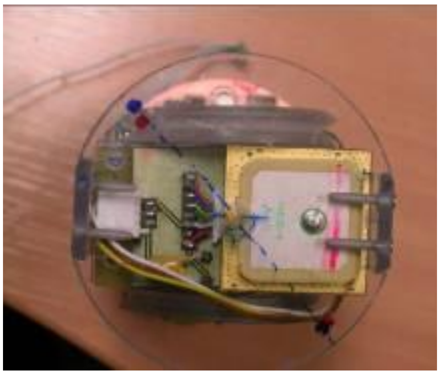
3. Ejection and parafoil opening tests: the Cansat is thrown from a higher place (small RF helicopter, parachutist plane...). The goal of this test is to see if the wing opens and stabilises when thrown with an initial speed.

4. Algorithm test: thrown from a RF helicopter (~100m high), we check the flight algorithm.

5. The final launch test is performed from a plane, with the algorithm. We also can check all the sequences of the flight and correct the final problems.

D. Operations

- 11/01 to 12/31: definition of the project and conception, preliminary design, purchase of the main parts (mechanical and electrical parts)
- 01/01 to 02/28: first structure and integration prototype built, development of the flight algorithm
- 03/01 to the competition date: tests in flight conditions



1. Mission timeline

We are currently developing this part of the project, which depends of the flight tests. A foreseen timeline for the Launch day will be sketched, specifying the role of each team member during the CanSat preparation, integration, GSE setup, operation and recovery. We have already done a first version of this document during our tests, but it is not finalized. The final week will be used for last testing in real conditions, as a pre-flight simulation. The timeline will also be completed then.

1 – Preliminary tests: checking of the transmission, taking of the weather conditions, goal GPS coordinates, battery levels

2 – Cansat is ON, radio transmission is enabled

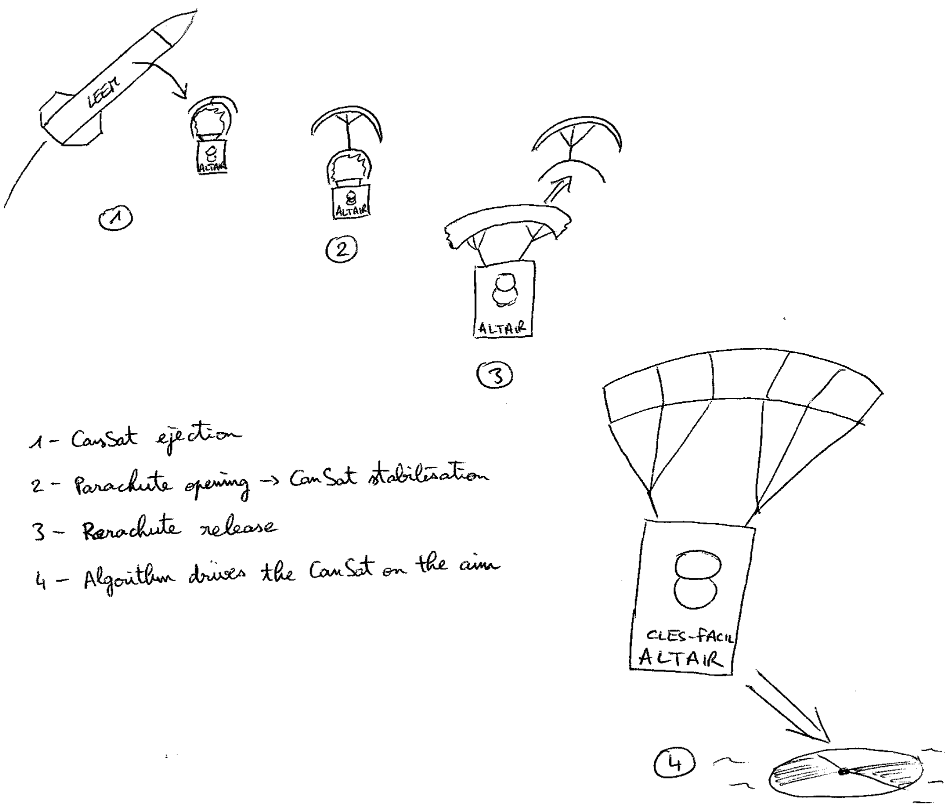
3 – Cansat is loaded in the RCB (warning: the radio will be turned ON before and while the rocket is standing on the Launch Area).

4 – Final pre-flight radio transmission tests

5 – Rocket launch

6 – Cansat ejection, first data verification during the flight on our GSE.

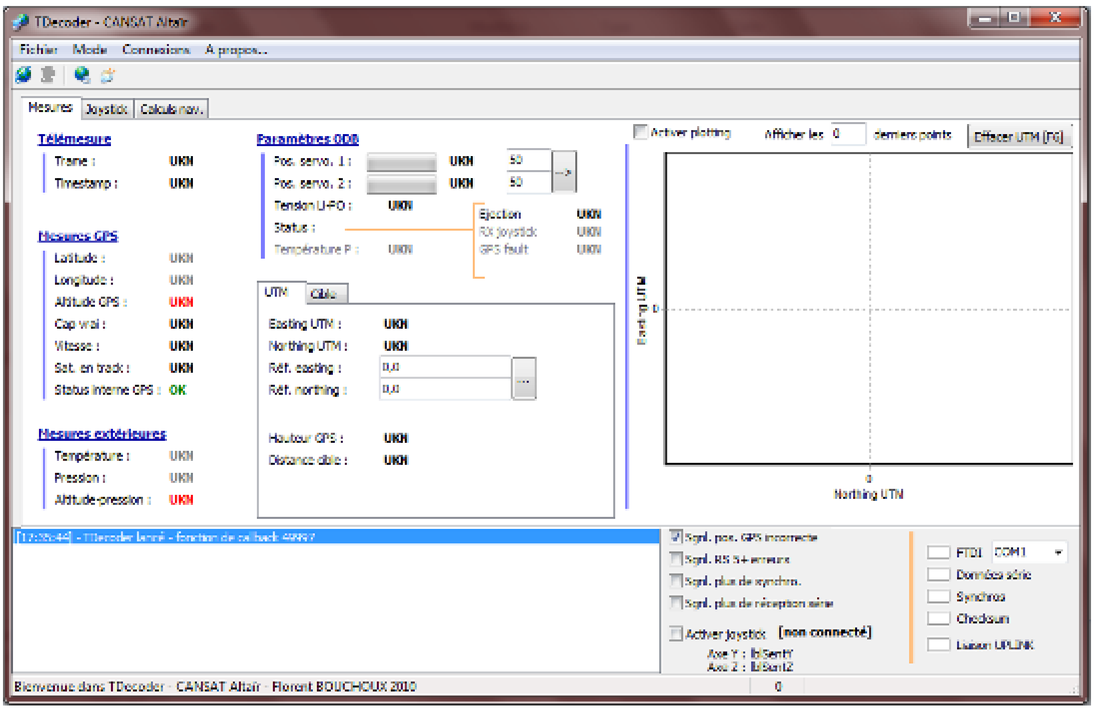
7 – Cansat recovery, data exploitation



2. Data Analysis

The GSE receives all the data from the sensors and information from the flying Cansat as described before. All the data is saved on the laptop computer in CSV files. Those data arrays can immediately after the flight be exploited with graphs tracing, Matlab calculating.

These quick exploitation possibilities will allow us to see immediately during and after the flight what was wrong or the different issues, thanks to the sensor data and the status received on ground.



E. Cost Estimation

Subsystem category	Designation	Man-hours estimation	Cost (in €)	Percentage
Mechanics	Plexiglas (gross)	-	100	14,7
	machining	20h	0	0,0
	hardware	-	40	5,9
	parafoil wing	-	47	6,9
	servomotors	-	78	11,5
	tooling	-	50	7,4
Electronics	batteries	-	54	8,0
	radio chip	-	70	10,3
	GPS	-	60	8,8
	µC card	15h	180	26,5
GSE	Laptop computer	-	350	0,0
	radio chip	-	70	0,0
	batteries	-	40	0,0
	electronic card	15h	80	0,0
	PELI case	-	180	0,0
Miscellaneous	Tests	80h	0	0,0
TOTAL			**679 €**	**100%**

F. Schedules

- Flight diagram