ESTACA SPACE ODYSSEY REPORT

"Basics to lead an experimental rocket project"

Based on the experimental rocket Solinas

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It's fine to celebrate success but it is more important to heed the lessons of failure.

Bill Gates

Preface This report is available at ESTACA SPACE Odyssey as a printed exemplary and on Planète Sciences website <https://www.planete-sciences.org/national/>.

This work is called "Basics to lead an experimental rocket project" because it deals with all the domains which are involved in a rocket design. The experiment we have made is a classic one. That is a very good training to learn all the basics in Mechanics, Electronics and on Management. This report can also be used for mini-rockets.

I have tried to give maximum information as possible to share our experience. I hope it will be useful for future motivated beginners who are eager to involve in experimental rocket projects. Personally, I think that my team and I would have won a lot of time if we had found such a report at the beginning.

I wrote it in English to enable international team to use it as the C'Space is an international event. I also used for the first time the latex system to write it. My goal was to create a nice report which would be easy to read.

I would be happy to have feedback on this report if you have any comment. I am available by email at vincent.gadanho@estaca.eu. I did my best to explain what I understood and to use a comprehensible English vocabulary, but some improvements can certainly be made.

Acknowledgments The Solinas team would like to gratify all the people who made this adventure possible. We are thinking to our school ESTACA which supports our organization ESTACA Space Odyssey (ESO), Planète Sciences which follows the projects and organizes the C'Space and the CNES which funds this event.

We also want to thank ESTACA Space Odyssey for their help, advise, and the materials lent. In particular, we want to thank :

- Clément Rousseau who gave us extremely precious advise in all the electronic fields ;
- Jean-Loup Gaté and Tom Bozonnet, members of the bureau of ESO, which gave us very good advise when critical choices has to be made. Moreover, we want to gratify Tom Bozonnet who built our parachute alone and helped us on the final assembly ;
- The former members Alexandre Simon and Armelle Frenea-Schmidt for their advice ;
- Rémi Claudel to give us a model of the launch chronology ;
- Robin Piebac to help us on the final rocket assembly ;
- Mr Faux who milled our aluminium rings ;
- David Tessier to lead us with his car when we needed to buy parts.

Personally, I would like to thank my family who gives financial help and encouraged me in my projects.

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Part I
Introduction

ESTACA is one of the leading french engineering school in the field of transport. It belongs to the ISAE group which includes ISAE Supaéro, ENSMA and Ecole de l'Air. The school is present in Saint-Quentin-en-Yvelines (78) and in Laval (53). The formation is generalist and a specialization is selected in the Space, Aeronautics, Cars or Guided transport domain.

Figure 1: ESTACA in Saint-Quentin-en-Yvelines (left) and in Laval (right)

ESTACA Space Odyssey (ESO) is an aerospace organization belonging to the school ESTACA. It was created 25 years ago and focused on more than hundred projects. In 2016/2017, more than 100 members took part of 14 various projects in this organization. The different teams worked for example on experimental rockets, a stratospheric balloon, a water rocket, an hybrid propeller or a multi-stage rocket.

Figure 2: ESTACA Space Odyssey Logo

The Solinas project is one of these projects. It was led by a team of 12 students, in parallel of the ESTACA curriculum. The goal of this experimental rocket was to find a method to measure the velocity of the rocket on-board. A way to succeed is to take pressure measurements with a Pitot tube and determine the velocity with some formulas. That is what we decided to implement.

Figure 3: Experimental rocket Solinas

Firstly, some of the main specifications to create an experimental rocket will be developed. It is important to take this part into account before beginning an experimental project, and to keep it in mind all the project along. Then, all the domains present in the Solinas project are presented : the Mechanics, the Experiment and the Safety fields. The power supply used for the rocket will also be described, as how the C'Space event happened. Finally, a part on the Team and Project management is written. I shared how I felt to lead such a project. The last part is the members feedback. 9 over 11 members accepted to explain how they lived the project.

Part II
Main experimental rocket specifications

1 Book of specifications for Single Stage Experimental Rockets

Before beginning a project of an experimental rocket, it is extremely important to keep in mind the specifications for such a rocket. All these specifications are written in the document “Book of specifications for a Single Stage Experimental Rockets” on the Planètes Sciences website <http://www.planete-sciences.org/espace/publications/techniques/cahier_des_charges_fusex_english.pdf>.

2 The experiment

Creating an experimental rocket can only be justified if you have an interesting experiment to propose. Otherwise, you will be encouraged to build a mini-rocket which has not the same book of specifications.

According to the “Book of specifications for a Single Stage Experimental Rockets” :

- The experiment consists of analyzing a physical phenomenon.
- Measurement is the means of characterizing this phenomenon. Measurement is not the goal of the experiment.

The use of telemetry is not an experiment, it is just a way to save the data of the experiment.

Before proposing a project of an experimental rocket, I advise to inquire about the previous experiments of experimental rockets. They can be found on the Planètes Sciences website. Most of all, it is important to discuss with the bureau and the experimented members of the organization, to know if our experiment is achievable. For example, the first Solinas project was refused because we did not have a relevant experiment. We needed to review our specifications and included a Pitot velocity measurement experiment.

3 Specifications example : the mechanical structure

Particularly, the camber [flèche] of the rocket was one of the biggest problem we faced in the Solinas project. The figure 4 is an extract of the book of specifications where are described the values which has to be respected.

MEC1 : The club must draw up mechanical plans for all of the parts as well as their integration.

MEC2 : Camber< 1 % (10 mm/m)

MEC3 : Resistance to compression:
Each part of the rocket must be able to bear a force of compression F=2 x *Max Acceleration* x *Msup*. *Msup* is the weight of the upper part.

(numerically acceleration is expressed in m/s ^{2} and weight in kg to give a strength F expressed in Newton).

MEC4 : Longitudinal fins resistance:
The fins must be able to bear a longitudinal force of :
F = 2 x *fin weight* x *Max Acceleration*
(numerically the mass in kg and the acceleration in m/s^2 gives F in Newton)

MEC5 : Transverse resistance of fins:
A force F = 0.104 x *fin surface* x *Vmax*^{2} (in Newton) may lead to a transverse fins camber which is lower than 10°. (the surface in m^2 and the speed in m/s).

MEC6 : Fin alignments< 1°

MEC7 : Angle between two consecutive fins : 90° ± 10°

MEC8 : Fins or the fastening of fins made from composite materials are forbidden for rockets going faster than Mach 0.8 . The sole exception would be a supporting document from the club agreed by PLANETE SCIENCES(cf dispensations).

Figure 4: Experimental rocket mechanical specifications

4 Stabtraj : stability of the rocket, fins dimensions and canvas surface

At the beginning of the project, the team has to decide which features in terms of height and diameter are necessary to achieve the experiment. Thanks to this main features, it is possible to determine other important features with an excel document provided by the CNES : Stabtraj.

The excel file Stabtraj is composed of several windows. The main windows are Stabilito and Trajecto. Stabilito enables to determine the features of the fins (ailerons) to have a stable rocket. Without a stable rocket, it is impossible to launch the rocket because it could have a dangerous trajectory.

When the position of the mass center and the weight of the rocket are known, Trajecto enables to determine the surface of the parachute needed. Indeed, when the rocket falls, a maximum value of velocity must not be overtaken. Trajecto gives the surface of the parachute canvas [toile] to achieve this regulation.

Part III
Experimental rocket Solinas

1 Team presentation

The Solinas team was composed of 12 persons :

- GADANHO Vincent, Manager, 2^{nd} year eng. cycle, 2^{nd} year at ESO ;
- GRANDIN Tiphaine, 2^{nd} year eng. cycle, 2^{nd} year at ESO ;
- SOUPRAMAYEN Thomas, 2^{nd} year eng. cycle, 2^{nd} year at ESO ;
- BONIT Thibaut, 2^{nd} year eng. cycle, 1^{st} year at ESO ;
- GUEGAN Erwan, 2^{nd} year eng. cycle, 1^{st} year at ESO ;
- PANORYIA Ariane, 2^{nd} year eng. cycle, 1^{st} year at ESO ;
- ROIG Anton, 2^{nd} year eng. cycle, 2^{nd} year at ESO ;
- RIDEY Romain, 2^{nd} year eng. cycle, 2^{nd} year at ESO ;
- DE MERTIAN Tanguy, 1^{st} year eng. cycle, 1^{st} year at ESO ;
- HURST Benjamin, 1^{st} year eng. cycle, 1^{st} year at ESO ;
- BENZAARI Michael, 1^{st} year eng. cycle, 1^{st} year at ESO ;
- MORACHE Clara, 2^{nd} year eng. cycle, 1^{st} year at ESO (only the first semester of the year) ;

It was the first experimental rocket project for everybody. Only few of us worked the previous year on a mini-rocket, but there was no experiment on board and we only learned the steps to build a rocket. Thus, it has been a real challenge for all of us to lead this wonderful project, but we all learned a lot.

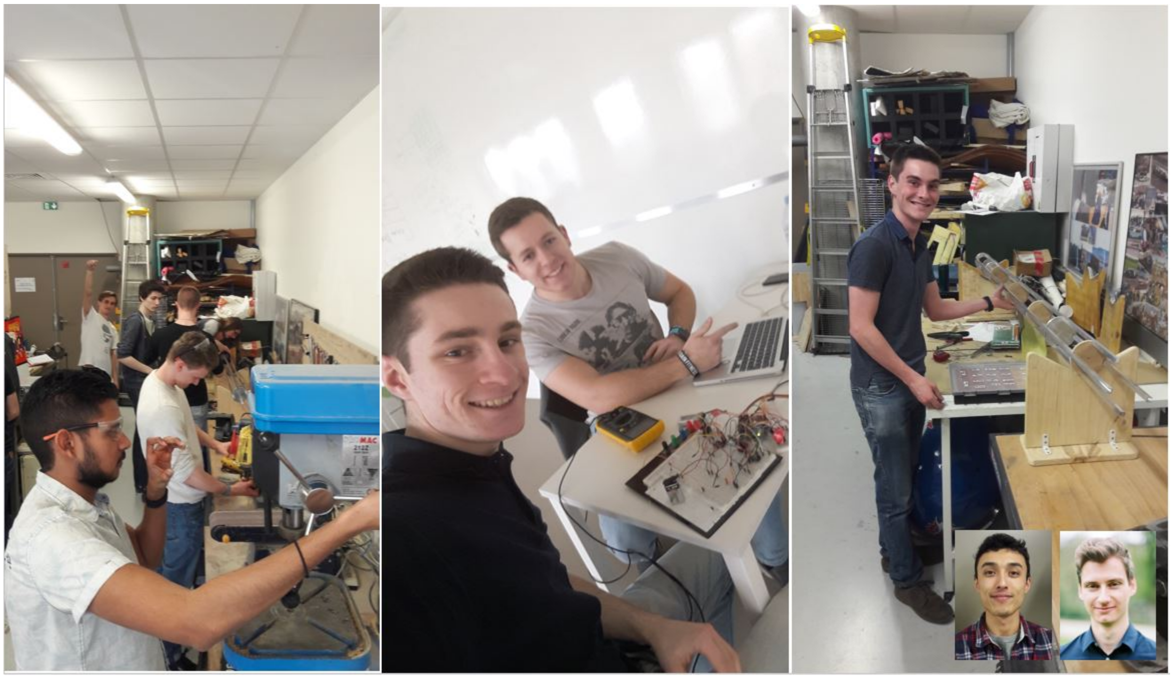


Figure 5: Solinas team

2 Solinas rocket features

For our experiment (measurement of the velocity with telemetry and ejection of a Cansat) we decided to build a rocket with a height of about 2 meters, a diameter of 100mm and a weight of 7kg without propeller.

Finally, the features were as follows :

- a total mass of 9.6kg;
- a height of 2160mm;
- a diameter of 100mm;
- a fairing of 200mm high;
- 4 fins [ailerons] with a root [emplanture] of 430mm, a tip [saumon] of 350mm, a camber [flèche] of 160mm and a span [envergure] of 127mm;

- a budget of 900 euros (700 euros for the rocket and 200 euros for the Cansat Swarog)

For more details, final Stabilito and Trajecto can be found page 125 and 126 in appendix of this report.

Figure 6: Solinas final assembly

Part IV
Mechanics

1 Steps to build a rocket

The mechanical part of a rocket is extremely important as the rocket will be hardly strained during its launch. It will be a deciding factor if the rocket will be launched at the C'Space.

Moreover, the inside of the rocket needs to be well-organized to place all the components. For example, electronic cards could be damaged if they are too close or not well attached.

All the steps described in the next sections has to be respected in sequence to build a strong and well-organized mechanics.

1.1 First step : knowing all the elements in the rocket

The first step before defining an architecture is to know all the components which will be necessary to achieve the experiment. The intuitive behavior is to begin the Computer-Aided Design (CAD) very soon but it will change if you add other components.

A good way to succeed would be to list all the components and then discuss with someone experimented to know if you do not forget anything.

1.2 Create the rocket architecture

1.2.1 Rocket basic structures

Two mainly structures are used in the field of experimental rockets. Either the a rocket is based on an internal structure, or it is based on a skin structure.

For an internal structure, the rocket is composed of long metal profiles. These profiles are linked to few structural rings. The advantage of this configuration is that the integration of the components is easier than for a skin structure. Moreover it is more convenient to change the place of the components in the rocket and easy to access. But the metal profiles must be extremely rigid to avoid a camber of the structure. The impact is a high increase of the weight of the rocket and the degradation of flight performances.

Personally, I have found another drawback for this structure that we used for Solinas. It is not convenient when all the team works in the same time on the rocket . If someone needs to drill a ring in the middle of the structure, the whole team has to come with him next to the drilling machine. It is not possible to get the ring out of the structure without taking all the other rings away.

Figure 7: Solinas internal structure

For a skin structure, the solidity of the rocket depends on the skins which avoid the use of metal profiles. The gain of weight is huge and even better if carbon fiber is used to build the skins. As I described previously, it is necessary to take the skins off to integrate the components between the rings. Thus, the integration is only possible with a disassembled rocket as the structure depends on the skins.

Figure 8: Panoramix mini rocket based on skin structure (built by some Solinas members in 2015/2016)

A lot of people like using an internal structure, but I strongly advise not to use this structure. Using such a structure should be only be accepted if the team has made solidity studies. It is important to take into account the material of the profiles, the distribution of the weight in the rocket and the length of each stage to know how much the structure will bend. It is not imaginable to wait C'Space acceptance in July to know if the rocket can fly !

1.2.2 Definition of the structure

The definition of a structure can be made as follows :

- choosing one of the two common rocket architectures : a rocket with an internal structure or a skin based structure;
- defining the position of the components in the rocket and the number of stages (Experiment, Electronics, Telemetry, Parachute...);

- defining the dimensions of the stages;
- drawing the rocket on a paper like in the Figure 9.

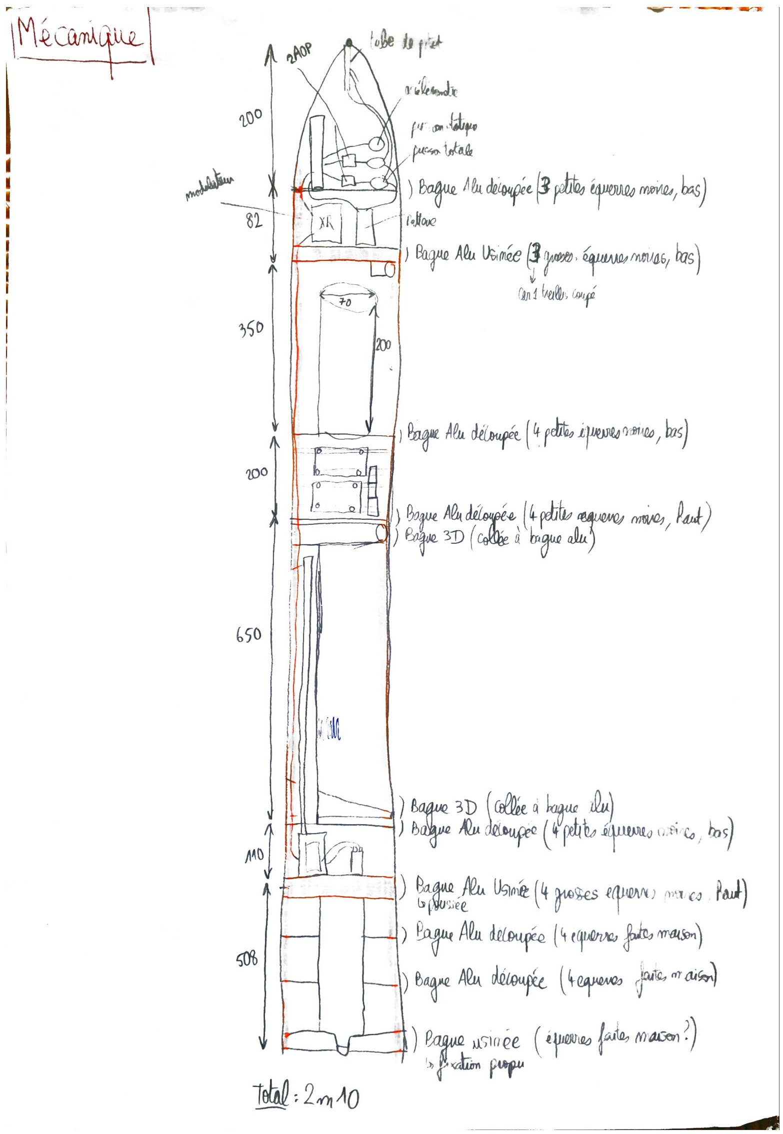


Figure 9: Solinas drawing

Just after all these steps, it is possible to begin the CAD.

1.2.3 Computer-Aided Design

The accuracy of the CAD model will have a huge impact on the evolution of the project. If all the components find their place very well in the CAD, it will be easier to integrate them during the final assembly. Problems will also be easier to solve in the CAD than in reality.

For example placing the screws on the CAD can make realize that you put too much drills in the rocket. If you do not do this, you will not be able to correct it without changing all the structure. Another example is if you do not detail how to hold a component in your rocket. Maybe you will have to use a place-consuming system to fix the component. If you do not anticipate that, you will have to put components in the stage behind. But if the stage behind is already busy, it will be necessary to move all the stages.

To conclude, a well-organized CAD rocket will help to save a lot of time during the final assembly. Building an experimental rocket is so complex that it is not possible to anticipate all the possible problems !

1.2.4 Final assembly

The final assembly can begin when the mechanical parts has been built (aluminium rings, carbon skins...). When the structure is totally assembled, then it is possible to begin the integration of electronic cards.

The final assembly session has to be lived to understand how much time it takes to assembled all the rocket. The Solinas team always met problems during this stage. We arrived at the C'Space with some progress in Mechanics but it was not possible for us to finish it in 5 days (from the early morning to the evening) with 6 persons. It is really time-consuming to change parts, take screws off, drill, and so on.

2 Solinas Mechanics

2.1 Common experimental rocket architecture

At the beginning of the year, it was decided by the ESO organization to create a common architecture for all the experimental rockets. Among others, the rocket had to have the same metal profiles.

The members voted and two profiles get out of this vote : U aluminium profiles (Figure 10) and empty square aluminium profiles (Figure 11). The one which was selected was the U profile because it was much softer than the square one. However, the square profile was much stronger.

Figure 10: U aluminium profile

Figure 11: Empty square aluminium profile

I voted for the square profile because I knew that an important feature would be the mechanical rigidity of the rocket. However I should have taken my responsibilities and not have respected the vote. As a manager, I made my biggest mistake at this moment which probably costed the launch of our rocket.

The manager knows better than anyone what will be inside the rocket. That is also why it is important to have an experimented and multi-skilled manager, to be able to take such a determinant decision. The project is the responsibility of the manager.

Figure 12: Structure prototypes with U and square profiles

After the selection of the U profiles, the next step to create a common architecture was to create the same CAD. The CAD team of Solinas had to work with the CAD team of the experimental rocket Aeris, but it was not efficient at all. They had not the same availabilities as us, not the same number of stages and not the same way to work. I decided to stop the collaboration in November. The Solinas team only kept the architecture of the 3D printed rings, which we finally did not use at the end of the project.

To summarize, I advise not to take a common architecture. It adds a lot of problems and the manager has to be very experimented for this type of situation. Moreover, it is easier for a team to create its own CAD from the beginning without taking parts from other teams.

2.2 General description

The Solinas rocket was composed of 7 stages (Figure 13). From the top to the bottom, the stages were :

- the “Experiment stage” in the fairing with the Pitot tube, the two pressure sensors, the two amplification cards and the Arduino microcontroller ;

- the “Modulator stage” with the modulator, the regulation voltage card for the modulator, 2 batteries of 9V for the modulator, 1 LIPO battery, the switchers and LED for the Arduino and the modulator);
- the “Cansat stage” ;
- the “Analog timers stage” with 2 analog timers, 2 batteries of 9V, 4 batteries of 1.5V, the switchers, and the LED ;
- the “Parachute stage” ;
- the “Kiwi transmitter stage” ;
- the “Propeller stage”.

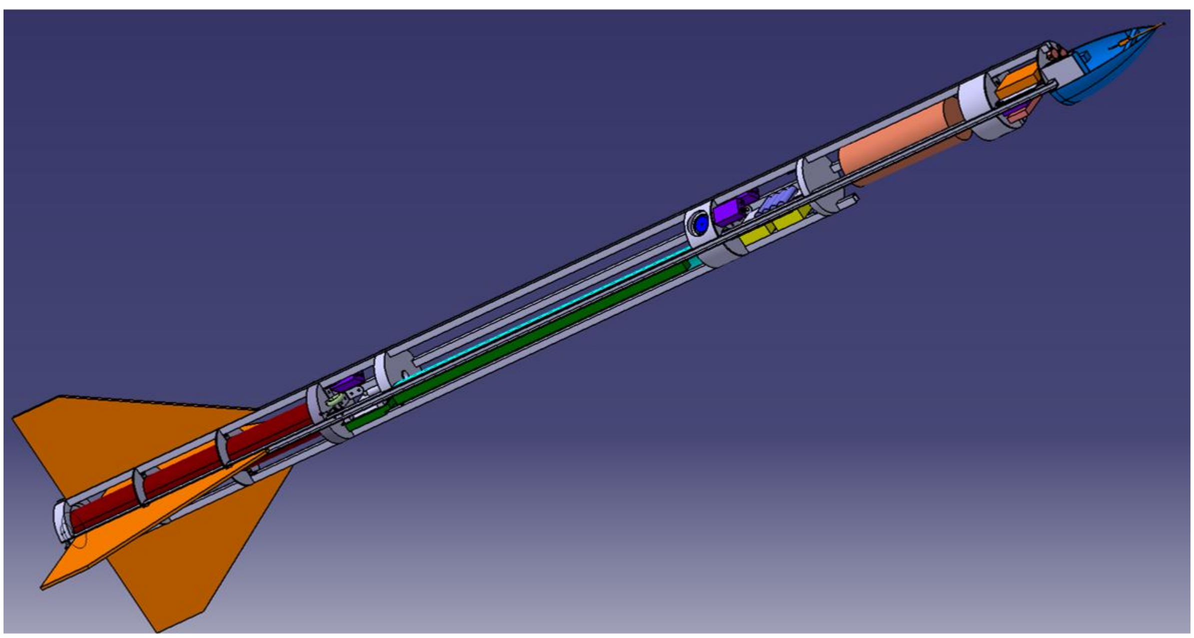


Figure 13: Experimental rocket Solinas without skins on CATIA

Each stage was separated by rings : five aluminium rings (including two aluminium rings to center the propeller), three wood rings and three 3D printed rings.

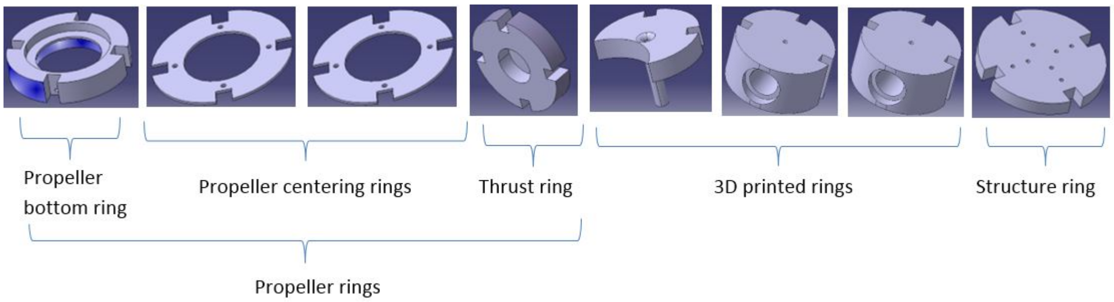


Figure 14: Aluminium and 3D printed rings on CAD

2.3 Solinas CAD

The Computer-Aided Design was made with the CATIA software from October to January 2017. We fixed the final architecture late because it took time to find the best way to achieve our experiment, and all the components needed.

In January 2017, I made the decision to stop the CAD and begin to build the parts, even if our CAD was not finished. A perfect CAD is necessary to avoid assembly problems, but if we finish it too late and we do not have time to build the parts, it is worth. For example, the dimensions of the rings has to be fixed very soon to begin the milling [usinage], which takes a lot of time at ESTACA.

Here are the different CAD stages of Solinas. As I explained before, they do not represent the final assembly. In particular, we did not take into account the size of the amplification cards in the fairing (Figure 15). We also did not anticipate the fact that switchers, electronic cards with LED and a regulation voltage card would be necessary. Consequently, the "Experiment stage" and the "Modulator stage" were very stuffed for the final assembly (Figure 19). We should have let more space.

Moreover, we did not design the fixations. We had to make "Do It yourself" fixations during the assembly and fix everything as best as we could.

One aluminium profile had to be cut for the ejection of the Cansat, as we can see in the middle of the Figure 16 .

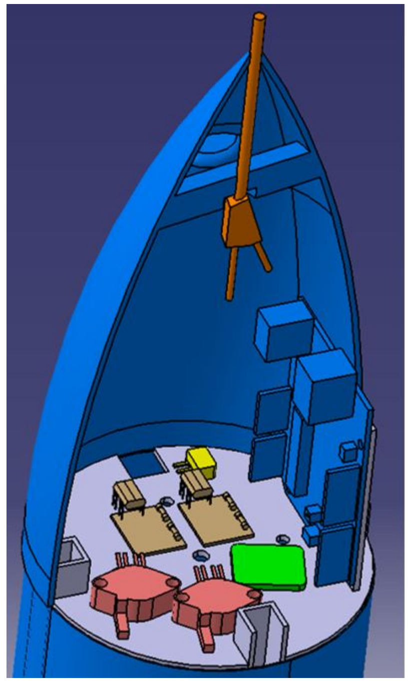


Figure 15: “Experiment stage”

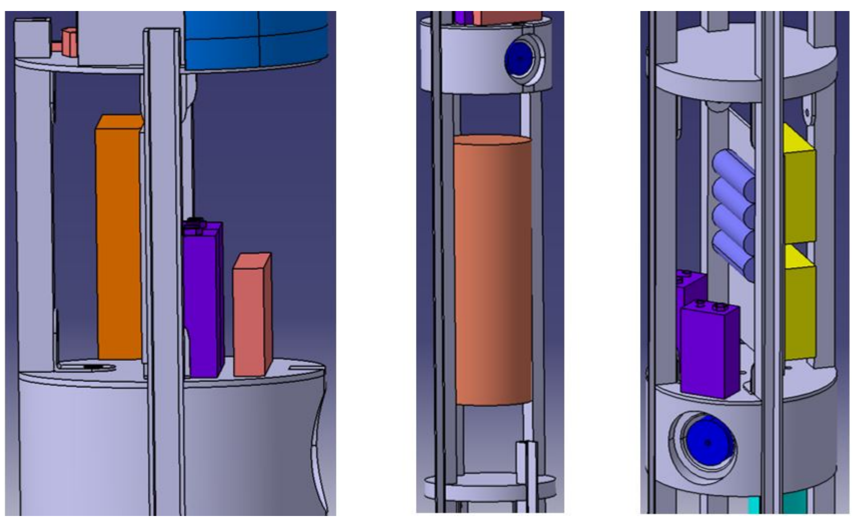


Figure 16: “Modulator stage” (left), “Cansat stage” (middle), “Analog timers stage” (right)

The length of the transmitter's antenna was a problem. It was about 50cm long and needed to be isolated from the electronic cards. Moreover, it was impossible to put it in the fairing because this place was reserved for the Pitot tube. The only solution we found was to separate the "parachute stage" into two compartments : one for the parachute and one for the antenna (Figure 17).

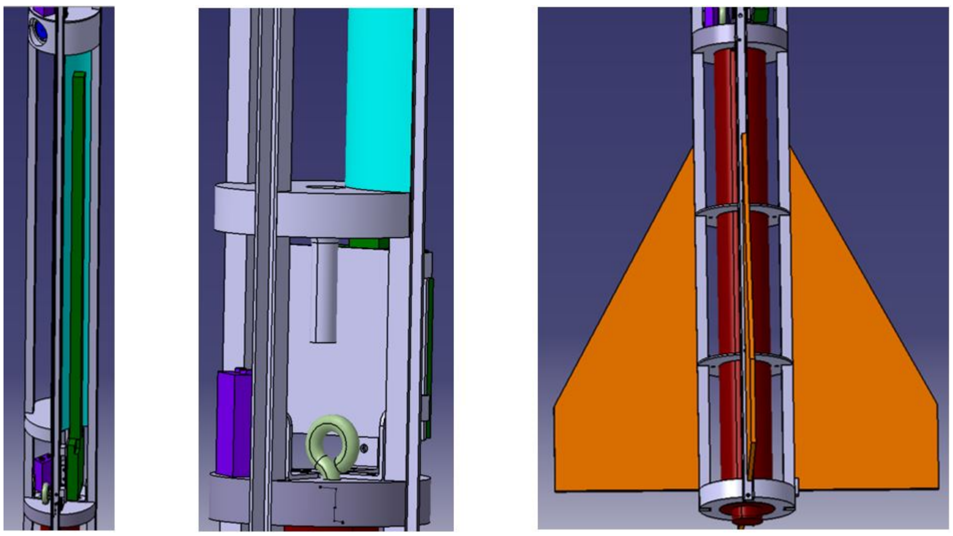


Figure 17: "Parachute stage" (left), "Kiwi transmitter stage" (middle), "Propeller stage" (right)

2.4 Solinas final assembly

2.4.1 Before the C'Space

Before going to the C'Space, the final rocket was assembled with all the rings and all the skins as on the Figure 18. But the doors were not made and no electronic cards was integrated in the rocket. The remaining work was huge. But only one member was available to work on the rocket from May to July, in parallel with his internship.

2.4.2 At the C'Space

The final assembly was made at the C'Space. It took us one week to assembled everything as it is described in the next part "C'Space". We can

Figure 18: Final assembly before the C'Space

easily see the importance of the CAD. Indeed, if we compare the "Experiment stage" and the "Modulator stage" on the Figure 15, 16 and 19, we see that the place available is not the same. Our CAD did not take all the components into account.

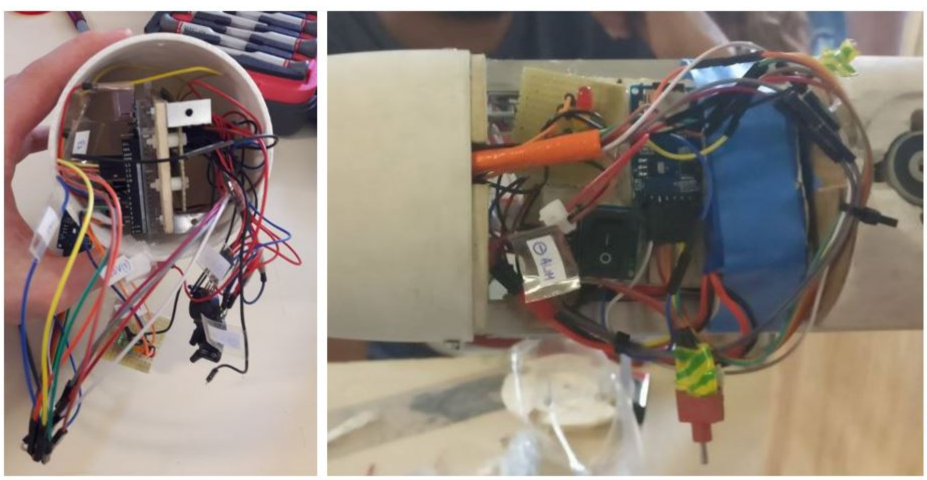


Figure 19: Final "Experiment stage" (left) and "Modulator stage" (right)

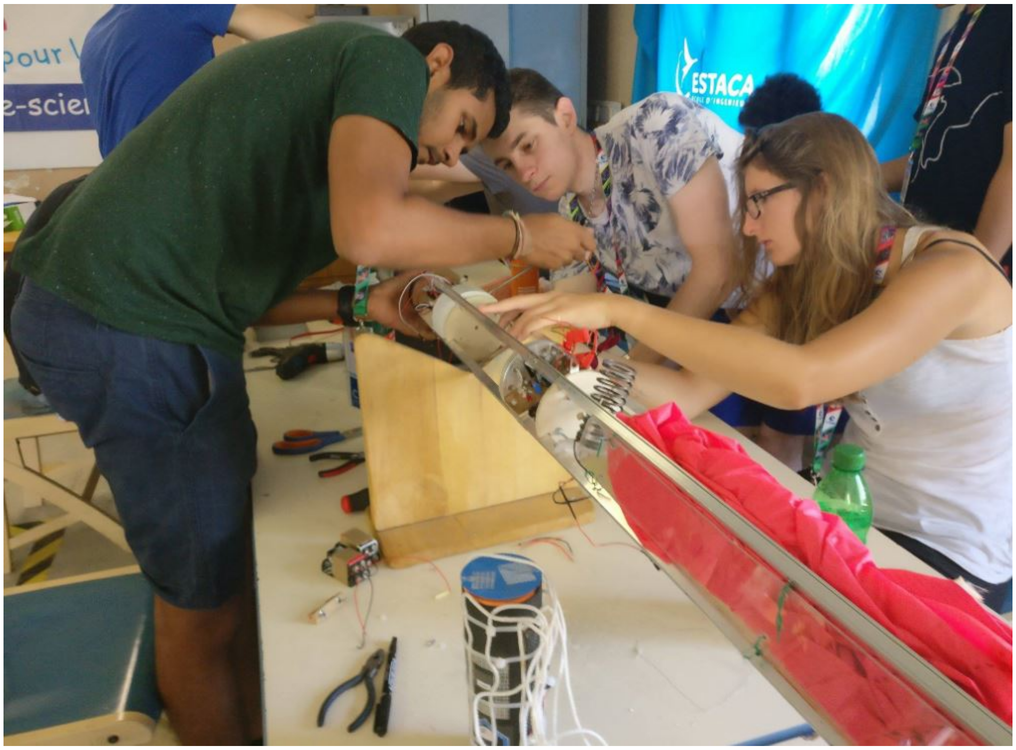


Figure 20: Final assembly at C'Space

Part V

Experiment

1 Goal and formula

The main experiment was to measure the velocity of the rocket during the launch. To succeed, we used two pressure sensors to calculate the absolute pressure and the static pressure. With these two pressures, we determined the velocity with a microcontroller thanks to a formula. The goal was to save the data on a micro-SD card and send it by telemetry.

For Mach < 0.3, air is incompressible and $v^2 = \frac{2\times(p_t - p_s)}{\rho}$.

For Mach > 0.3, air is compressible and $\frac{p_t}{p_s} = (1 + \frac{\gamma - 1}{2} \times M^2)^{\frac{\gamma}{\gamma - 1}}$. Thus,

$v = \sqrt{((\frac{p_t}{p_s})^{\frac{\gamma-1}{\gamma}} - 1) \times \frac{2 \times a^2}{\gamma - 1}}$.

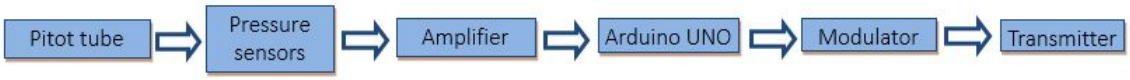


Figure 21: Measurement chain

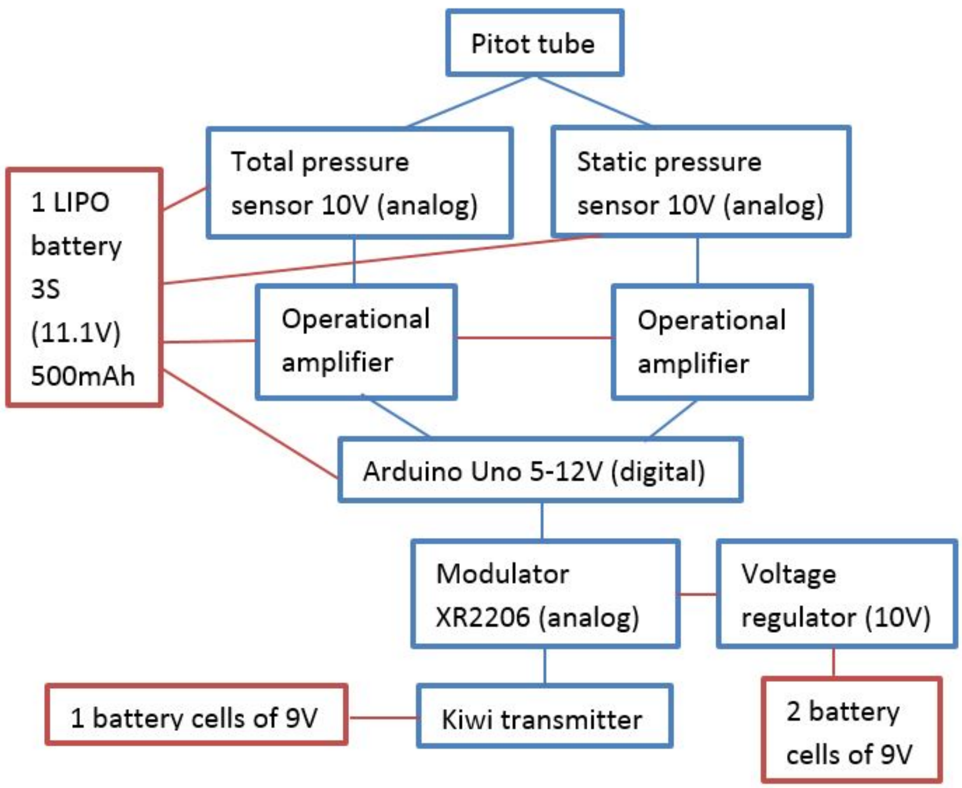


Figure 22: Experiment architecture

2 Pitot tube

A Pitot tube is composed of two different inputs, as described on the figure 23. It is possible to measure two pressures at the output : a total and a static pressure.

The first input is perpendicular to the air flow and gives a static pressure.

The second one is coaxial to the air flow and gives a dynamic pressure. This dynamic pressure is combined with the static pressure to give a total pressure.

Be careful, the static input must be in the air flow. In the Solinas project, we designed the fairing in order to have the static input in the fairing. It was not right and we had to make some modifications during the C'Space. The static input has to be outside of the fairing.

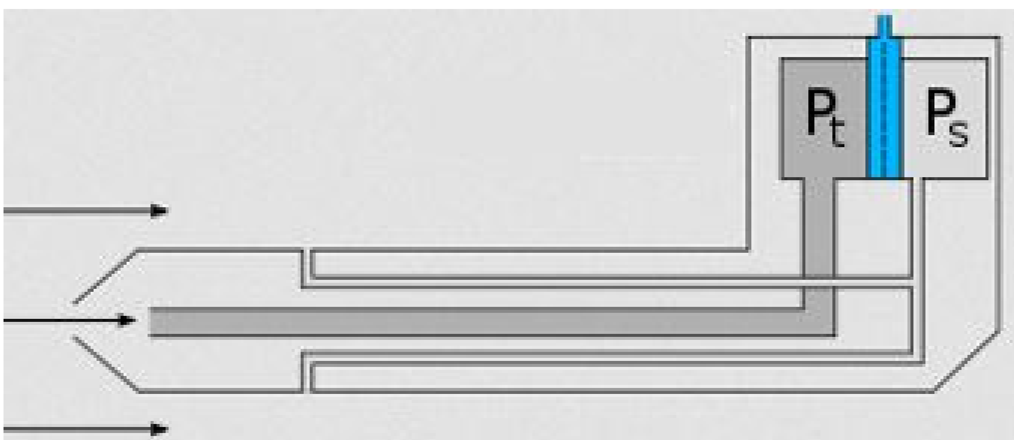


Figure 23: Pitot tube schema

The Solinas Pitot tube was bought on Aliexpress website for about 7 euros (Figure 24). It measured about 10cm high, it was light and looked strong.

Another solution would have been to create our own Pitot tube but we did not choose this option because of a lack of time. Documents can be found on the internet or on previous project to describe how to design your own Pitot tube.

Figure 24: Solinas Pitot tube

3 Sensors

3.1 Pressures definition

In our experiment, we were eager to measure the total and the static pressures. Thanks these two pressures, we will be able to determine the velocity, as we saw previously.

The total pressure P_t is the sum of the static pressure P_s and the dynamic pressure P_d.

$$P_t = P_s + P_d$$

The dynamic pressure P_d appears when the object is in movement. It depends on the velocity V and the air density ρ [masse volumique de l'air] :

$$P_d = \frac{1}{2} \times \rho \times V^2$$

The static pressure P_s is the pressure measured by a motionless sensor. Its value is about 1 bar in the atmosphere and is divided by 2 every 5km.

3.2 Pressure sensor operating

A pressure sensor is composed of a deformation gauge. When a pressure is applied on this gauge, it creates a define electrical resistance which can be measured. This resistance corresponds to a voltage, which depends on the value of the pressure.

Thus, the input of this sensor is a pressure and the output is a voltage. Thanks to the datasheet of the sensor we can measure the voltage and infer which pressure is applied on the sensor.

3.3 Pressure sensors selected : MPX2200AP

Two absolute pressure sensors MPX2200AP were used to achieve the experiment. Each one was linked to an output of the Pitot tube thanks to a pipe. The goal was to respectively measure the total pressure and the static pressure. They costed about 7 euros per unit on Radiospares website.

The sensor is composed of two pins to be supplied by an electrical power and two pins to measure the voltage (Figure 25).

Its supply power is 10 V in continuous current. The sensor can measure a pressure between 0 and 2 bars. That is a good range for our experiment as the static pressure will decrease from 1 to 0.7 bar and the total pressure will increase from 1 to maximum 1.5 bars (values calculated with the formulas given previously).

The output voltage of the sensor is included between 0mV and 40mV. According to the datasheet page 101 in appendix, 0mV corresponds to 0bar and 40mV corresponds to 2bars. The evolution of the pressure in function of the voltage is linear.

Figure 25: Pressure sensor MPX2200AP

4 Signal amplification

The voltages at the output of the sensors are in millivolts and have to be linked to the Arduino. However, the Arduino uses voltage with an order of magnitude of volts. Thus, to be read by the Arduino, the voltages have to be amplified with an electronic card.

4.1 Operating

A safe amplification of one voltage is made with three operational amplifiers [Figure 26].

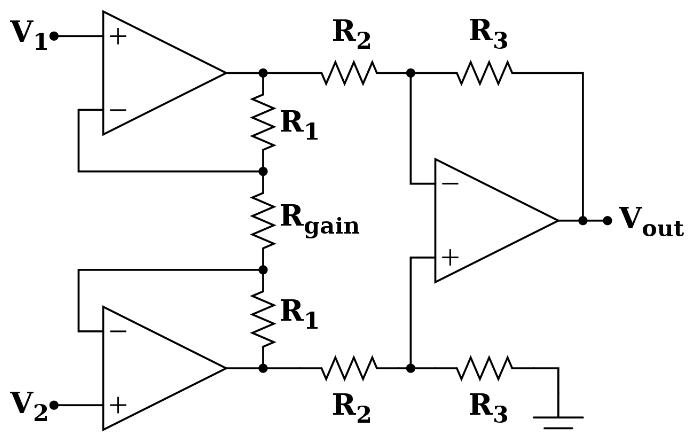


Figure 26: Amplification circuit

The two one on the left of the figure 26 protect the sensor if the values of the resistances are too small. Indeed, for the same value of voltage at the input, if the value of the electrical resistance is too small, the value of the current will be high and it could damage the sensor. These two amplifiers are named "voltage followers" [suiveurs]. We recognize them because their output is linked to their negative input.

The third operational amplifier on the right of the figure 26 is the one which amplify the voltage. It follows the following equation :

$$\frac{V_{out}}{V_2 - V_1} = (1 + \frac{2 \times R_1}{R_{gain}}) \times \frac{R_3}{R_2}$$

V_{out} corresponds to the value of the amplified voltage. $V_2 - V_1$ is the value of the voltage measured on the pressure sensor. We can infer that the value of the electrical resistance can easily be tuned to have the wished output voltage.

I advise to add a potentiometer (variable resistance) in serie with the resistance R_{gain} to adjust very precisely the value of the amplified voltage V_{out}. It enables to correct the uncertainty error between identical resistances. This point is really important. For example in our project, as we had two sensors and two amplification circuits, the two amplification cards needed to have the same amplification coefficient. Otherwise the voltage read by the Arduino would have been wrong.

4.2 Achievement

This kind of amplification can be achieved with a LM324AN component. This component has four operational amplifiers inside. In our case, three amplifiers over four were necessary for one sensor.

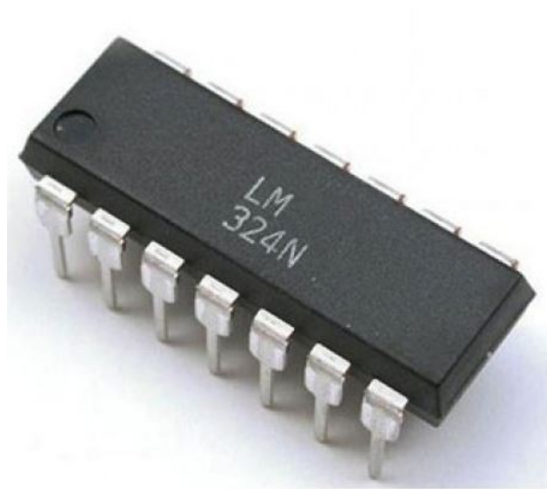


Figure 27: LM324AN component

The LM324AN component needs to be power supplied. To amplify a voltage, the power supply needs to be higher than the amplified voltage. LM324N can be supplied by a voltage of maximum 32V. In our case, a voltage of 11.1V was used.

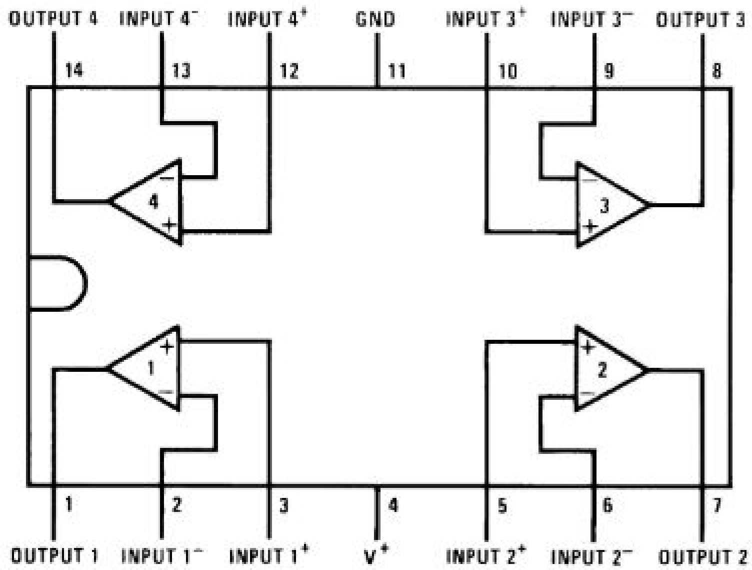


Figure 28: LM324AN schema

The final circuit is a combination of the circuits of the Figure 26 and the Figure 28. The inputs are the voltages of the sensors and the outputs are the voltages amplified.

The two amplification cards were soldered [soudées] on a Printed Circuit Board (PCB) [circuit imprimé]. A printed circuit was not created with the Proteus software as we did for the analog timer and the modulator because of a lack of time.

4.3 Electronic advice

When you solder a component, you firstly have to heat with the soldering iron the part of the board where you will put the tin [étain] droplet and the pin which will be soldered. As soon as it is heat enough, you will be able to create a tin droplet when you will touch the board with your tin wire. Melting the tin on your soldering iron is not a good way to solder.

If you want to create a line of solder, sometimes it is easier and faster to solder the two edge of a metal bar (a pin of a resistance for example).

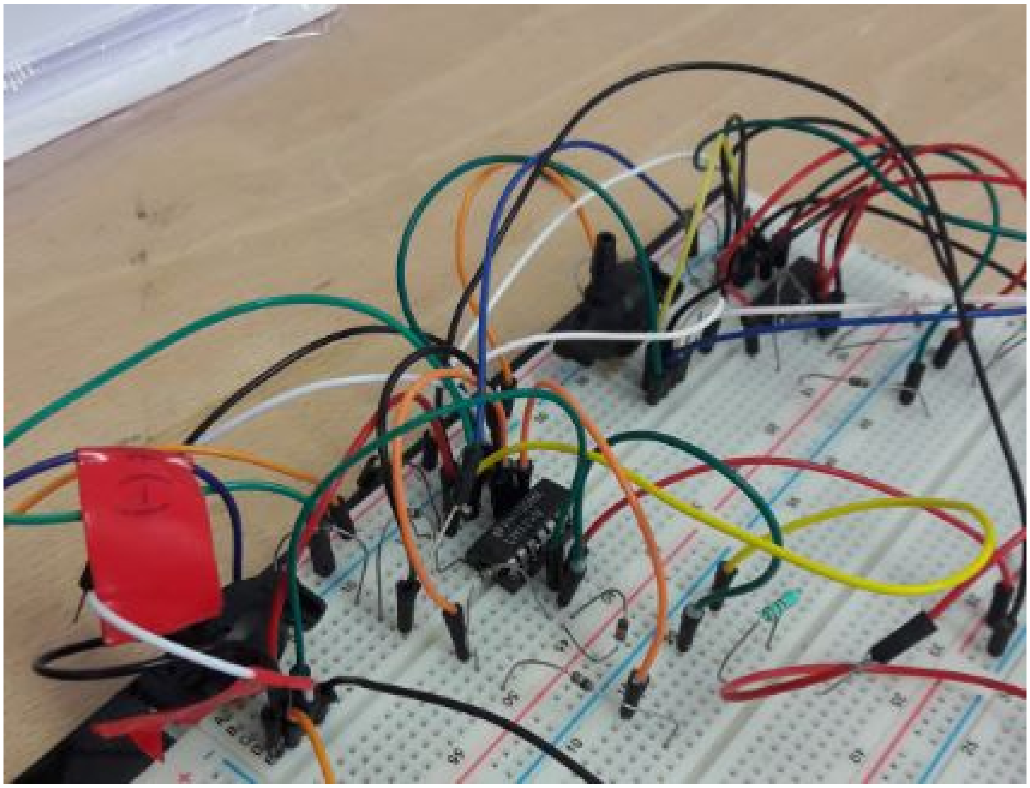


Figure 29: Amplification circuit on breadbord with sensors

Solders on an electronic card are extremely important. The lack of experience in soldering led us to plenty of problems during all the year. Just the fact of moving an electronic card can destroy a solder. Then, it is hard to understand why the card does not work anymore.

Using a breadboard can create contact failures between components. Soldering your final card avoids a lot of problems.

5 Microcontroller Arduino

5.1 General microcontrollers description

5.1.1 Microcontrollers introduction

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system.

A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip. The processor executes the program written by the user. Memory enables to save the program and to make operations when the program is running. Finally, the microcontroller uses I/O peripherals to read sensors voltage (analog or digital) and activate actuators.

5.1.2 Microcontroller Arduino description

Different kind of Arduino microcontrollers can be found on the market. I would say that there are three very famous Arduino microcontrollers :

- The Arduino Nano has small dimensions. Particularly, it is convenient when you have not a lot of place. It is really common to find this one in Cansat projects.

- The Arduino Uno is the most typical Arduino microcontroller. It has about the same performances as the Nano.

- the Arduino Mega is used when a lot of input/output pins are necessary. It has 54 digital pins and 15 analog pins (against 14 digital pins and 6 analog pins for the Nano and Uno). It is really useful when you use a lot of sensors and shields. Moreover the Random Access Memory (RAM) and the flash memory are much larger in an Arduino Mega than another Arduino. It is convenient when you make a lot of operations and you need many libraries. In our Arduino Uno, we had a lack of memory and we were not able to add an accelerometer. The libraries of the accelerometer was taking too much space. Moreover, it is impossible to create arrays with a big number of columns.

5.1.3 Arduino program description

An Arduino program is composed of four main parts.

The first part has no defined name, it is where all parameters which will be used in the program are defined. The libraries which will be necessary to use some added shields are also imported here (for example an micro-SD card shield in our program).

The second part is named the "setup" part. It begins with "void setup()". The code is written between the two curly brackets "". In this part, you will initialize all the pins that will be used and define if the signal will go in or go out of the microcontroller.

The third part is named the "loop" part. The code in this part will be executed in loop. It is the main part of the code, all the calculations and algorithm are here.

The last part is composed of functions which will be created to execute your experiment. It enables to reduce the weight of the "loop part" as this function will be called in the previous part. A function can be defined in writing "void function Name()".

5.2 Solinas Arduino configuration

5.2.1 The shields used

An Arduino Uno was used for the Solinas project (Figure 30). Shields were bought to achieve our experiment : a shield for SD card (Figure 31) and one switcher (Figure 32). We also created an electronic card with LED to show to the user the state of the program when the Arduino is running.

As soon as a file was created on the micro SD card and the Arduino program was ready to write on the micro SD-card, an orange LED lightened. When the user put the switcher on, the green LED lightened. It meant the program was writing on the SD-card. Finally, if the red LED lightened, it meant that a problem was encountered and the program was not saving data on the micro SD card.

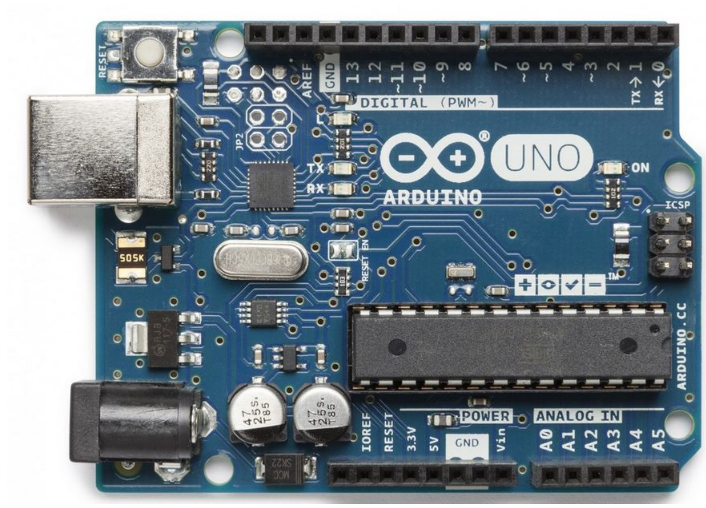


Figure 30: Arduino Uno

Figure 31: Arduino micro SD card shield

The switcher and the electronic card with LED were Thibaut BONIT's ideas and I advise to do it when a micro SD-card is used, it is really convenient. Of course, do not forget to put resistance in serial with the LED to protect them against a high value of current.

Figure 32: Arduino switcher shield

5.2.2 Micro SD shield problems

The micro SD-card shield has to be configured like the pin description in the next section. Several problems appeared in using it. The program was sometimes not able to create a file on it. In this case, I advise to proceed as follows :

- Solution 1 : get the SD card out, get in again and reset the Arduino
- Solution 2 : upload [téléverser] the program again
- Solution 3 : reformat the SD-card

Be careful when you reformat your SD card. The configuration is important to be read by the micro SD shield. I have found this following configuration which worked :

Capacity : 1,87Go
Files systems : FAT32
Size of the allowance unity : 32Ko
Volume name : Arduino

Be also careful when you write the volume name. You have to write the same one as in your Arduino program for the SD card !

5.2.3 The pins configuration

The analog pins used were as follows :

- A0 : Static pressure input
- A1 : Total pressure input
- A2 : -
- A3 : -
- A4 : -
- A5 : -

The digital pins used were as follows :

- 1 : -
- 2 : Red LED
- 3 : Orange LED
- 4 : CS for SD-card shield
- 5 : Green LED
- 6 : -
- 7 : Switcher
- 8 : -
- 9 : -
- 10 : Transmitter output
- 11 : MOSI for SD-card shield
- 12 : MISO for SD-card shield
- 13 : CLK SCK for SD-card shield

5.3 Solinas Arduino program architecture

The Solinas Arduino program can be found page 111 in appendix.

In the first part, the variables are defined and libraries are uploaded (for the SD card).

In the "setup part", the first line is "Serial.begin(9600)". This line has to be present in all the Arduino programs. Then, the SD card is initialized and a folder is created on the card. Finally, all the pins are initialized as output or input depending on what they are linked (sensors, switch, LED).

The "loop part" contains the algorithm and instructions driving peripherals.

"switcher" corresponds to the state of the switcher. While switcher is on, the loop is running. When the program runs the loop for the first time, a file is created.

After creating a file, the program uses the analog values given by the sensors and determine the corresponding value of pressure thanks to the datasheet. It is the calibration of the sensors.

Then, physical values are determined. In particular, the velocity is calculated.

Values are printed on the window with "Serial.println" commands.

Finally, velocity values will be converted into binary frames and sent to the modulator. Data will be saved on the SD-card. However it is not possible to do both at the same time for the Arduino. That is why "compteur" was created. Each loop, this value increases by one. The data are always saved on the SD card, but each 1 over 5 loop, data are also converted into binary frame and sent to the modulator.

The last part is composed of the following functions :

- SDcardWritten() : to write on the SD card;
- couleurLED() : to turn the LED on;

- convertToBinary() : to convert the value of the velocity into a binary frame;
- transmission() : to send the binary frame to the modulator.

5.4 Important advise

I would add some practical advice :

- Concerning the power supply, digital and analog ground (GND) pins has to be linked. It is the same case for other electronic cards : all the ground has to be linked to close the circuit !
- It is advised to avoid to supply an electronic circuit with the power of the Arduino. The Arduino is not made to supply.

Two Arduino microcontrollers were destroyed in the year so it is extremely important to have a minimum of two Arduino with you. During the C'Space, I had to go from Tarbes to Pau to buy another Arduino Uno. And I was lucky to find another one ! Otherwise, we should have borrowed an Arduino from another team.

I am almost sure that the microcontrollers broke themselves because of the power supply wire. The wire was damaged, the connection was sometimes bad and it created contact failures. So pay attention to the material you use with the Arduino.

I also advise to use a switcher between your battery and the Arduino (or the other electronic cards) to avoid to disconnect hundreds of times the power supply wires. It is easier, and a much safer with a switcher ! Indeed, when you make a lot of tests and you have to disconnect very soon the wires, you take risks to connect it in the wrong way. The electronic card would be short circuited and could be destroyed. This problem occurred one time for me but I disconnected the wires very fast and fortunately I had no damage. We are humans and everything has to be done to ensure that we have no way to do a mistake.

In each case, it is essential to have several copy of your electronic components. It would be a bit exaggerated but why not creating two identical cards for each electronic card that you use.

6 Telemetry and modulator

6.1 Operating

At the output of the Arduino, the digital signal has to be changed into a sinusoidal signal to be sent with the Kiwi transmitter. To keep the information transmitted by the Arduino, the signal has to be modulated. It means that one bit will correspond to one physical value of the analog signal.

Figure 33: Kiwi transmitter

Two types of modulation are commonly used in telemetry : the Frequency-Shift Keying (FSK) and the Amplitude-Shift Keying (AMD), using respectively the frequency or the amplitude.

In the Solinas project, we used the FSK modulation. One frequency F_0 corresponded to the bit 0 and another F_1 to the bit 1. Thus, the input signal was a digital one with two values of voltage, corresponding to 0 or 1, as in the Figure 34 on the left. The output signal was a sinusoidal analog signal with two frequencies, as on the Figure 34 on the right.

A way to make FSK modulation is to use the XR2206 component. This component is hard to find and I advise to buy several of it at the beginning of the project.

The next step is to define the two frequencies of the carrier signal [la porteuse]. The frequencies which will be used depends on the signal flow in bauds. But the bigger the flow will be, the smaller the range [portée] of the

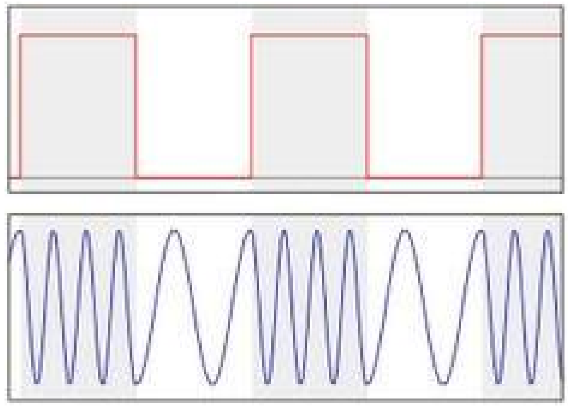


Figure 34: Modulator input signal (top) and output signal (bottom)

signal. Moreover, the signal will be less stable.

Advised by Clément Rousseau, we decided to take a signal of 4800 bauds. According to the table in the Figure 35 found on the Planète Sciences website, we can infer the frequencies which has to be used : $F_0 = 15000$Hz and $F_1 = 9000$Hz.

Débit	Fréquence "0" (0V)	Fréquence "1" (5V)	Amplitude modulation Kiwi
600 baud	1 500 Hertz	900 Hertz	0,5 Vcc
1 200 baud	2 650 Hertz	1 900 Hertz	1 Vcc
4 800 baud	15 000 Hertz	9 000 Hertz	1,5 Vcc
9 600 baud	24 000 Hertz	14 400 Hertz	2 Vcc
14 400 baud	36 000 Hertz	21 600 Hertz	2,5 Vcc

Figure 35: Frequencies for a define signal flow

6.2 Achievement

After knowing the two frequencies to use, the resistances R_1, R_2 and the capacitor C ca be selected (the Figure 36). The frequencies are defined as follows :

$$F_0 = \frac{1}{R_1 \times C} \text{ and } F_1 = \frac{1}{R_2 \times C}$$

The value of C must be between 4.7nF and 100nF. We selected a capacitor of $C = 41nF$ and resistances of $R_1 = 2710\Omega$ and $R_2 = 1626\Omega$.

In the Figure 36, the symbol of the pins 3 and 10 corresponds to a polarized capacitor.

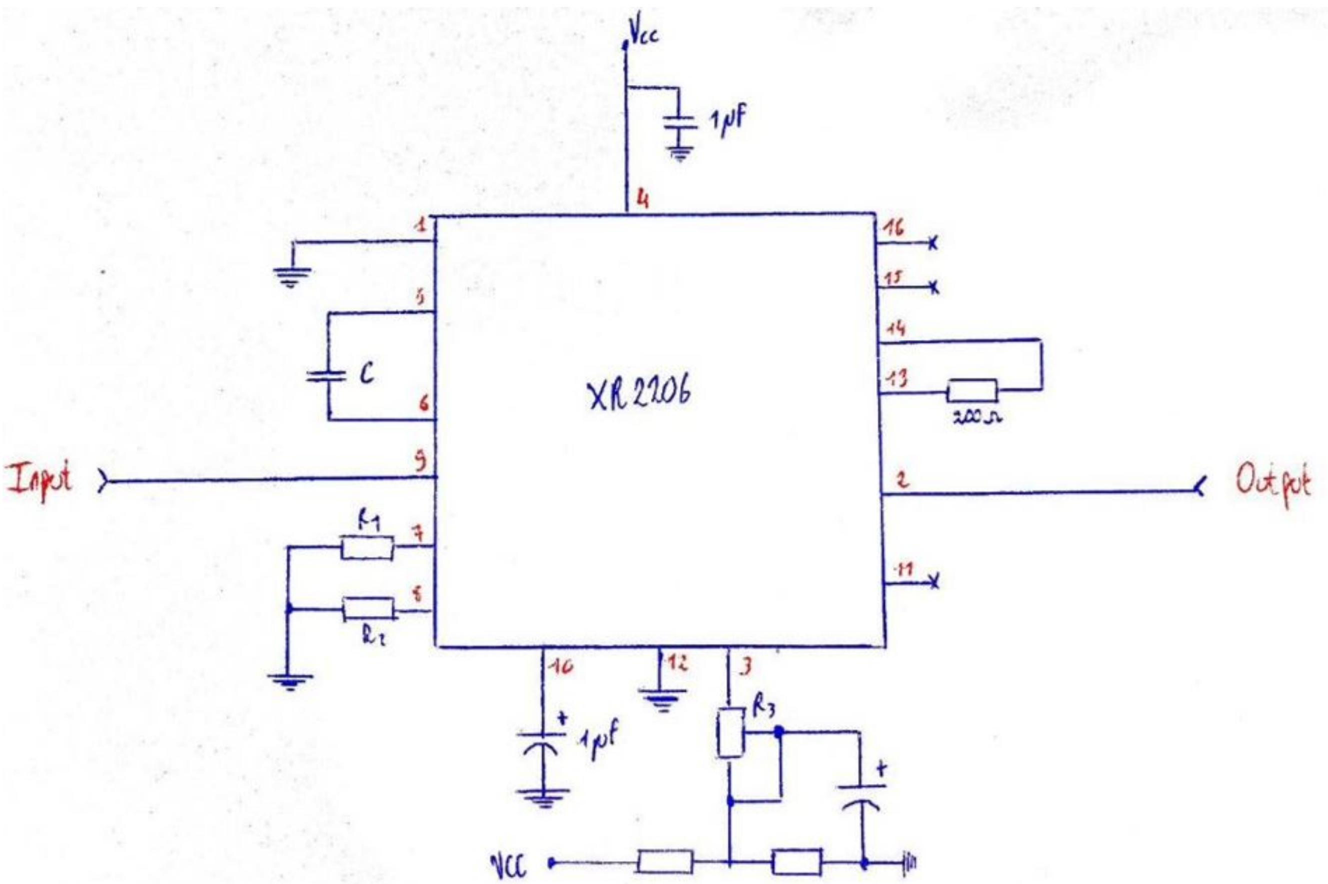


Figure 36: Modulator card schema

6.3 Important advise

The frequency with which the Arduino sends the digital data to the modulator depends directly on the frequency of the emitter. It is important to take

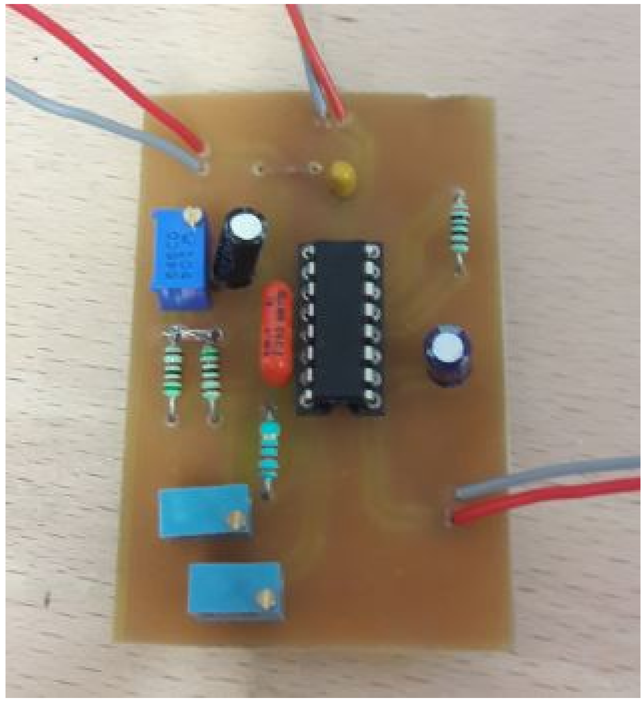


Figure 37: Final modulator card

this point into account when the frequency of saving data on the SD-card and converting into binary frame [trame binaire] is defined in the Arduino program !

A problem for the telemetry in the Solinas project was the aluminium profiles. Electromagnetic waves can not go through metal. When the rocket turns on itself, aluminium profiles will be between the telemetry center and the antenna at some moments. Consequently, the antenna is hidden from the telemetry center and no data is received during this period.

As a conclusion, the antenna has to be be placed at the top of the rocket, or the rocket needs to have a skin based structure in fiber glass for telemetry.

7 Tests before the launch

Before the launch, the experiment was ready. Using a syringe, we simulated static and total pressures, calculated a velocity, saved the data on a SD-card, created binary frames for the modulator and changed the binary frames into an alternative signal with two frequencies.

However, a point we could improve was the precision of the measurements.

A problem we could not solve was the constant variation of the sensors' voltage. The voltage was moving of 0.01mV, but as one voltage is associated to one pressure, the total and static pressures never were the same. The pressure were moving of about 100Pa. Consequently, the velocity calculated by the Arduino was moving from -10 to +10m/s, even if the rocket was not moving.

To improve this precision, I think the power supply has to be constant. It is necessary to add a voltage regulator at the input of the sensors.

8 VBA program and data treatment

The VBA program can be found page 119 in appendix. The program created curves as you can see in the Figure 38.

The Arduino saved data on the SD card in tables. Then it was possible to import the data on an excel file. Finally, we draw charts of velocity, pressure or temperature evolution with the VBA program.

However, the Figure 38 gives just a curve which was made during a test. The results can not be interpreted. Moreover, as our rocket was not launched, we will never know if the real data would have been interesting to treat.

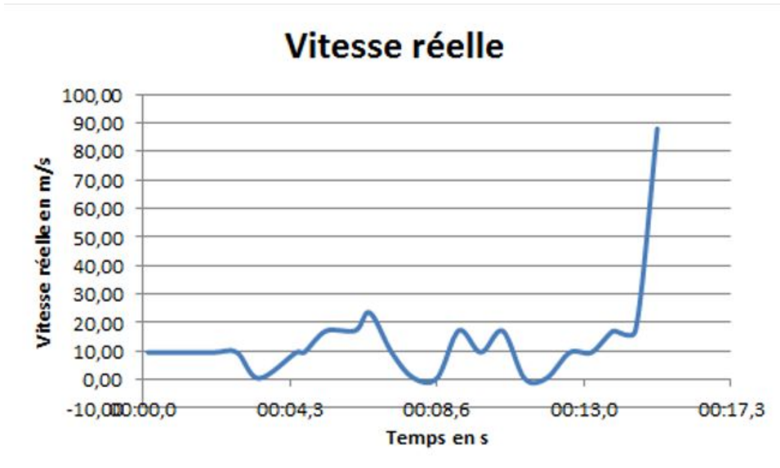


Figure 38: Velocity curve after data treatment

Part VI
Rocket safety

1 Analog timer

The goal of a timer is to delay an action on a define actuator. In the Solinas project, we were eager to eject a parachute 16 seconds after the launch. At t = 16s, the rocket's propulsion is finished and the rocket comes back to the ground. For the safety, its fall has to be slowed down with a parachute.

The parachute is stored in the rocket behind a door. A magnet suction cup [ventouse aimantée] maintains the door closed. When the timer is activated, the magnet suction cup is powered and it releases the door. A spring ejects the door and the parachute gets out to slow down the fall of the rocket.

1.1 Operating and time of ejection

The analog timer is composed of three main systems.

The first one is the RC circuit. This part determines the moment when the timer is activated. It depends on the time constant of the RC circuit,

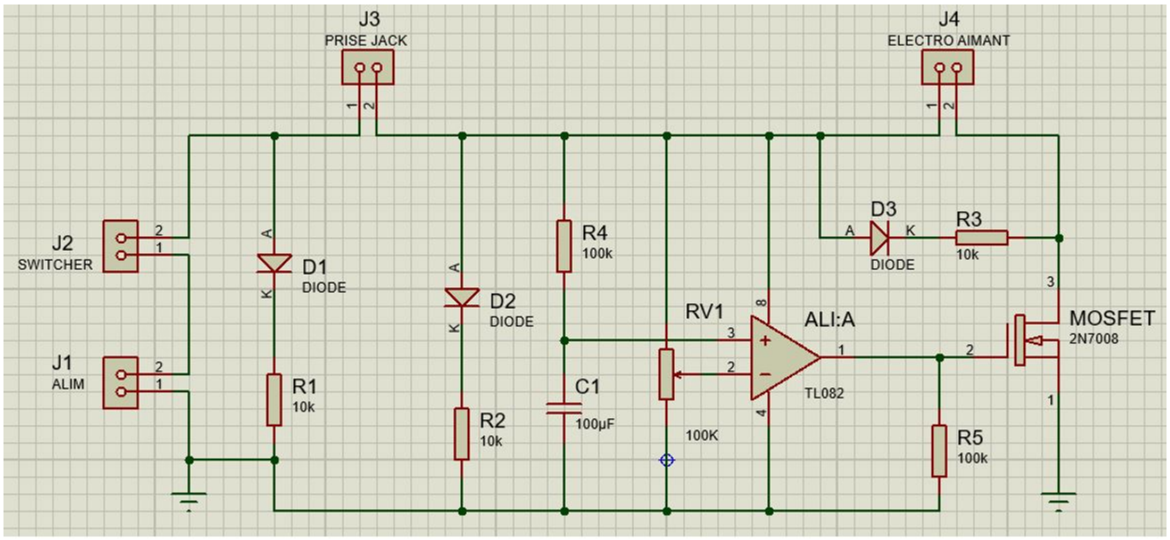


Figure 39: Solinas analog timer architecture on ISIS software

which also depends on the values of the resistance R and the capacitor C.

The second one is the operational amplifier. This component lets the current flow when the voltage of the RC circuit becomes higher than a reference voltage.

The last one is a MOSFET (Metal Oxyde Semiconductor Field Effect Transistor). This kind of transistor has a high switching speed and a good efficiency at low voltages, that is why we use it in this case. It plays the same role as an interrupter. When the MOSFET is powered, it closes the circuit with actuator and the magnet suction cup is powered by the main power supply.

Finally, it is necessary to add some LED to respect the book of specifications.

1.1.1 RC circuit and operational amplifier

RC circuit The flow of the time can be estimated thanks to different electrical components. The one we will use for the Solinas safety is the capacitor which can electrically charge or discharge itself. Be careful, the values of the components in the Figure 39 are default values. The values used for the Solinas analog timer are written in this section.

Operational amplifier An operational amplifier can achieve multiple functions. In this circuit we use it as a comparator. It delivers no voltage when the voltage V_{IN} is under the voltage V_{REF}, and it delivers the voltage power $V_{CC} = 12V$ when V_{IN} is over V_{REF} (Figure 40).

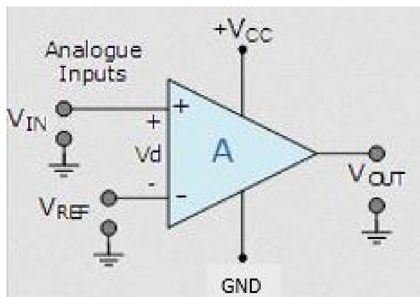


Figure 40: Operational amplifier schema

In our case, V_{IN} corresponds to the voltage of C_1 and V_{REF} corresponds to the constant voltage of RV_1. We selected $RV_1 = 340k\Omega$ to have $V_{REF} = 2.35V$.

Evolution of the capacitor's voltage A jack is used to short-circuit the capacitor. At the launch of the rocket, the start of the timer is detected when the jack get out. At this moment, the RC circuit is no more short-circuited, the capacitor C_1 will charge itself and the voltage V_{IN} will increase as follows :

$$V_{IN} = 4.7 \times (1 - exp(\frac{-t}{R_4 \times C_1})$$

The evolution of the voltage V_{IN} is showed in the Figure 41.

Determination of the resistance of the RC circuit We are eager to active the actuator 16 seconds after the launch. Thus, it is possible to determine the value of R_4 to achieve this condition. We use the previous equation

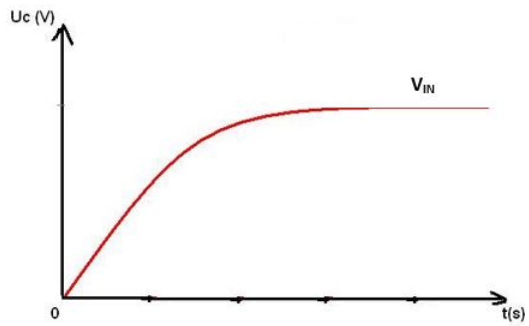


Figure 41: RC voltage evolution depending on time

for $V_{IN} = V_{REF}$. It corresponds to the moment when V_{IN} overcomes V_{REF}. As this moment, the operational amplifier delivers 12V at its output and powers the MOSFET (Figure 42).

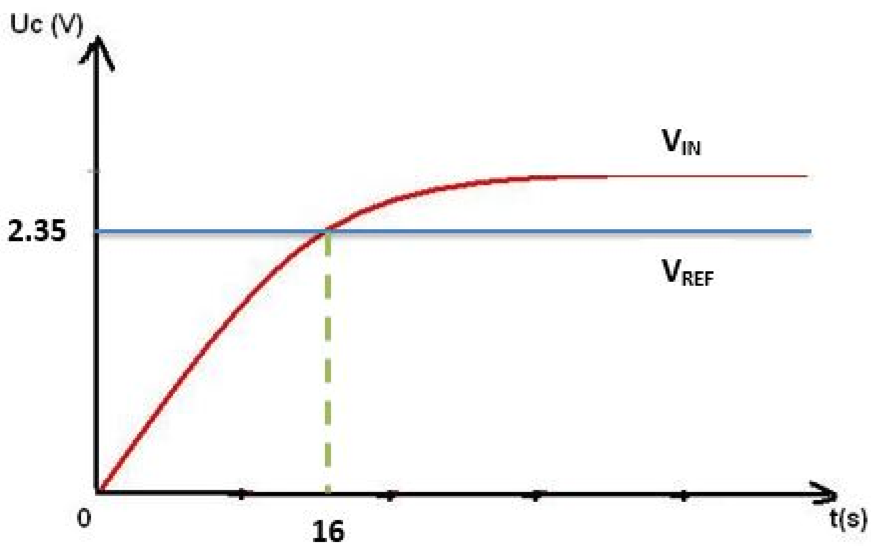


Figure 42: Evolution of V_{IN} compare to V_{REF}

The value of R_4 is given by the following formula :

$$R_4 = \frac{-t}{C_1 \times ln(1 - \frac{V_{REF}}{4.7}})$$

For $V_{REF} = 2.35V$ and $C_1 = 47\mu F$, we obtained $R_4 = 490k\Omega$.

1.1.2 MOSFET

The MOSFET is composed of three pins : the gate, the drain and the source (Figure 43). It can be considered as an electronic interrupter. When the gate is electrically powered, the circuit between the drain and the source is closed. Otherwise, when the gate is not powered, the circuit is open.

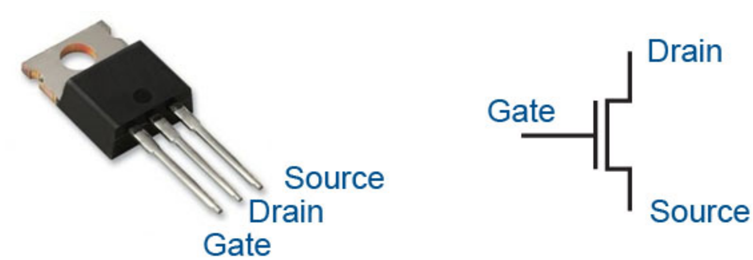


Figure 43: MOSFET diagram

In the Figure 39, the MOSFET is in serie with the magnet suction cup and the power supply. It will close the circuit when the operational amplifier will let the current arrive to the gate, at $t = 16s$. Consequently, the magnet suction cup will be powered by electricity, it will be deactivated, the door will be opened and the parachute ejected.

1.2 Analog timer architecture

Firstly, we found an analog timer schema on the Planète Sciences website. An ESO member Clément Rousseau simplified the schema as in the Figure 39.

Then, the circuit was tested on a breadboard. As soon as we succeeded to deactivate the suction cup, we were ready to build the real electronic card.

The next step was to define the architecture of the printed circuit with the Proteus software. Two modules are used in the Proteus software to create an electronic card : ISIS and ARES.

Firstly, a digital schema of the analog timer had to be created on ISIS (Figure 39).

Then, we imported the ISIS file on ARES to automatically determine the optimum position of each component on the card (Figure 44 on the left). It is possible to see the position of the component in 3D (Figure 44 in the middle). If the position of some components is not convenient to solder or to position them, they can be moved manually. After this, it is possible to edit both faces of the printed circuit board on tracing paper [papier calque] (Figure 44 on the right).

Figure 44: Digital cards created on ARES software

This tracing paper with the circuit printed on it will be used to trace the printed circuit on a copper [cuivre] plate. For this, the plate will be lightened for 2 minutes by a UV platesetter [insoleuse] with the tracing paper on it. Then, the card will be put in a bin of soda [soude] to reveal the circuit and see if it was well traced. The next step is to put the card in a bin of iron perchlorate [perchlorate de fer] to withdraw the rest of copper on the circuit. After all, the card has to be cleaned with acetone to permit a good solder between the tin [étain] and the copper. The card is ready to be soldered !

All the steps necessary to create an electronic card are summarized on

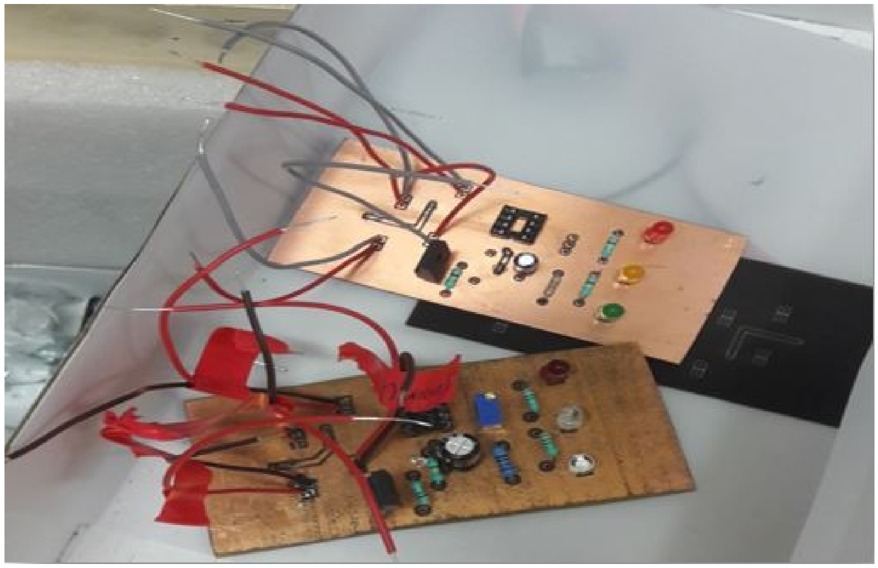


Figure 45: Final analog timers

the Figure 46.

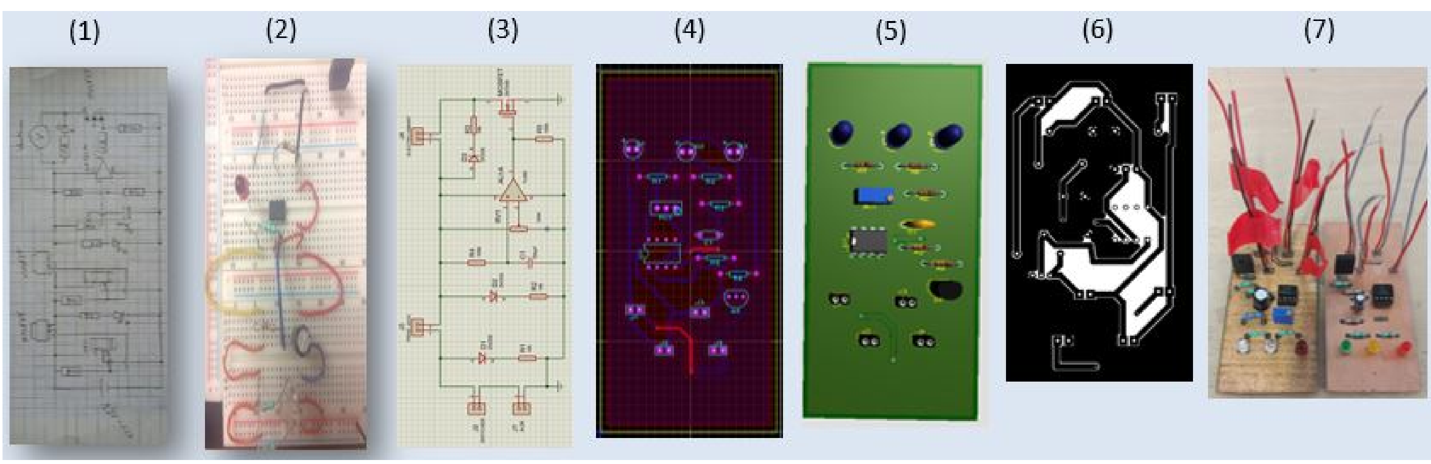


Figure 46: Summary of analog timer creation steps

Part VII
Power supply

The power supplies were as follows :

- 1 LIPO battery of 11.1V and 500mAh (3S);
- 5 batteries of 9V;
- 4 batteries of 1.5V.

The LIPO powered the Arduino, the sensors and the operational amplifiers.

The operational amplifiers needed a power supply bigger than the amplified voltage. They can receive until 20V according to their datasheet. So a power supply between 3V and 20V is adapted.

The sensors needed a power supply between 10V and 16V according to the datasheet. The power of the LIPO was also adapted.

Finally, the advised power supply for an Arduino is included between 7V and 12V. The limit power supply is between 6V and 20V. If the power is smaller, the performances of the Arduino will not be well. Over 20V, the Arduino will have damages.

Another important value to check is the consumption. The LIPO needs to deliver enough power to supply everything. We did not calculate accurate values of consumption in the Solinas project. I really advise to do it for next projects. Besides, a schema of the power supply electronic card has to be drawn.

For one analog timer, one battery of 9V and two batteries of 1.5V were used. An analog timer needs an average value of 12V to work well.

The modulator was powered by two batteries of 9V in serie to have a good autonomy. But as it needed a constant value of 10V, a voltage regulator was used between the power supply and the modulator to transform the 18V into a constant value in the time of 10V.

Concerning the transmitter, a power supply of 9V was sufficient. Its power consumption is described in the Kiwi Millenium document of Planètes Sciences at <https://www.planete-sciences.org/espace/IMG/pdf/manuel_kiwi_millenium.pdf>.

Part VIII
Cansat Swarog

The Cansat was made by another team of five students at ESTACA. Their goal was to take physical quantities measurement during the fall of the Cansat, after its ejection from the rocket.

The Cansat could not be ejected from our rocket as Solinas was not launched. But it was registered to the "Cansat contest" and could fly. It is important to subscribe the Cansat to a contest. It enables to save data even if the rocket is not launched.

Figure 47: Cansat Swarog

Part IX
C'Space

The C'Space event was really unique. It is for one week and is extremely exhausting. The Solinas team was incredible during this week ! We worked from early morning (some days we began at 7.00am) until the night (everyday until 23.30pm). 6 of the 12 members were present and some of the members even came from Lithuania to attend this event.

When we firstly arrived, the Mechanics was not ended. It took us about 3 days to finish it. Then, we passed the first controls and discovered that the camber of our rocket was bad. It took us all the week to correct the camber. We added consolidations between the profiles but it was still bad. Then, we bought steel profiles, disassembled everything and assembled again. This time, the camber was almost good : only one side of the rocket had a bad camber. But as we were late and the end of the controls was coming, we assembled everything very fast. During the last control, we finally started the real tests on the rocket. One screw broke out on a fin and we did not have time to change it. The organizers decided not to launch the rocket.

Figure 48: Solinas camber

I really advise to go to the C'Space with a finished Mechanics because there always are problems you can not anticipate. You will need time to correct them. Moreover, it is important to come without a bad camber of your rocket. We have lost almost one week to correct it and we have not got time to focus on other problems. I am almost sure that our rocket would have been launched without the camber problems.

I also advise to create a list before going to the C'Space as you can see for the Solinas list page 127 in appendix. No part has to be forgotten when you go to the C'Space. It is also crucial to take several exemplars of your parts. For the Solinas project, we had two Pitot tubes, two pressure sensors and two other operational amplifiers in additional. I should also have taken another Arduino microcontroller and another XR2206 component for the telemetry. For example, I had to get out from C'Space site and travel about 50 kilometers (from Tarbes to Pau) to buy another Arduino microcontroller. It was really stressful with all the problems we already had on the Mechanics.

Finally, it is important to take pictures ! You will never forget this week. Even if your rocket is not launched, you will remember the C'Space as a good time. You can find some nice pictures of the Solinas team at the C'Space in the Figure 49, 50 and 51.

Figure 49: Solinas C'space team posing (1)

Figure 50: Solinas C'space team posing (2)

Figure 51: Solinas C'space team posing (3)

Part X
Team and project management

This part is kind of my project feedback. I will describe how I have managed the work, how I have felt to lead such a project, what I have learned and how it could be improved by future team manager. But describing the way of managing would deserve a whole report. I will only develop a little part of this large and complex domain.

Figure 52: GADANHO Vincent (Manager)

Clearly, leading this project was one of my biggest challenge until today. Managing for the first time a one-year project (from September 2016 until September 2017, without holidays), with twelve beginner members (including me), who were volunteers, and who were my friends, asked me a huge organization and implication of myself. The same year, I also involved myself in the bureau of the association as a secretary. It taught me a lot, but also took me a lot of time.

Finally, I worked about 30 hours per week for these two jobs, and some weeks until 50 hours. Moreover, I had to assist to my lessons at the ESTACA, assuming my exams and I was eager to keep my previous social life. I can say that it was not a relaxing year at all, but I am proud and happy of having kept my implication and motivation until the end.

1 Team management

1.1 The team manager I was

1.1.1 Sub-teams organization concept

I organized each team into sub-teams and each sub-team was responsible for one domain. I identified four main domains : Mechanics, Experiment, Telemetry and Safeguard. For me, each domain had the same importance and had to progress at the same time with the other domains. Even if the experiment is extremely important. Indeed, it needs to work if we want to get the permission to launch the rocket.

1.1.2 Repartition of the work in the team

Firstly, I asked on what everybody wanted to work. The motivation of a member is the most powerful factor. If a member wanted to do something, I let him work on this subject. For example, I knew that Erwan was interested in Mechanics and Thibaut was interested in the Arduino programming. I also knew that Erwan had good skills in Mechanics and had taken part of many organizations' projects. That is why I designated him responsible for the Mechanics of the rocket. Thibaut also worked on the Arduino.

Anton had previous skills on the Proteus software and a good knowledge in numerical electronic. I decided to put him on the Telemetry and the Safety to help on the creation of the electronic cards, on both domains. He did a very good job on designing the modulator and the analog timer cards. Anton was always available when I needed him and it was an important benefit for me in my managing job.

Ariane had good theoretical skills and she had a good experience in Mechanics as she was the only one to have participated to a C'Space in 2016. That is why she began to work with Thomas and then passed on the Mechanics part. Ariane also developed alone the VBA program to process automatically the data of the SD card during the launch. It was a hard job but she did it very well as the program worked. Unfortunately, as the rocket was not allowed to be launched, we could not use it for the processing of flight data.

Romain, Tanguy, Benjamin and Michaël worked on a wide range of fields even if they were all busy during the year. Romain worked on the basics of amplification. Tanguy, Benjamin and Michaël were in the first year of engineering cycle and it was their first year in the association. Thus it was hard for them to take initiatives but they hung on and I find it remarkable. I tried to make them work in all the fields. I think it is important for new members to have a wide vision of the necessary steps to create an experimental rocket. I did my best to form them with the little time they had to spend. Michaël and Benjamin worked with Erwan on the rocket modeling and on the final assembly. Benjamin designed pieces in the rocket like the Pitot tube for example. Michaël worked for example on how to print a CATIA file with a 3D printer. He also found the camera we bought. Tanguy worked on the beginning of the amplification card with Romain and on the final assembly. He was able to work and learned by himself so it is a good point.

I would add that it is important to put a new member with someone experimented to help him. If the member is lost, he won't come again. It would have bad impacts for the next year. If we do not want that our work be useless, it is important to transmit the knowledge to new generations.

Clara Morache worked on the Arduino selection but she had to leave to study in England and could not continue with us.

I want to congratulate the work done by those who worked on just one subject all the year. Sometimes they were eager to discover new fields but it was very important for the progress of the rocket that they keep their activities.

Thibaut did a really good job from September to April. He concentrated all his activities on developing the Arduino program we used for our experiment and he had no experience at the beginning. The program was well-organized, documented and everything worked when we made tests with the sensors. When I had to use his work to link the Arduino to the amplification cards, it helped me to save a lot of time.

Thomas worked on the telemetry which is a complex domain. I trusted him to understand documentation to know how it works, and to make it work. I was right as he succeeded. He was very autonomous and he was one of the leader in the team.

Tiphaine developed the analog timer and he did not have previous experience in electronics when he began. He was not particularly interested in electronics and would have liked to work in the Mechanics. But he kept his role all the year and I find it really remarkable. He played an important role in the team.

Erwan had a lot of responsibilities on himself as I put him responsible for Mechanics and the work in Mechanics is as big as all the experiment part. I should have put someone else experimented with him all the year. The team would have needed another experimented member in Mechanics. Erwan did his best to do the CAD of the rocket and to work on the assembly. He played an important role in the team.

1.1.3 Repartition of my work

This project made me work in almost all the fields.

The beginning of the project was maybe the hardest part for me because I had to lead the team, but I was myself a beginner in all the domains. I spent a lot of time to prepare the work that each 12 members (including me) had to do every weeks. We worked every Thursday afternoon and each member had to know what he had to do. Moreover, I wrote every week an advancement paper for all the team to summarize how the project was moving forward. I kept this organization two or three months until the end of November.

At the end of November, each sub-team knew what has to be done and everybody was more independent. It enabled me to help in the sub-teams which needed help. The part who had to progress was the Mechanics. I worked with Erwan on the CAD of the rocket until the end of December. In parallel, we understood that it was necessary to amplify the voltage of the sensors. I worked a bit with Romain and Tanguy who began to look for how to safely amplify a voltage.

In January, we finally fixed all the components who were necessary to achieve our experiment. It was late because the CAD was constantly moving and we needed to finish it to start making the mechanical pieces. We would have won a lot of time if someone experimented would have worked with us.

At the end of January, Tanguy and Romain were less present and I had to switch to the Experiment sub-team to work on the amplification card. I designed a voltage amplification on a breadboard. But I used only one operational amplifier for one sensor and it was not safety enough. Thanks to Clément Rousseau (responsible of electronics on the rocket Aeris at ESO), I found the good amplification schema with three operational amplifier.

I spent three months to create the two amplification electronic cards and made them work with the sensors. In parallel, I worked on the creation of the mechanical pieces as the fiberglass and carbon fiber structure, the aluminium rings and the selection of aluminium profiles. I also continued to prepare the work for the other sub-teams.

The 1^{st} May 2017, right away after my exams, I began my internship in Brussels. I took the Arduino microcontroller, the amplification cards and the sensors with me. The evening after my internship or during the week-end, I worked on the Arduino program which was finished by Thibaut. I learned how to use a microcontroller and linked it to my sensors. I made all the measurement chain work for the C'Space in July. It was a critical part and I had some pressure. If I could not make it work, our rocket could not be launched.

1.1.4 Sub-teams organization summary

The team was organized as follows :

- Vincent : supervising the team and working in the domain which needed progress to respect the deadlines;
- Thibaut, Thomas, Tiphaine and Erwan : working on one domain all the year;
- Anton and Ariane : working on several domains all the year to help others who needed help;
- Romain, Michaël, Benjamin and Tanguy : working on several domains during the year when they had time.

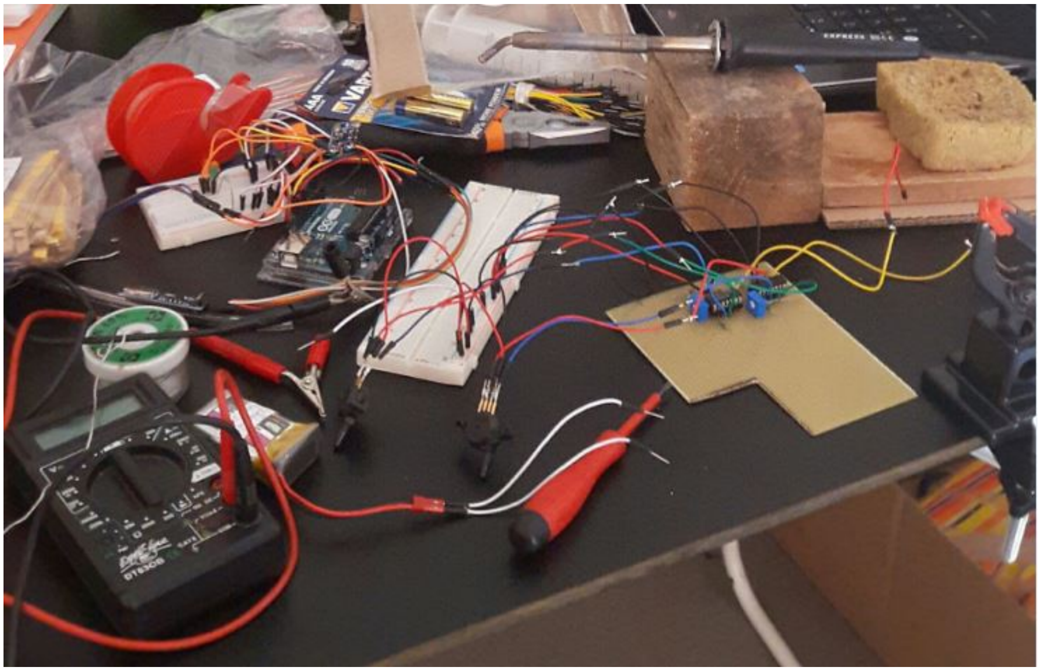


Figure 53: Soldering electronic cards in my flat in Brussels

I think it was the optimum organization to progress as we all were beginners, and we have to remember that everybody was here to take good time as it was a voluntary project. Thus, I constantly had to adapt myself to the unforeseen events which touched everybody and the duty beside this project (exams, sport, events, sickness...). It was a constant challenge for me and that is why I had to work in all the fields. It enabled to keep a constant progress and to respect the deadlines. A manager in a firm would not have worked in all the domains as I did.

1.2 A good team manager

I think a good team manager is someone who can feel how to spread people in each sub-teams to have the same progress in each domain.

For this, he has to take into account :

- the work necessary in each domain;

- the strong and weak points of the members;
- the relationships between the members to be efficient;
- a possible loss of motivation of some members;

Challenges for a team manager of a voluntary and beginner students team are :

- keeping in mind that they are volunteers;
- finding the good resources to help them in their work (contacting experimented people, finding relevant websites or reports);
- finding the medium point between motivate them a lot and make them upset.

2 Project management

Three main things are essential to manage a project :

- a planning;
- a list of the parts you need and you already have;
- a treasury file to manage your budget.

The planning is maybe the most important one. It makes you realize the time you can assign to each task and enables you to manage the future evolution of the project. If a task takes too much time and you pass the deadline, it shows you that you will have less time for the next labors.

The parts list helps you to anticipate the parts you will need for each domain. A lot of time can be lost without this list. It is the case when a member solders an electronic card and one component is missing. The member will have to wait to receive the component and to continue his work. Moreover, the delivery times are sometimes long and you could wait one month to finish the card.

The treasury file enables to manage the budget. The manager will be able to spend more or less money in each domain. He could also anticipate a lack of money in beginning to search sponsors.

2.1 The project manager I was

2.1.1 Planning

I have begun late to write my own planning. At the beginning of the year, I only made tasks lists. But it was very helpful for me to create a planning because it showed me that most of the deadlines were passed. It also helps to make realize to your member that a lot of work is necessary.

It is important to update the planning very often. The Solinas project was a special one because we constantly discovered new tasks in the year and the deadlines were constantly changing. Thus, it was hard to keep constant deadlines. But the planning played an important role in the management of the project : it showed us that the time available for each task was decreasing weeks after weeks.

Do not forget to take into account the period when members will not work like exams, revision weeks, holidays... The most critical moment for the project is the end of the academical year, when internships begin. During this period, the members are no more available or have other things to do. Moreover, it is really hard to work at the end of the day, just after your internship.

2.1.2 List of rocket parts

An example of a rocket parts list can be found in the Figure 56. A possible improvement would have been to add all the electronic components needed to create the electronic cards. Each part should be described in this list to anticipate all the problems.

2.1.3 Budget management

In the Figure 57 can be found an extract of the budget management file.

3 Improvement for the Solinas project

A good thing would have been to have some experimented people in our team to teach and advise us. As a team manager, I played this role in searching a lot of information on the internet, in asking the bureau of the association

	Electronique			Mécanique	
	Minuterie	Télémesure	Expérience	CAO	Réalisation
14-nov	Lecture Méthode de conception et de réalisation des Fusées amateurs + chercher composants nécessaires à l'atelier + faire schéma au propre		Réaliser des premiers programmes avec Arduino Uno + sélectionner un des deux capteurs	CAO	
21-nov	Tests sur plaque à essai		Réaliser premiers programmes avec l'Arduino Uno	CAO	
28-nov	Tests sur plaque à essai		Savoir faire des programmes avec Arduino Uno + premier jet du programme pour tube de Pitot	CAO	
05-déc	Révisions Partiels				
12-déc	PARTIELS				
02-janv	Réussir à déclencher les électro-aimants au bout d'un certain temps sur une plaque à essai	Lecture de la documentation sur la télémesure Comprendre le fonctionnement du modulateur	Sélection des batteries Définition de toute la chaîne de l'expérience		Pas d'avancée, chef mécanique non disponible
09-janv	Conception de la minuterie sur le ISIS	Lecture de la documentation sur la télémesure Comprendre le fonctionnement du modulateur Réunir les composants nécessaires pour la modulation du XR2206	Rédaction du code Arduino Détermination des éléments nécessaires pour l'AOP (tous à disposition)		CAO ajustée avec dernières modifications
16-janv	Conception de la minuterie sur ISIS	Test de l'ensemble de la chaîne de mesure sur plaque à essai : Création d'un signal avec un capteur (pression ou accéléromètre), l'amplifier avec l'AOP, effectuer une modification simple avec Arduino, puis moduler le signal avec le XR et mesurer le signal obtenu avec un oscilloscope du laboratoire			[illegible] seulement 3 treillis => pour pouvoir ajouter des bagues intermédiaires (treillis + bagues séparation étage découpée dans plaque) Mise en plan sur CATIA des bagues à usiner Calcul et commande du ressort sur GEFI, sélection électroaimant => fixer forme bague 3D sur CATIA
		[illegible]			[illegible]

Figure 54: Extract of the planning

and older students for advice. But I also helped everybody in each domain, focused myself on the amplification card and organized the different tasks in the team. So I ran out of time.

	Vincent	Ariane	Thomas	Erwan	Tiphaine	Anton
Dimanche	9h-12h : remonter bagues qui ont été démontées 14h-15h : découpe deux cartes élec et soudage du dernier câble 15h-19h : Intégration expérience et tests	9h-12h : remonter bagues qui ont été démontées 14h-19h : Agrandir trou coiffe et coller tube de Pitot + Fixer Kiwi	x	x	x	x
Lundi	9h-12h : Fixation des ailerons 14h-19h : fixation caméra	9h-12h : fixation des ressorts 14h-19h : guidage Cansat	14h-19h : Intégration modulateur + relier à l'Arduino avec Câble blindé + relier au Kiwi	14h-19h : Découper portes + trous au niveau des LED, interrupteurs et jacks	14h-19h : Intégration minuteries + Relier électroaimants	14h-19h : Fixation de toutes les piles et batteries + barette de fixation en bas du propu
Mardi	Intégration parachute et Cansat + Tests + Peser la fusée + Mesure du centre de masse + test de la flèche => si tout bon passer au contrôle et aller acheter peinture					
Mercredi						

Figure 55: C'Space planning

I am convinced of one thing, Mechanics is extremely important and it is not possible to put only one experimented guy on it. Erwan began to work with Benjamin and Michaël, I helped him when they were not with him. But it would have needed a strong team to define a very good Mechanics and avoid all the problems we had. The role of a Mechanics leader is as important as the role of the manager.

4 How to motivate special members to work in the team ?

4.1 Method to manage not motivated members

I realized that it is sometimes necessary to yell a bit on someone who did not do its work. Maybe he will be a bit upset on the moment and show you that he will not change, but he will probably think about it alone and try to do it. The important thing is to find the right resources for him to make his work. If the member has all the tools to succeed and you motivate him, he will do his work.

Another important advice is that if you want to have a good impact on

	Nature	Nombre	Dispo	En cours	A faire	Fixations
Structure	Vis	200				A acheter si pas assez au local
	Ecrous	200				A acheter si pas assez au local
	Rondelles	200				A acheter si pas assez au local
	Grosses équerres inox (4 trous)	8				
	Petites équerres inox (2 trous)	20				
	Profilés U (11,5mm)	4				
	Bagues impression 3D	2				
	Bagues usinées Alu	3				
	Bagues découpées Alu	6				
	Ailerons	4				
	Peaux en fibre de carbone	2				
	Peaux en fibre de verre	1				
	Coiffe impression 3D	1				
	Fixations	?				
Coiffe	Tube de Pitot	1				Fixation à définir
	Tubes en plastique	2				Scotché
	Capteur pression statique MPX2200AP	1				Vissés à la bague séparation étage
	Capteur pression totale MPX2200AP	1				Vissés à la bague séparation étage
	Accéléromètre	1				A changer car prends que du 8g et pas du 17g
	AOP	2				Vissés à la bague séparation étage
	Arduino Uno	1				Fixé verticalement : Soit à une plaque en bois ou aluminium de faible épaisseur vissée au treillis qui dépasse - Soit à une plaque en bois ou aluminium de faible épaisseur tenue avec des équerres vissées au treillis qui dépasse - Soit visser directement l'Arduino au treillis qui dépasse
	Adaptateur SD Arduino	1				/
	Carte SD 16Go	1				/
	Câbles mâle/femelle Arduino					/
	Régulateur de tension	1				Vissés à la bague séparation étage
						Fixé verticalement : Soit à une plaque en bois ou

Figure 56: Extract of the parts list file

members, you have to speak with them one by one. You have to designate someone when you give an instruction, otherwise nobody will take the responsibility to do it.

4.2 Method to solve the problems

The method to implement depends of course on the members' personalities in the team but I will try to explain the method I used for critical situations. Moreover, it corresponds to my personal point of view, other methods are certainly possible..

If your member does not want to do his work because he is very busy or

Commande radiospäre 3 (31/01/2017)				
Nature	Nombre	Prix unitaire	Prix total	Lien
Crochet	1	6,48	6,48	http://fr.rs-onl
Potentiomètre 100 kohms	4	2,67	10,68	http://fr.rs-onl
Régulateur de tension	4	0,84	3,36	http://fr.rs-onl
Pile 9V	2	4,4	8,8	http://fr.rs-onl
Condensateur 100microfarad 50V	5	0,174	0,87	http://fr.rs-onl
Total =	30,19			
Commande radiospäre 4				
Potentiomètre 100 kohms	4	2,67	10,68	http://fr.rs-onl
AOP LM358P	10	0,16	1,6	http://fr.rs-onl
Porte-pile (deux 1,5V)	2	0,81	1,62	http://fr.rs-onl
Commande Amazon (06/04/2017)				
Câbles mâle-mâle (24 avril-4mai)	1	1,36	1,36	https://www.a
Carte micro SD et adaptateur	1	4,88	4,88	https://www.a
Autres				
Tube de Pitot 1	1	7,31	7,31	
Tube de Pitot 2	1	7,67	7,67	
Batterie LIPO 500maH 3S 20C	1	5,87	5,87	
Adaptateur micro SD Arduino	1	1,7	1,7	
Carte SD 16 Go	1	7,29	7,29	
Cable Arduino	1	4,38	4,38	
Seringue (18 avril)	1	1,68	1,68	https://www.a

Figure 57: Extract of the budget management file

lazy :

- You discuss with him to find a period in the week when he will be able to do its work. If it is necessary, you show him that it is really important for the rocket, that he took commitments and so on. Of course, if it is a special week which is very busy for him, you try to find another moment.

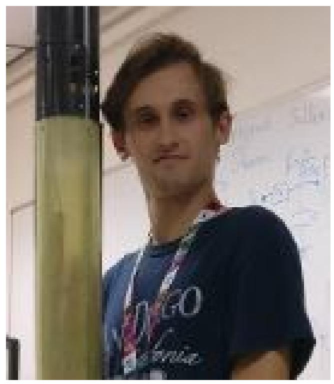
Then :

- Keeping communication is very important to motivate him. The next exchange needs to be funny and not arrogant to remember him that you still think about your discussion, but your are not upset at all. A good manager always have to step back and keep his own feelings for him. To motivate him, you can show him the work you have done or something which works very well is showing him that the other members did great work on their subject. Someone who is very busy or lazy, and tells you ”I will do it” will not do it. He will tell himself my team manager has maybe forgotten, or I will tell him an excuse. It is strange to say, but you have to let him no way to tell you that he could not do his work. The only thing he can tell you has to be “I did not want to do it”. If it tells you this, it will change the way you have to manage the point. You can for example finding him another subject to work. But if you gave all the tools to your member to succeed, he will be compelled to change his mind.

Leading a team is a constant challenge for the manager because he always have to face problems and find solutions. But in all the case, it would not be funny if it was too easy, and that is what make the managing job interesting. You work with humans, do not forget it !

Part XI
Members feedback

1 Anton ROIG



Personal experience

- **How did you feel your first experimental rocket project ?**
We already had realized a miniature rocket last year, but this experimental rocket was our first big one year project, so we were not very experimented but we learned a lot, especially more practical skills that are not taught in school. It represented a lot more work than last year, in different fields that we are not used to practice in ESTACA, as electronics for example. Hopefully, we were not alone to realize this, more experimented students from ESO were helping us and we even had some electronic courses from them, because it was quite new for us. It was interesting to switch between the electronics team and the mechanics team, and do various tasks in both.

- **On what did you worked and what have you learned ?**
In electronics I have learned how to use Isis and Ares, software used for electric circuits modeling. We also learned how to realize electronic cards with few members. In mechanics I have participate in the assembly, seeing that even when all seems good, there are always some problems, the rocket bent in our case, so we had to reinforce its structure with steel.

- **What interested you the most ?**
  All tasks were quite interesting but the one that I have liked more was the assembly of the rocket, seeing the project for which we have worked all this year coming to life. There was not really tasks that I disliked, just some of them were quite repetitive after sometime.

- **What should be improved in the association for the members formation on experimental rocket ?**
  In order to form better new ESO members, the association need to create a data base with the previous projects, to have more feedback. It is essential that the older members of the association help the new ones through some formations, as in electronics this year and also by supervising the projects.

C'Space feedback

- **How did you live the C'Space ?**
  The C'Space was a great experience for me and my friends, showing that even with the stress of the deadlines coming to fast, our team stayed united, even if we were working from the early morning until the closure at midnight. We did not manage to launch our rocket this year but it was still a very positive experience, and we had the chance to assist to some rocket launches.

- **What should we have improved to launch our rocket ?**
  In order to launch we should had to go more prepared to the C'Space, with the rocket already assemble during the year, in order to have more time to correct the defaults that the different tests showed.

- **Which advice would you give to prepare a C'Space ?**
  Like I said before, my biggest advice to be prepared for the C'Space is to know the tests that the rocket will need to pass in advance, asking older members that already have been at the event in his previous editions.

Management feedback

- **Comments on the team and project management during the year :**
  The team was well coached by the project manager, who was organizing

regularly working sessions, explaining to everyone the tasks that they need to do and their deadlines. The members were switching from different fields during the year to see both mechanics and electronics aspects of the work.

- **How would you have managed the project in terms of planning ?**
  In order to be more efficient during the assembly of the rocket, it needs a good very detailed CAD on CATIA or SolidWorks, and in parallel other members already starting the mechanic part. A planning is need in order to have a global view of the advancement of the project and the deadlines of the different tasks.

- **How would you have managed the project in terms of tasks organization ?**
  The thing that would be good to change for the next year is to organize other working sessions for those who cannot on the usual ones, as it was the case for some younger members. Some work can also be done at home if the members are motivated.

- **Give one strength and one point to improve of the project manager :**
  This year, the project manager was very motivated and did a good job, always knowing the advancement of all the tasks in different field and was multi-skilled, helping the members that needed him. The only negative point was that, as he was also the secretary of the association, he also had a lot of work for this responsibility. Maybe combining both (responsibilities in ESO as secretory, treasurer or president, and project manager of a big experimental rocket) is too much work.

2 Ariane PANORYIA

Personal experience

- **How did you feel your first experimental rocket project ?**
  As for the whole team, Solinas was my first experimental rocket. Last year I was part of a mini rocket with which I acquired a little experience. But this project was more important and complete because of all the

new subjects we had to work on such as the telemetry for example. At first, it was a bit difficult to do the link between all the parts and subjects used for this project. But at the end, I think it is the part I preferred about Solinas, the fact that there was lots of things to learn in different subjects. To be completely honest, Telemetry and Electronics were not sounding like very interesting subjects to me but thanks to Solinas, I found an interest in those. That is what I like the most with building a rocket by ourselves, applying what we have learned in classes in practice.

- **On what did you worked and what have you learned ?**
  In this project, I had not a fixed role. I just helped this others in different parts of the project, which enabled me to learn about many different subjects such as electronics, telemetry or mechanics. My main contribution to Solinas was the mechanical part in which I felt most comfortable.

- **What interested you the most ?**
  I liked all of the actions I did in this project because there was always something to learn about.

- **What should be improved in the association for the members formation on experimental rocket ?**
  One of my advice would be to constitute teams with at least two people who have a consequent experience in building experimental rockets. This way, they can share what they know about it.

C'Space feedback

- **How did you live the C'Space ?**
I really appreciated to participate to this session. Indeed, even if we had lots of problems, we always did our best to try to solve them and we always kept a good spirit and a great atmosphere in the team. I've learned more than I could expect in mechanics and this is one of the reasons I participated to the C'space. Even if our rocket did not pass the controls and did not fly, it is really a wonderful memory and I would do it again if I had the choice.

- **What should we have improved to launch our rocket ?**
What we could have changed to be able to fly is the choice of doing a "standard" structure whereas lots of people were quite sure that the structure chosen was not strong enough. And they were right... We have lost a lot of time trying to strengthen the structure. That was our weakest point.

- **Which advice would you give to prepare a C'Space ?**
To be ready for the C'Space, it is important to know what is going to happen there. For example, which kind of controls your rocket will need to pass, what are the requirements and so on... Moreover, it is really important to have almost finished the rocket before coming to the C'Space, in order to have time to do all the rectifications you will need to do after the first controls.

Management feedback

- **Comments on the team and project management during the year :**
I did appreciate the way this project was carried out by Vincent Gadanho. He was an excellent manager. We did not feel forced to realize the things we had to do but we were happy to do them thanks to him. He was always understanding but knew how to tell us that it was time to work. I think he really did a great job because it is not always easy to lead our own good friends, which he succeeded in perfectly with always keeping a great atmosphere in our team. Congrats to him !

- **How would you have managed the project in terms of planning ?**
To realize an experimental rocket, I think it is really important to have a

good CATIA at the beginning, so that it is easy to make the mechanical part. Indeed, we had to make again some parts of our rocket because of wrong information on our CATIA. A great thing would be to have the CATIA ready in September so that we can begin the construction sooner. Moreover, only one afternoon per week is not enough. I think it would be a good idea to also work on the rocket on the evenings, after class.

- **How would you have managed the project in terms of tasks organization ?**
  If we had to do this again, I think I would give in advice that the CATIA need to be really precise and be ready for the end of September. But I know my team did the best it could and I am proud of what we managed to achieve.

- **Give one strength and one point to improve of the project manager :**
  Our manager has a great sense of humanity and was a great leader. As I wrote it above, he was always understanding but also knew how to lead and how to achieve his objectives. I can not find any negative point in his way of managing our team. I really think he did a great job!

3 Thomas SOUPRAMAYEN

Personal experience

- **How did you feel your first experimental rocket project ?**
  This project has been my second as an ESO member but I can say it was my first real rocket project as the level was far above the first one. I wouldn't say it was difficult to adapt myself to this project because I was motivated but the expectations were not the same and the result had to be perfect. My main contribution was on electronics and most of what I did, I learned it by working on it. I had a lot to learn but it wasn't too much as it was interesting.

- **On what did you worked and what have you learned ?**
  I did a bit of mechanics at first and at the end of the project but the main part of my work was on developing the modulator that would link the Arduino and the Kiwi transmitter. Thanks to this project, I am more able to use ISIS software to design electronic boards, I learned how to print a circuit board on copper and how to solder cleanly electronic components on the board. Besides, I developed a critical mind in mechanical engineering that I think will be helpful in my career.

- **What interested you the most ?**
  All the tasks I had to do interest me as I wanted to learn as much as possible. Obviously, some tasks were more exciting like soldering and testing the printed circuit but globally I enjoyed it all.

- **What should be improved in the association for the members formation on experimental rocket ?**
  I think ESO has a problem in communicating about the fundamental knowledge required in a project like this. There should have more training dedicated to basic stuff like soldering, how to do a good CATIA model, or what to do first and what is fundamental for the C'space checks.

C'Space feedback

- **How did you live the C'Space ?**
  The C'space week was very intense, more than I couldn't expect. Working from 8a.m to 12p.m every day was difficult for everyone I guess but It was an unforgettable moment with my friends I will remember even if our rocket did not fly.

- **Which advice would you give to prepare a C'Space ?**
  I think ESO has a problem in communicating about the fundamental knowledge required in a project like this. There should have more training dedicated to basic stuff like soldering, how to do a good CATIA model, or what to do first and what is fundamental for the C'space checks.

Management feedback

- **Comments on the team and project management during the year :**
  I think our biggest mistake from the beginning of this project was the choice of the mechanical structure that made us waste a lot a time during the week. We should have known the checking list our rocket has gone through before we started. From my point of view, a better CATIA model would have been helpful because at the end we were just trying to fix a lot of little problems that I think we wouldn't had with a complete CATIA model on which the final and non-editable structure should have been based on.

- **How would you have managed the project ?**
  Concerning the management of the project and the team, my only reproach would be on the too high flexibility of the meetings. Maybe a compulsory meeting for everyone (I said everyone) would have helped to follow more carefully the project's progress.
  Finally, I would add that on a complex project such as this one, the deadlines must be respected. A solution, according to me is a careful tracking of the progress to bring solutions in time and even more people to help and absolutely respect the deadlines.

4 Tiphaine GRANDIN

Personal experience

- **How did you feel your first experimental rocket project ?**
  Designing and building an experimental rocket this year was a challenge for us. Indeed we were just beginners in rocketry and we had a lack of knowledge in this area because last year we were not very involved in our project. But we were motivated and we did our best to make it

real. Our project could have work if we have work more or work with qualified people.

- **On what did you worked and what have you learned ?**
  My main mission was to design and make two electronic timers. I was the more qualified for this task but it wasn't enough. It takes me a long time understand how a timer work but at the end, I finally succeed and the two electronic timer were working before the integration.

- **What interested you the most ?**
  I'm not good in electronic and I don't like it, but as I said, I was the more qualified for this task so I accept the job. However I had fun during the integration working on mechanics problematic.

- **What should be improved in the association for the members formation on experimental rocket ?**
  To be more efficient, ESO Association should only accept project where there is various people and not only friends. Different level of knowledge in rocketry would be interesting for those who are new in ESO for example.

C'Space feedback

- **How did you live the C'Space ?**
  C'Space was really cool; I think we all had a good time being there. We worked a lot and it was really intense but we all keep the smile during this week. Volunteer part of C'Space team was trying to motivate and stimulate us and made their best to see our rocket fly.

- **What should we have improved to launch our rocket ?**
  We should have begun the integration before the C'Space and realize how difficult it is to succeed in the first try. Maybe with an additional week, we would have the opportunity to fly.

- **Which advice would you give to prepare a C'Space ?**
  For more efficiency, take in your team someone who had already launched a rocket at C'Space and he could warn you about some difficulties you may deal with during the week.

Management feedback

- **Comments on the team and project management during the year :**
  The Manager was good and he makes a realistic planning but I think we begin to work too late and we lose precious time. An experimental rocket can be achieved by ten persons but in reality half of those people were really working.

- **How would you have managed the project in terms of planning ?**
  In the future, it will be good to have the same planning but with shorter due date. To do that, people have to work more, or we have to recruit more people.

- **How would you have managed the project in terms of tasks organization ?**
  It was a good manager even if we haven't launched our rocket. My advice to Vincent would be: Try to not understand everything and every area in the rocket for your personal knowledge but focus on your manager mission.

5 Erwan GUEGAN

Personal experience

Starting the building of an experimental rocket is a really exciting experience. Making a big Rocket is some kind of a child's dream come true and you really want to get involved in such a project. But this can also lead

to a wobbly project that will never work out in the end. Indeed, you know it's a big rocket but you might not realize the complexity of it, even if the experiment inside isn't.

Personally, I had trouble understanding what was asked from me sometimes as I was asked to perform miracles. I was asked to know everything from a subject I didn't master at all (experimental rocket) and above all, I was asked to build one. Because of that, I wish I had been taught how to build a Rocket, for example, on the previous ESO rockets and the reasons behind their success/failure.
Indeed, because of my lack of knowledge, I did a mistake that penalized all my team and prevented us to launch Solinas. This mistake was the U shaped beam. At the beginning of the year, we decided to make a rocket based on an internal structure instead of a skin based structure. We also decided to use U shaped beam because it was lighter. Because I didn't know the stress the rocked would face, I didn't realize how big a mistake this was and I strongly approved this solution. In the end this was the major problem of our Rocket and the main reason why we didn't launch it.
I think it is important that a member is taught how to dimension his rocket and most of all that he know the different options he has got.

Furthermore, one of the biggest problem of my team was communication. I asked many time the number and dimensions of the pieces the other members of the team were preparing and all I got were vague answers. Because of that, I couldn't design the rocket properly and that lead to a delay in its assembly. This problem wasn't due to my teammates being lazy but more because they didn't know them-selves those information as they didn't know either how to do for example a timer with an electronic card, or even how to weld electronic components. People involved in such a project must be taught and trained before trying to make something by themselves.

Finally, the major problem of my team was the lack of experience. Indeed, it was my first rocket ever and I was directly in charge of the CAD and the design. The others were not really more experienced than me, the only project they had being a minif.
Furthermore, our team manager, even if he managed to cut down a monstrous amount of work during the year, was only motivated by "launching a big rocket" as were most of the group members.
It is why this project didn't include a complex experiment, because it's purpose was mostly to justify the launch of an experimental rocket. That's because I think experimental rocket projects should be more overseen and justified in order to avoid groups like ours. I think we should favor innovative projects that are trying to experiment new things or technologies instead of projects like Solinas.

Despite all that, I really enjoyed the liberty we had to design our rocket and the fact that I was doing a project from scratch till the end. Most of my work was on the mechanical part, the CAD and assembly of the rocket. Overall, it was a really rewarding experience and I glad to have been a part of it.

C'Space feedback

C'Space is an impressive event with students from several schools gathered to launch their project of a year. It's really interesting to see all those project and different ways of functioning in groups.
For us, C'Space was also a really stressing event because our rocket wasn't ready at all when we arrived. We were prepared and we knew that the week would be hard to finish our project. It was a really intense week and I really enjoyed it, I think it is the best way to enjoy your C'Space. But despite all our efforts, Solinas wasn't able to fly in the end.

Indeed, our Rocket was never able to pass qualifications because of its deflection and of several design flaws. In order to make it flyable, we should have finished it before C'Space in order to notice those flaws and right them prior to bring Solinas to the event. Our problem was that we never had time to correct those design flaws during the week so the qualifications were impossible to pass.

In order to be well prepared for the C'Space, ESO should provide a way to perform every test that are included in the qualification process of C'Space in order to verify each project and correct every flaws in the conception. ESO should start a project to develop a bench for every test and a procedure to correct the possible flaws before C'Space.

Management feedback

Our group was mainly composed of a group of friend with a team manager being a member of the executive of the association. Our team manager worked hard to guide us all and try to make a coherent and efficient group. Unfortunately, I think our project didn't work out in the end because our group was not well organized.

Indeed, I think that in order to build a rocket, you need a perfect conception on CAD and to achieve that, electronics must be either defined by the CAD or developed at the same time as the CAD.
The best being in my opinion that the people in charge of electronics also be in charge of the integration of their part in the rocket. During the development phase of the project, I had to do the integration of the electronics my-self and I had trouble doing it, the number and dimensions of the cards changing every week and the communication between me and the electronic teams a bit chaotic.

Furthermore, in order to arrive prepared at C'Space, it is imperative to make a planning for the development of the rocket. It also necessary to respect those deadlines, which can be really hard when the members only come to work on the project on Thursday afternoon every two weeks. In order to finish a project, you have to be willing to give every Thursday afternoons of the year plus some evenings. It wasn't the case for everyone in our group and so we arrived with an incomplete rocket.

Finally, working in little groups to divide work in small bits like electronics and mechanics is a very good idea, it makes the project go faster and allow to use everyone's faculties at best. But it is important to maintain a good communication between groups or else it will soon become a nightmare. It was the case for our group and it lead to delays and quick fixes in the end that weren't viable.

6 Thibaut BONIT

I joined this association for the first time this year (2016-2017) to start working on this experimental rocket project called Solinas. We were around 10-15 people working on the same rocket and we started it from nothing. The project began in September and had to be finish by the end of June.

Quickly at the beginning, I worked with a small group of friends to define the shape and the dimensions we needed to give to our rocket by drawing patterns and modeling the experimental rocket thanks to an Excel software already developed. It was interesting for me to see how we start a project that big and how we define the first constraints (with the maximal weight and dimensions) which will allow us to achieve or not the flight goal we have.

Then, I was interesting by the software development and electric systems of the rocket, so I decided to work on this part with others students. It was totally new for me to work on an Arduino board, but it wasn't so complicated to learn and I enjoyed this part.

I investigated missions I already knew I would like during this project, so I kept a high level of motivation and I learnt a lot of things in comparison with the time I spent on this project (other people have spent much more time than me for sure). My only regret is that at the end of the year, during the exams period, I was too busy to work on the project. Then, I had to leave school to go aboard for my internship directly after this period. So, I left the project without having time to complete the assembly of the components I developed to incorporate them inside the rocket. Also, I couldn't participate to the C'Space which would have been an awesome experiment as far as I know.

Personal experience

- **How did you feel your first experimental rocket project ?**
  Easier to start when we are part of a team you already worked on a similar project before.
- **On what did you worked and what have you learned ?**
  I developed a software program to take over the experiment's sensors. I had some skills in programming before I started the project but I never worked on Arduino before. I was the first time for me I used real sensors to execute order in real life through the code and it was really captivating.
- **What interested you the most ?**
  Same as the previous point.
- **What should be improved in the association for the members formation on experimental rocket ?**
  A first meeting for everyone to explain the project and the mission would be better than a simple email description. It's also a good way to understand to main problematic and to answer questions you might have right at the beginning.

Management feedback

- **Comments on the team and project management during the year :**
  The deadlines were really well organized thanks to the project manager who always took care that everything was done on time. I pretty sure

that without all these deadlines, if we had only one big at the end of the project, we wouldn't have been able to finish it on time.

- **How would you have managed the project in terms of planning ?**
  It was pretty easier for me to work on my own part (software) and release it to the whole team when it was done. At this time, they were still working on the Mechanics, so the experiment integration came at the very end.

- **How would you have managed the project in terms of tasks organization ?**
  Order the components quicker because I "lost" almost 2 months to search information on sensors and Arduino to be sure I made the good choice because it was totally new for me at this time.

7 Benjamin HURST

Personal experience

- **How did you feel your first experimental rocket project ?**
  As a new member of the ESO I was enjoying the fact that my work would contribute to a real project, which I had never been part of before. The difficulty for me was to find the time to allocate to the association since I live quite far away, even though I tried to help when I could. There was a very diverse technical aspect to building of rocket

which I discovered, and unfortunately I did not manage to cover it all despite it very interesting.

- **On what did you worked and what have you learned ?**
  I've spent most of my time modeling on CATIA some various parts which were needed, the more "under the hood" type of components which were needed for the experiment. I was also asked to find solutions to certain problems encountered during development, such as finding out how to place certain pieces physically inside the rocket as the CATIA model was a detailed one but didn't specify how everything held together.

- **What interested you the most ?**
  I liked having to think of solutions for the type of problems mentioned with one of my teammates because I really felt a sense of responsibility and impact on the whole project, as well as a challenge since I was never faced with a task such as this before even if it seems simple. What I least enjoyed, despite it being necessary, was having to research the right type of spring and magnet for the parachute system. It had to be done but aside from the available space in our rocket I had no real search criteria back then, but I guess that's the kind of problem I'll have in the business world.

- **What should be improved in the association for the members formation on experimental rocket ?**
  I know the members of my group were learning at the same time as I was, so I couldn't expect them to teach me everything as they were busy discovering what there was to do themselves. But maybe the association could organize the members of each project into several duos or trios where one person has more experience. They can always work on the same task as others, but it would be more like the tutoring system at ESTACA.

Management feedback

- **Comments on the team and project management during the year :**
  The project manager was always very punctual and totally invested in this rocket, so he was always updating us on how far we were and what

the next steps were. The rocket was advancing at a steady rate thanks to these steps which didn't seem impossible to achieve when they were well broken down, so I was quite pleased with this.

- **How would you have managed the project in terms of planning ?**
  I think that having fully completed the CAD model of the rocket can save time and money later during production, and certain members can take a few steps ahead in the meantime by finding out how to build each part for the rest of the team. I found that setting deadlines left the freedom for everyone to organize themselves on how to accomplish the task at hand.

- **How would you have managed the project in terms of tasks organization ?**
  I think it all went very well and I wouldn't have done anything differently.

- **Give one strength and one point to improve of the project manager :**
  Very well organized, methodical and present in this project throughout the year. Can't find anything negative to say really.

8 Tanguy DE MERTIAN

Personal experience

- **How did you feel your first experimental rocket project ?**
  This project brought me lots of skills, as well as deeper knowledge in the rocket domain. I worked in the communication and clockery domains, but with electronics basics, i succeeded in helping building the project. It is my first year at the ESTACA and I never worked on such a project. Nonetheless, i think i adapted well to the operation.

- **On what did you worked and what have you learned ?**
  I mainly participated to the implementation of the clockwork inside the rocket. Thus i extended my knowledge in electronics, and it also permitted to use my theoretical formation already acquired.

- **What interested you the most ?**
  I found everything i did great, but what was the best in my opinion was the implementation of the electric circuit of the rocket.

- **What should be improved in the association for the members formation on experimental rocket ?**
  During the project, i was lucky to have a clockwork class, which helped me a lot understanding how it works. I think multiplying this kind of initiatives could help new members to get along with several domains linked to space.

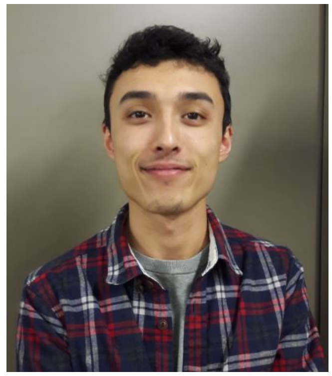
Management feedback

- **Comments on the team and project management during the year :**
  We were separated in small groups that could change over time to work faster on the project. I found this well managed and efficient.

- **How would you have managed the project ?**
  I don't think I have enough experience in projects like this to judge, but i really admired the very serious work of the manager, and at the same time his optimistic point of view.

9 Michaël BENZAARI

Personal experience



- **How did you feel your first experimental rocket project ?**
  This project was my first one in the aerospace domain and it was a good discovery for me. Indeed, the build and design of this experimental rocket was completely new and I learnt a lot of tips about the build of an electronic clock, CAD on CATIA. I acquired some basics knowledge about the structure and the equipment inside a rocket.
  It was easy to adapt myself because the team was really kind with new students and I already know two people.
  Finally, the aerospace domain is wide and there is a lot to learn about, I entered in this project to discover and see how it works inside a group project.

- **On what did you worked and what have you learned ?**
  I had some knowledge about the electronic but I learnt how to build an electronic clock, so it was interesting to apply what I have learnt the past years.
  I also improved my skill with CATIA by doing the design of small pieces and assembly.
  Finally, I had no idea about the management and the process of a project, when I watched how it is hard to manage this kind of project I realized that I don't want to be project leader but more in designing.

- **What interested you the most ?**
  In my opinion, all I did was interesting, I only regret one thing. I hadn't enough time to help more and I realize this project needed a lot of work.

- **What should be improved in the association for the members**

formation on experimental rocket ?
I think they should make a small presentation about how an experimental rocket works, and introduce the new students to the specifications to be more understandable.

Part XII
Conclusion

As a conclusion, I am convinced that all the team took good time in working on this project. We all are passionate by space activities and it was a good way to express ourselves. I advise to anybody to take part of such a project. It gives you skills that studies can not teach you and prepare you for the professional work.

It was really nice to lead this project with this team even if we all were beginners. We already were good friends and this project straightened our friendship. Beautiful values has been observed all the year as solidarity, passion, determination or tolerance. Everybody pushed himself forward and it encourages us to continue such projects.

The fact we could not launch our rocket was of course a huge deception. But I think only positive feelings get out. It shows that we took risks and we wanted to succeed. I would say it is even a victory to fail so close from our goal, when we see how far we began.

However, it raises the following question : should it be allowed to beginners to lead an experimental rocket project ? At the beginning of the year, we were advised by experimented members not to lead such a project because of our lack of experience in experimental rocket. They were right as our rocket was not launched. But is learning not the main goal of a student ? We wanted to lead an ambitious project for our last year and we would have not learned so much on a mini-rocket. I think this question depends on the behavior and motivation of the students, if they want to push themselves and are ready to do everything to succeed.

We have decided not to pursue the project next year because of two reasons. The team has been separated because of studies. Moreover, it is more interesting for everybody to begin a new project. The progression is more important for members when they are faced to new subjects. It is also easier to start from the beginning to make a strong structure and adapt the height of the stages in function of the components.

Finally, we want to thank again everybody who helped us for making this adventure possible. I also hope that this report, based on the Solinas experiment, will be useful for next experimental rocket projects.

Part XIII
Appendix

Appendix 1 : Pressure sensor MPX2200AP datasheet

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Operating Characteristics

Table 1. Operating Characteristics (V_S = 10 V_{DC}, T_A = 25°C unless otherwise noted, P1 > P2)

Characteristic		Symbol	Min	Typ	Max	Units
Differential Pressure Range[1]		P_{OP}	0	—	200	kPa
Supply Voltage[2]		V_S	—	10	16	V_{DC}
Supply Current		I_O	—	6.0	—	mAdc
Full Scale Span[3]		V_{FSS}	38.5	40	41.5	mV
Offset[4]		V_{OFF}	-1.0	—	1.0	mV
Sensitivity		$\Delta V/\Delta P$	—	0.2	—	mV/kPa
Linearity	MPX2200D Series MPX2200A Series	—	-0.25 -1.0	— —	0.25 1.0	$\%V_{FSS}$
Pressure Hysteresis(0 to 200 kPa)		—	—	±0.1	—	$\%V_{FSS}$
Temperature Hysteresis(- 40°C to +125°C)		—	—	±0.5	—	$\%V_{FSS}$
Temperature Coefficient of Full Scale Span		TCV_{FSS}	-1.0	—	1.0	$\%V_{FSS}$
Temperature Coefficient of Offset		TCV_{OFF}	-1.0	—	1.0	mV
Input Impedance		Z_{IN}	1300	—	2500	Ω
Output Impedance		Z_{OUT}	1400	—	3000	Ω
Response Time[5] (10% to 90%)		t_R	—	1.0	—	ms
Warm-Up Time[6]		—	—	20	—	ms
Offset Stability[7]		—	—	±0.5	—	$\%V_{FSS}$

1. 1.0 kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range. Operating the device above the specified excitation range may induce additional error due to device self-heating.
3. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
4. Offset (V_{OFF}) is defined as the output voltage at the minimum rated pressure.
5. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
6. Warm-up Time is defined as the time required for the product to meet the specified output voltage after the pressure is stabilized.
7. Offset stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

Maximum Ratings

Table 2. Maximum Ratings(1)

Rating	Max Value	Unit
Maximum Pressure (P1 > P2)	800	kPa
Storage Temperature	–40 to +125	°C
Operating Temperature	–40 to +125	°C

1. Exposure beyond the specified limits may cause permanent damage or degradation to the device.

Voltage Output versus Applied Differential

The output voltage of the differential or gauge sensor increases with increasing pressure applied to the pressure side (P1) relative to the vacuum side (P2). Similarly, output voltage increases as increasing vacuum is applied to the vacuum side (P2) relative to the pressure side (P1).

Figure 1 shows a block diagram of the internal circuitry on the stand-alone pressure sensor chip.

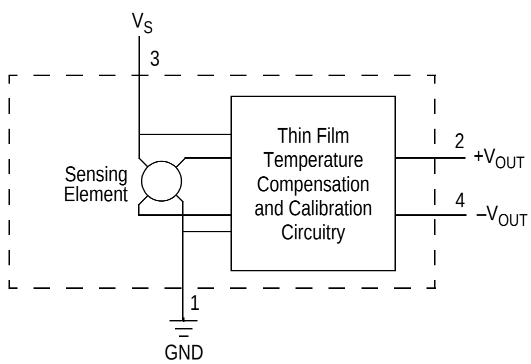


Figure 1. Temperature Compensated and Calibrated Pressure Sensor Schematic

On-Chip Temperature Compensation and Calibration

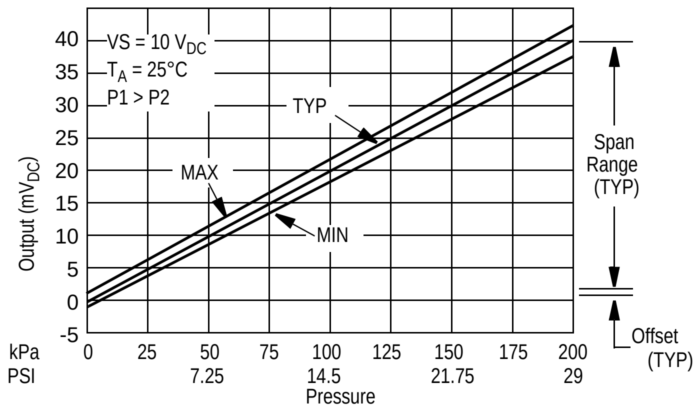


Figure 2. Output vs. Pressure Differential

Figure 2 shows the output characteristics of the MPX2200 series at 25°C. The output is directly proportional to the differential pressure and is essentially a straight line.

The effects of temperature on full scale span and offset are very small and are shown under Operating Characteristics.

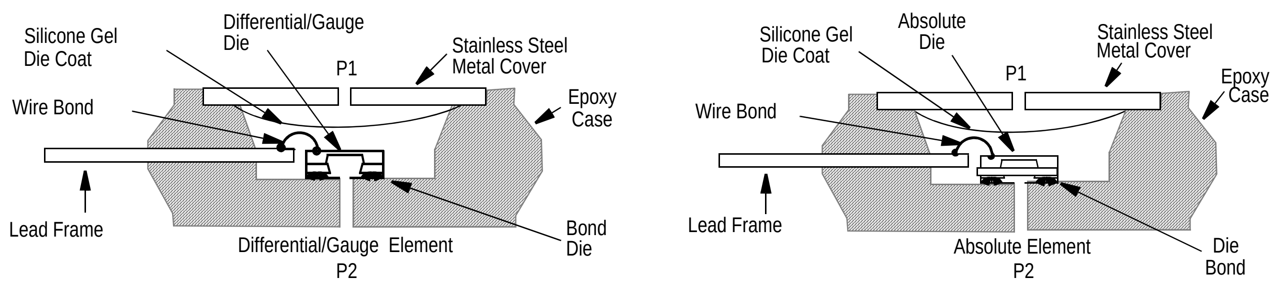


Figure 3. Cross Sectional Diagram (not to scale)

Figure 3 illustrates the differential/gauge die in the basic chip carrier (Case 344). A silicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the silicon diaphragm.

The MPX2200 series pressure sensor operating characteristics and internal reliability and qualification tests are based on use of dry air as the pressure media. Media other than dry air may have adverse effects on sensor performance and long term reliability. Contact the factory for information regarding media compatibility in your application.

LINEARITY

Linearity refers to how well a transducer's output follows the equation: $V_{OUT} = V_{OFF}$ + sensitivity x P over the operating pressure range. There are two basic methods for calculating nonlinearity: (1) end point straight line fit (see Figure 4) or (2) a least squares best line fit. While a least squares fit gives the "best case" linearity error (lower numerical value), the calculations required are burdensome.

Conversely, an end point fit will give the "worst case" error (often more desirable in error budget calculations) and the calculations are more straightforward for the user. Freescale's specified pressure sensor linearities are based on the end point straight line method measured at the midrange pressure.

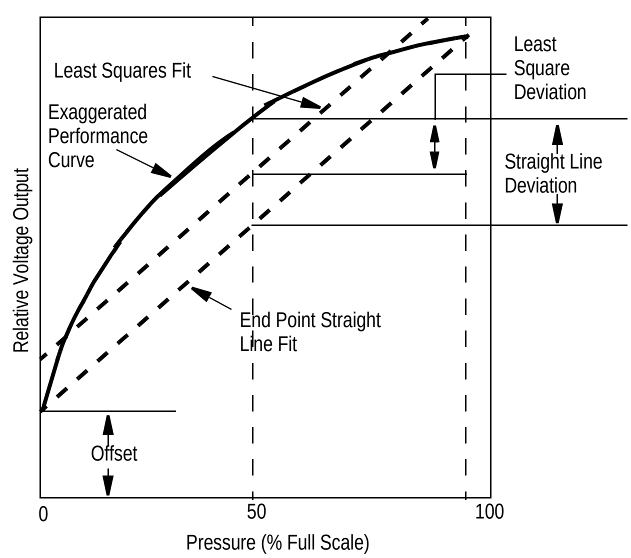
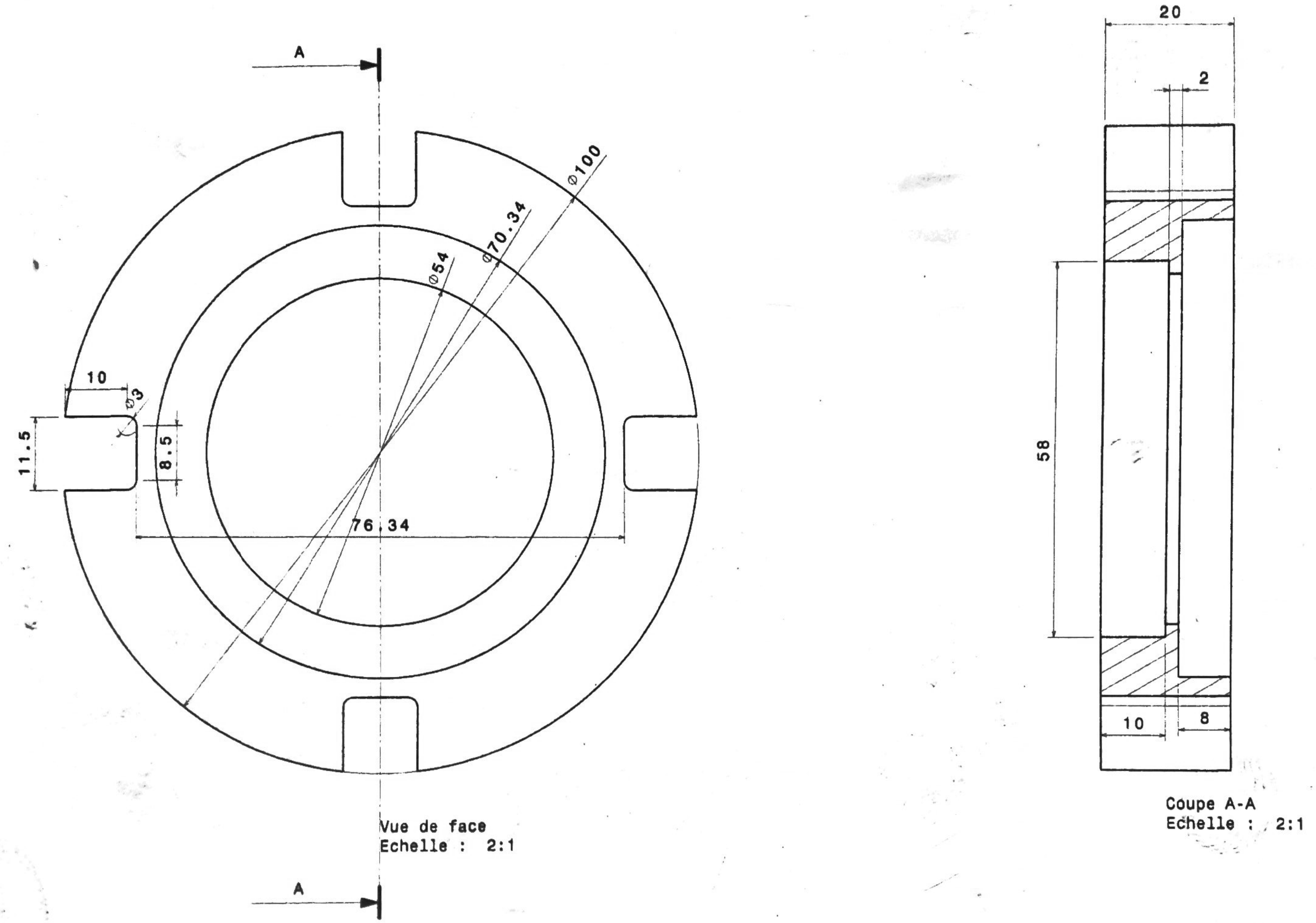


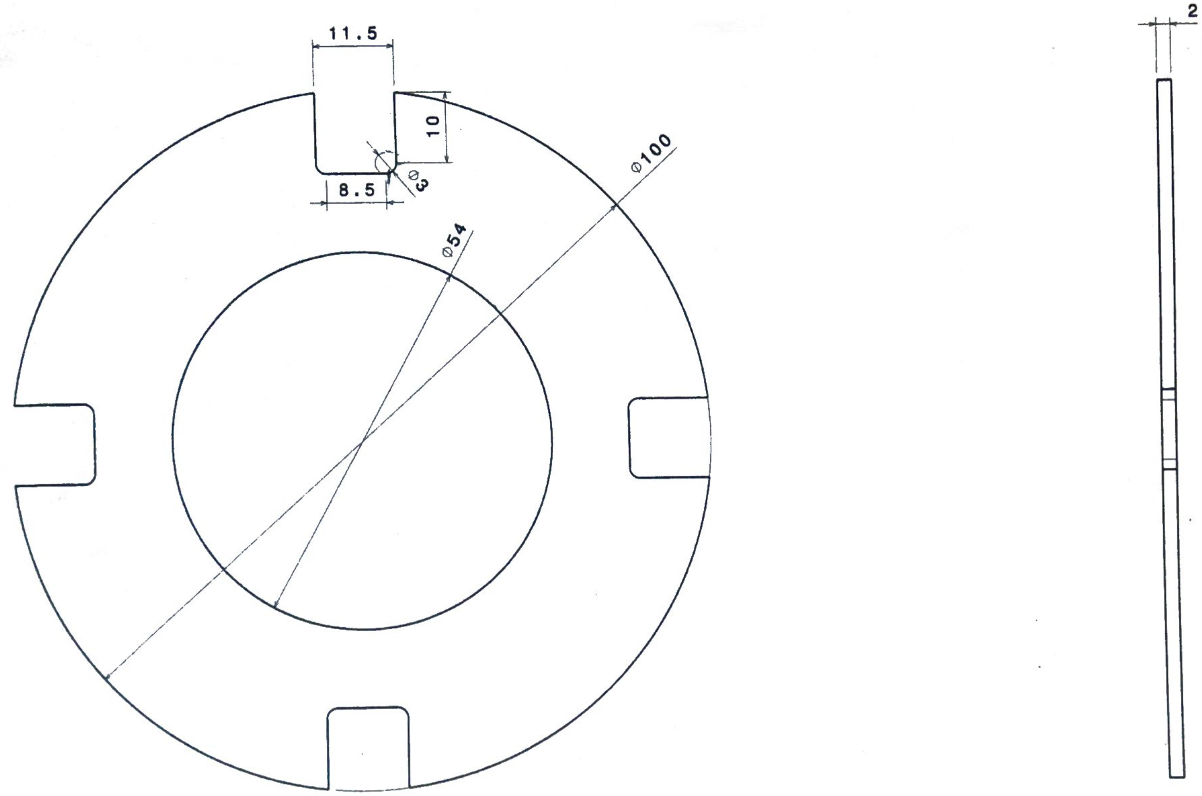
Figure 4. Linearity Specification Comparison

Appendix 2 : Rings plans

Next page



DESIGNED BY: 5537400	Propu inférieur		
DATE: 09/02/2017			
CHECKED BY: XXX			
DATE: XXX			
SIZE: A2	Solinas ESO		
SCALE: 1:1	WEIGHT (g): XXX	DRAWING NUMBER: XXX	SHEET: 1/1



Vue de face
Echelle : 2:1

Vue de gauche
Echelle : 2:1

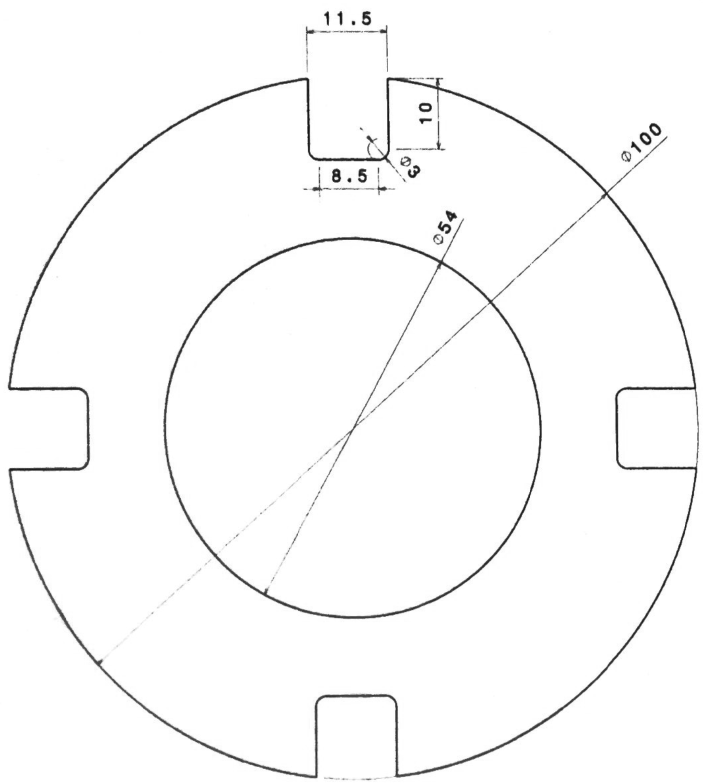
DESIGNED BY: 5537400
DATE: 09/02/2017
CHECKED BY: XXX
DATE: XXX
SIZE: A2
SCALE: 1:1
WEIGHT (kg): XXX

Centrage propu 1

Solinas ESO

DRAWING NUMBER: XXX
SHEET: 1/1

I	-
H	-
G	-
F	-
E	-
D	-
C	-
B	-
A	-



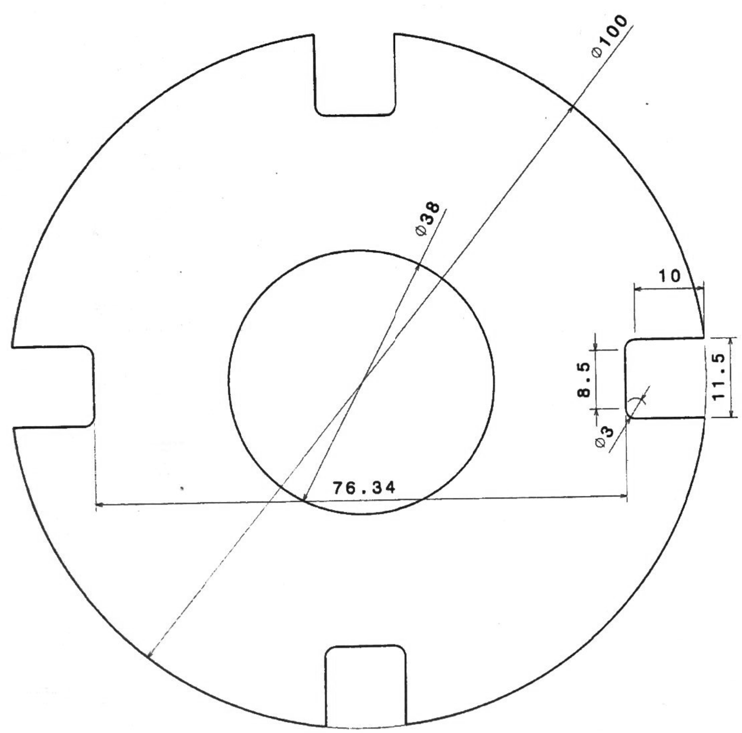
Vue de face
Echelle : 2:1

Vue de gauche
Echelle : 2:1

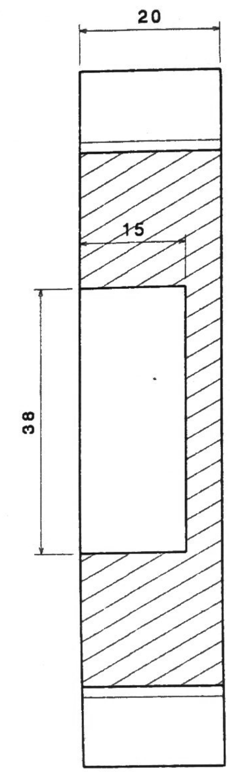
5537400	Centrage propu 2		
09/02/2017			
XXX			
XXX			
A2	Solinas ESO		
1:1	XXX	XXX	1/1

I	-
H	-
G	-
F	-
E	-
D	-
C	-
B	-
A	-

X 120.
Y 120.
Z 42,2.
P 27,4



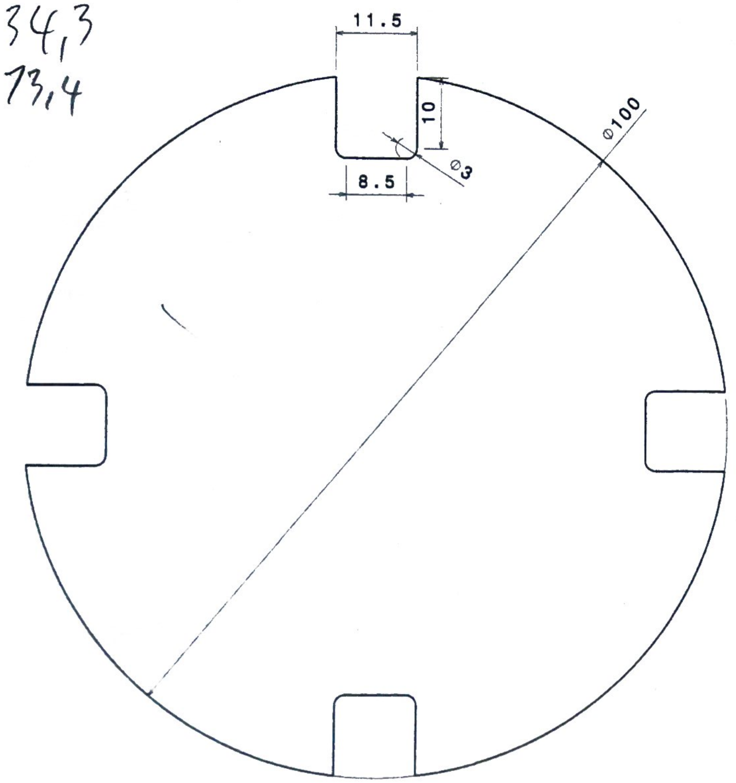
Vue de face
Echelle : 2:1



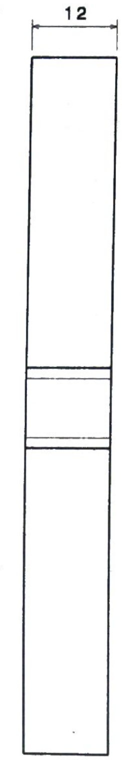
Coupe A-A
Echelle : 2:1

DESIGNED BY: 5537400	Bague de poussée		
DATE: 09/02/2017			
CHECKED BY: XXX			
DATE: XXX			
SIZE: A2	Solinas ESO		
SCALE: 1:1	WEIGHT (kg): XXX	DRAWING NUMBER: XXX	SHEET: 1/1

X 120
Y 120
Z : 34,3
P : 13,4



Vue de face
Echelle : 2:1



Vue de gauche
Echelle : 2:1

Designed by: 5537400	Bague de structure	
Date: 09/02/2017		
Checked by: XXX		
Date: XXX		
Size: A2	Solinas ESO	
Scale: 1:1	Weight: XXX	Drawing number: XXX	Sheet: 1/1

I	-
H	-
G	-
F	-
E	-
D	-
C	-
B	-
A	-

Appendix 3 : Arduino program

Next page

```
//Written by BONIT Thibaut – Completed by GADANHO Vincent


//VARIABLES UTILISEES DANS TOUT LE PROGRAMME
const int PORTPS = A0; //selectionner le port correspondant a Ps
const int PORTPT = A1; //selectionner le port correspondant a Pt

//Etalonnage

const float UsPatm = 24.95; //Tension statique avant ampli à Patm (mV
mesurés sur capteur)         /////// A AJUSTER AVANT VOL ////////
const float UtPatm = 24.75; //Tension totale avant ampli à Patm (mV mesurés
sur capteur)
const float UsPatmAmpli = 2.42; //Tension statique après ampli à Patm (V
mesurés sortie AOP)
const float UtPatmAmpli = 2.41; //Tension totale après ampli à Patm (V
mesurés sortie AOP)
const float A = (UsPatm/UsPatmAmpli+UtPatm/UtPatmAmpli)/2; //coefficient
d'amplification
const float Coef1 = 5.00; //coefficient directeur de la courbe de pression
en fonction de la tension (=200kPa/40mV)
const float Patm = 101.325; //en kPa
const float Coef2 = Patm - Coef1 * ((UsPatm+UtPatm)/2); // coefficient b de
la courbe de pression statique en fonction de la tension (y=ax+b)
float UsEq, UtEq;

const int Tsol = 20; //entier en degrés - entrer la température mesurée au
sol au début de l'expérience
const int r = 287;
const float Mair = 28.9653; //g/mol
const float R = 8.314;
const float Gamma = 1.4;
const float T0 = 273.15 + Tsol;
const float g = 9.81;
const float P0 = 101325; //en Pascal

float Ps, Pt;
float T, M, PsAnalog, PtAnalog, roh, TempsExecution;
float V = 0.0000, z = 0.0000;//valeur initiale
int a = 340; // car passage de la vitesse en int donc pour l'opération
M=V/a il faut que a soit un int

//CALCUL PRESSIONS MOYENNES
int compteur=0;
const int Ligne =15; //A MODIFIER, correcpond au nombre de valeurs de
pression dont on veut faire la moyenne          /////// ATTENTION : doit
écrire "const int" et pas "int" sinon fonctionne pas !!!
const int Colonne = 2; //(1ère colonne : Ps ; 2ème colonne : Pt)
float tableau[Ligne][Colonne];

//INTERRUPTEUR
const int PORTSWITCHER = 7; //numÃ©ro du port par l'interupteur utilisÃ©
boolean switcher; //Ã©tat de l'interupteur
boolean switcherCreate = true; //permet de rÃ©linitialiser un dossier la
1ere boucle que l'interrupteur est enclenchÃ©
float milis = 0; //variable qui permet de rÃ©initiliser millis quand
nÃ©cessaire pour nos donnÃ©es

//LED
const int PORTLEDVERT = 5; //numÃ©ro du pin choisi pour la LED
```

```
const int PORTLEDORANGE = 3; //numÃ©ro du pin choisi pour la LED
const int PORTLEDROUGE = 2; //numÃ©ro du pin choisi pour la LED
boolean LEDError = false; //Si on a une erreur la LED Rouge reste toujours
allumÃ©e

//CARTE SD
#include <SPI.h> //Library pour carte SD
#include <SD.h>
int tpsold = 0, tps = 0;
String folderName = "solinas"; //Nom du dossier, attention infÃ©rieur Ã  8
caractÃ¨res
File myFile; //nom donnÃ©e au fichier de la carte SD pour le programme
String fileName; //nom du fichier crÃ©e
/*
   SD card attached to SPI bus as follows:
   Vcc - 5v
   GND - GND
 ** MOSI - pin 11 digital
 ** MISO - pin 12 digital
 ** CLK SCK- pin 13 digital
 ** CS - pin 4
*/

//TRANSMISSION
int Bitsarray [8]; //8 bits de trame -> 256 valeurs
int VitesseConv;
const int xROutput = 10; //numÃ©ro du pin de transmission
int transmissCount = 2; //On transmet une vitesse toutes les X, sur la
carte SD
const int nbBitsTrans = 8;
int longueurTrame = nbBitsTrans * 1; //en ms

//ACCELEROMETRE
//      #include <Wire.h> //BibliothÃ¨ques
//      #include <Adafruit_MMA8451.h>
//      #include <Adafruit_Sensor.h>
//      Adafruit_MMA8451 mma = Adafruit_MMA8451();
//      float AcceX[2], AcceY[2], AcceZ[2], AcceTime[2]; //Accelerations
//      float Vx, Vy, Vz, Vfusee; //Vitesses
//      boolean accelerometreState = true;

///////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////

void setup() {
  // put your setup code here, to run once:

  Serial.begin(9600);

  //SD INITIALISATION
  Serial.println("Initializing SD card...");
  if (!SD.begin(4)) {
    Serial.println("initialization failed!");
  }
  else {
    SD.mkdir(folderName); //crÃ©e le dossier
    if (SD.mkdir(folderName)) {
      Serial.println("initialization done, folder name : " + folderName +
"\n");
    }
    else {
```

```
      Serial.println("error folder creation");
    }
  }

  //TRANSMISSION
  pinMode(xROutput, OUTPUT);  //sortie Ã  relier au modulateur
  digitalWrite(xROutput, LOW); //Ã  l'Ã©tat bas avant de commencer la
transmission

  //CAPTEURS
  pinMode(PORTPS, INPUT); //initialisation du capteur pression statique
MPX2200AP
  pinMode(PORTPT, INPUT); //initialisation du capteur pression dynamique
MPX2200AP

  //INTERRUPTEUR
  pinMode(PORTSWITCHER, INPUT); //initialisation de l'interrupteur

  //LED
  pinMode(PORTSWITCHER, INPUT); //initialisation de l'interrupteur
  pinMode(PORTLEDVERT, OUTPUT); //initialisation du LED
  pinMode(PORTLEDORANGE, OUTPUT); //initialisation du LED
  pinMode(PORTLEDROUGE, OUTPUT); //initialisation du LED

  //ACCELEROMETRE
  //      Serial.println("Adafruit MMA8451 test!");
  //      if (!mma.begin()) {
  //        Serial.println("Couldnt start");
  //        accelerometreState = false;
  //      } else {
  //        accelerometreState = true;
  //        Serial.println("MMA8451 found!");
  //        mma.setRange(MMA8451_RANGE_2_G);
  //      }

}

///////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////

void loop() {
  // put your main code here, to run repeatedly:

  switcher = digitalRead(PORTSWITCHER);

  while (switcher) {

    //CREATION FICHIER SUR LA CARTE SD
    if (switcherCreate) {
      fileName = folderName + "/" + String(millis()) + ".csv"; //nom lambda
donnÃ© au fichier de la carte SD si l'horloge est dÃ©faillante
      myFile = SD.open(fileName, FILE_WRITE); //crÃ©e le fichier sur la
carte sd
      Serial.println("File name : " + fileName);
      milis = millis();
      tpsold = 0;
      tps = 0;
    }
    switcherCreate = false;

    //CAPTEURS
```

```
    PsAnalog = analogRead(PORTPS) * (5 / 1023.0); //analogRead donne  une
valeur binaire, il faut convertir en Volts en faisant *5/1023.000000
    PtAnalog = analogRead(PORTPT) * (5 / 1023.0);

    UsEq = A*PsAnalog; //Tension statique avant ampli équivalente
    UtEq = A*PtAnalog; //Tension totale avant ampli équivalente

    Ps = (Coef1 * UsEq + Coef2)*1000; // y(Pa)=a*x(mV)+b => multiplie par
1000 car courbe est en kPa
    Pt = (Coef1 * UtEq + Coef2)*1000 -400;                    //
!!!!!!!!!!!!Coeff -400 à ajuster le jour de l'expérience, différence de
tension entre les deux capteurs après ampli!!!!!!!!!!!!!!!!!!!!!!!!

    Ps=Ps*0.01;
    Ps = (int) Ps;
    Ps = Ps*100;
    Pt=Pt*0.01;
    Pt = (int) Pt;
    Pt = Pt*100;

    tableau[compteur][0]=Ps; //Attention la numérotation commence à 0 et
pas à 1 !! => 1ere colonne
    tableau[compteur][1]=Pt; //=> 2ème colonne

    if (compteur > (Ligne-2)) { //2 valeurs inférieures au nombre de lignes

      //CALCUL PRESSIONS MOYENNES
      for (int i=0; i <= compteur; i++) {
        Ps=Ps+tableau[i][0]; //Attention la numérotation commence à 0 et
pas à 1 !!
        Pt=Pt+tableau[i][1];
      }
      Ps=Ps/(compteur+1);
      Pt=Pt/(compteur+1);

      //Permet de garder seulement 3 chiffres significatifs => la pression
est de la forme 123000.00Pa au lieu de 123540Pa      Ps=Ps*0.001;
      Ps=Ps*0.01;
      Ps = (int) Ps;
      Ps = Ps*100;
      Pt=Pt*0.01;
      Pt = (int) Pt;
      Pt = Pt*100;

      //CALCUL VITESSE
      z = (pow((Ps / P0), (R * a) / (Mair * g)) - 1) * (-T0 / a);
//alititude en m
      T = T0 - 6.50 * (z / 1000);
      roh = Ps / (r * T);
      a = sqrt(Gamma * Ps / roh);
      M = V / a;

      if (M < 0.3) {
        V = sqrt(abs(2 * (Pt - Ps)) / roh);
        V = (int) V;
      }
      else {
        V = sqrt((pow((Pt / Ps), (Gamma - 1) / Gamma) - 1) * (2 * pow(a, 2)
/ (Gamma - 1)));
        V = (int) V;
      }
```

```
      M = V / a;

      //AFFICHAGE
      Serial.println("Tension capteur Pt après amplification :" +
String(PtAnalog) + "V");
      Serial.println("Tension capteur Ps après amplification :" +
String(PsAnalog) + "V");


  //    Serial.println("As:" + String(As) + " At:" + String(At) + "
Coef2s:" + String(Coef2s)+ " Coef2t:" + String(Coef2t) + " UsEq:" +
String(UsEq) + " UtEq:" + String(UtEq));

      Serial.println("Pression totale :" + String(Pt) + "Pa");
      Serial.println("Pression statique :" + String(Ps) + "Pa");

      Serial.println("Vitesse :" + String(V) + "m/s \n");

      //TRANSMISSION
      if (transmissCount > 3) { // toutes les 2 boucles loop on transmettra
la vitesse
        VitesseConv = V * 5 / 6;
        //Attention : la vitesse est rÃ©duite de 5/6 pour la transmission
afin de prendre une marge de sÃ©curitÃ© pour ne pas dÃ©passer l'encodage en
8 bits
        //Il faudra penser Ã  multiplier cette valeur par 6/5 une fois
reÃ§ue pour retrouver la valeur exacte
        convertToBinary(VitesseConv);
        transmission();
        transmissCount = 0;
      }
      transmissCount ++;

      //ECRITURE SUR LA CARTE SD
      SDcardWritten(); //fonction qui Ã©crit dans le fichier de la carte SD
      //deboggage();

      //ACCELEROMETRE
      //Accelerometre();

      //AFFICHAGE
      Serial.print("TpsExe: ");
      Serial.print(TempsExecution, 0);
      Serial.print('\t');
      Serial.print("Freq: ");
      Serial.print(1000 / TempsExecution, 2);
      Serial.print('\t');
      //    Serial.print(accelerometreState);
      Serial.print('\n');

      switcher = digitalRead(PORTSWITCHER);
      //Serial.println(switcher);
      compteur=-1;
      Ps=0;
      Pt=0;
    }

   compteur++;

  }
  couleurLED(2); //orange = attente interrupteur off
```

```
  switcherCreate = true;
  myFile.close(); //ferme et enregistre le fichier sur la carte sd
}

///////////////////////////////////////////////////////////////////////////
/////////////////////////////////////////////////////////////////

//FONCTIONS CONNEXES APPELEES

void SDcardWritten() {
  myFile = SD.open(fileName, FILE_WRITE);
  if (myFile) {

    tpsold = tps;
    tps = millis() - milis;
    int seconds = (tps / 1000) % 60;
    int minutes = ((tps / 1000) / 60) % 60;
    int millisec = (tps % 1000);
    String temps = String(minutes) + "min " + String(seconds) + "sec " +
String(millisec);

    TempsExecution = tps - tpsold;
    myFile.print(temps + "," + String(Ps) + "," + String(Pt) + "," +
String(z) + "," + String(T) + "," + String(roh) + "," + String(a)  + "," +
String(M) + "," + String(V) + "," + String(VitesseConv) + ",");
    for (int i = 0; i < nbBitsTrans; i++) {
      myFile.print(String(Bitsarray[i]));
    }
    myFile.println("," + String(TempsExecution) + "," + String(tps));
    //Array Structure : [Temps Ps Pt z T roh a M V VitesseConv Bitsarray
tempsExe TempsBrute]
    myFile.close(); //ferme et enregistre le fichier sur la carte sd
    couleurLED(1);
  }
  else {
    Serial.println("Error finding the file !");
    couleurLED(3);

  }
}

void couleurLED(int choixLED) {
  if (choixLED == 1) {
    digitalWrite(PORTLEDVERT, HIGH);
    digitalWrite(PORTLEDORANGE, LOW);
    digitalWrite(PORTLEDROUGE, LOW);
  } else if (choixLED == 2) {
    digitalWrite(PORTLEDVERT, LOW);
    digitalWrite(PORTLEDORANGE, HIGH);
    digitalWrite(PORTLEDROUGE, LOW);
  } else {
    digitalWrite(PORTLEDVERT, LOW);
    digitalWrite(PORTLEDORANGE, LOW);
    digitalWrite(PORTLEDROUGE, HIGH);
  }
}

void convertToBinary(int VitesseConv) { //Conversion de la vitesse en
binaire
  Bitsarray[7] = 1 && (VitesseConv & B00000001);
  Bitsarray[6] = 1 && (VitesseConv & B00000010);
```

```
  Bitsarray[5] = 1 && (VitesseConv & B00000100);
  Bitsarray[4] = 1 && (VitesseConv & B00001000);
  Bitsarray[3] = 1 && (VitesseConv & B00010000);
  Bitsarray[2] = 1 && (VitesseConv & B00100000);
  Bitsarray[1] = 1 && (VitesseConv & B01000000);
  Bitsarray[0] = 1 && (VitesseConv & B10000000);
}

void transmission() { //Transmission de la vitesse
  Serial.println("Pre-Trame ...");
  digitalWrite(xROutput, HIGH);   //transmission de 8 bits de 1, signal que
l'on va transmettre une trame aprÃ¨s ces 8 bits
  delay(longueurTrame);
  digitalWrite(xROutput, LOW);

  Serial.println("Transmission en cours ...");   //transmission de la trame
  for (int i = 0; i < nbBitsTrans; i++) {
    digitalWrite(xROutput, Bitsarray[i]);
    delay(longueurTrame / nbBitsTrans);
  }
  digitalWrite(xROutput, LOW);
  Serial.println(String(Bitsarray[0]) + String(Bitsarray[1]) +
String(Bitsarray[2]) + String(Bitsarray[3]) + String(Bitsarray[4]) +
String(Bitsarray[5]) + String(Bitsarray[6]) + String(Bitsarray[7]) + "\n");
}

//void Accelerometre() {
//   if(accelerometreState) {
//          mma.read();
//          sensors_event_t evenement;  /* Get a new sensor event */
//          mma.getEvent(&evenement);
//          AcceX[2] =   AcceX[1];
//          AcceX[1] =   (float) evenement.acceleration.x;
//
//          AcceY[2] =   AcceY[1];
//          AcceY[1] =   (float) evenement.acceleration.y;
//
//          AcceZ[2] =   AcceZ[1];
//          AcceZ[1] =   (float) evenement.acceleration.z;
//
//          AcceTime[2] =   AcceTime[1];
//          AcceTime[1] =   millis();
//
//          Vx = (AcceX[2] - AcceX[1])*1000/(AcceTime[1]-AcceTime[2]);
//          Vy = (AcceY[2] - AcceY[1])*1000/(AcceTime[1]-AcceTime[2]);
//          Vz = (AcceZ[2] - AcceZ[1])*1000/(AcceTime[1]-AcceTime[2]);
//          Vfusee = sqrt(pow(Vx,2)+pow(Vy,2)+pow(Vz,2));
//
//
//      } else { //En cas d'erreur avec l'accelerometre
//        //couleurLED(3);
//        Vx = Vy = Vz = Vfusee = AcceX[1] = AcceX[2] = AcceY[1] = AcceY[2]
= AcceZ[1] = AcceZ[2] = 0;
//      }
//}
```

Appendix 4 : VBA program

Next page

```
Sub Ouverture_Fichier()
'Choix du Fichier

'Affiche la boîte de dialogue "Ouvrir"

    Fichier = Application.GetOpenFilename("Fichiers texte (*.csv),*.csv")

'On sort si aucun fichier n'a été sélectionné ou si l'utilisateur
'a cliqué sur le bouton "Annuler", ou sur la croix de fermeture.

    If Fichier = False Then Exit Sub

'Affiche le chemin et le nom du fichier sélectionné.

    MsgBox "Le fichier suivant a été ouvert : " & Fichier

'Importer le fichier TXT dans Excel

    Workbooks.OpenText Filename:= _
        Fichier, Origin:=xlMSDOS, _
        StartRow:=1, DataType:=xlDelimited, TextQualifier:=xlDoubleQuote, _
        ConsecutiveDelimiter:=False, Tab:=True, Semicolon:=False, Comma:=False _
        , Space:=False, Other:=False, FieldInfo:=Array(Array(1, 1), Array(2, 1)), _
        TrailingMinusNumbers:=True

'Appeler la fonction Repartition_et_Graphe
Call Repartition_et_Graphe

End Sub

Sub Repartition_et_Graphe()

'Détermination de la dernière ligne non-vide
Dim iFin As Double
iFin = Range("A" & Rows.Count).End(xlUp).Row

'Répartition des valeurs séparées par des virgules dans les colonnes, pour chaque ligne
For i = 1 To iFin
    Range("A" & i).Select
        Selection.TextToColumns Destination:=Range("A" & i), DataType:=xlDelimited, _
            TextQualifier:=xlDoubleQuote, ConsecutiveDelimiter:=False, Tab:=False, _
            Semicolon:=False, Comma:=True, Space:=False, Other:=False, FieldInfo _
            :=Array(Array(1, 1), Array(2, 1), Array(3, 1), Array(4, 1), Array(5, 1), Array(6, 1), _
            Array(7, 1), Array(8, 1), Array(9, 1), Array(10, 1), Array(11, 1), Array(12, 1), Array(13, 1 _
            )), TrailingMinusNumbers:=True
Next

'Faire en sorte que la colonne A est la bonne largeur pour ne pas cacher les données
 Columns("A:A").EntireColumn.AutoFit

'Recherche de la dernière colonne non vide
Dim col_Fin As Double
```

```
col_Fin = ActiveSheet.UsedRange.Columns.Count
L_col_Fin = Split(Cells(1, col_Fin).Address, "$")(1) 'Lettre de la colonne

'Remplace les points par des virgules
Range("A1:" & L_col_Fin & iFin).Select
   Selection.Replace What:=".", Replacement:=",", LookAt:=xlPart, _
      SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _
      ReplaceFormat:=False

'Mettre les données (sauf première colonne) sous format nombre
Range("B1:" & L_col_Fin & iFin).Select
   Selection.NumberFormat = "0.00"
For Each Cel In Range("B1:" & L_col_Fin & iFin)
Cel.Value = CDbl(Cel.Value)
Next Cel

'Mettre la première colonne sous format heure

Range("A1:A" & iFin).Select
   Selection.Replace What:="min ", Replacement:=":", LookAt:=xlPart, _
      SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _
      ReplaceFormat:=False
   Selection.Replace What:="sec ", Replacement:=".", LookAt:=xlPart, _
      SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _
      ReplaceFormat:=False

'Tracer les graphes
 Dim plage
 Dim LC As String

   For j = 2 To col_Fin - 3
      LC = Split(Cells(1, j).Address, "$")(1) 'Lettre de la colonne
      Set plage = Range("A1:A" & iFin & "," & LC & "1:" & LC & iFin)
   ActiveSheet.Shapes.AddChart.Select
   ActiveChart.ChartType = xlXYScatterSmoothNoMarkers
   ActiveChart.SetSourceData Source:=plage, PlotBy:=xlColumns

'Mise en forme des graphiques
Dim Colonne As Boolean
Colonne = True
Select Case Colonne

Case j = 2
   'Positionner le titre en haut et le renommer
     ActiveSheet.ChartObjects("Graphique 1").Activate
         ActiveChart.Legend.Select
         ActiveChart.SeriesCollection(1).Name = "=""Pression statique"""
         Selection.Delete
   'Ajout des titres aux axes
      ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
          ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
          ActiveChart.ChartArea.Select
```

```
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Pression statique en Pa"
            ActiveChart.ChartArea.Select

Case j = 3
'Positionner le titre en haut et le renommer
        ActiveSheet.ChartObjects("Graphique 2").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Pression totale"""
           Selection.Delete
    'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Pression totale en Pa"
            ActiveChart.ChartArea.Select
Case j = 4
'Positionner le titre en haut et le renommer
        ActiveSheet.ChartObjects("Graphique 3").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Altitude"""
           Selection.Delete
    'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Altitude en m"
            ActiveChart.ChartArea.Select

Case j = 5
'Positionner le titre en haut et le renommer
        ActiveSheet.ChartObjects("Graphique 4").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Température"""
           Selection.Delete
    'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Température en K"
            ActiveChart.ChartArea.Select

Case j = 6
'Positionner le titre en haut et le renommer
       ActiveSheet.ChartObjects("Graphique 5").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Masse volumique"""
           Selection.Delete
    'Ajout des titres aux axes
```

```
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Masse volumique"
            ActiveChart.ChartArea.Select

Case j = 7
'Positionner le titre en haut et le renommer
       ActiveSheet.ChartObjects("Graphique 6").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Vitesse du son"""
           Selection.Delete
   'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Vitesse du son en m/s"
            ActiveChart.ChartArea.Select

Case j = 8
'Positionner le titre en haut et le renommer
       ActiveSheet.ChartObjects("Graphique 7").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Mach"""
           Selection.Delete
   'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Mach"
            ActiveChart.ChartArea.Select

Case j = 9
'Positionner le titre en haut et le renommer
           ActiveSheet.ChartObjects("Graphique 8").Activate
           ActiveChart.Legend.Select
           ActiveChart.SeriesCollection(1).Name = "=""Vitesse réelle"""
           Selection.Delete
   'Ajout des titres aux axes
        ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
            ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
            ActiveChart.ChartArea.Select
            ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
            ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Vitesse réelle en m/s"
            ActiveChart.ChartArea.Select

Case j = 10
'Positionner le titre en haut et le renommer
           ActiveSheet.ChartObjects("Graphique 9").Activate
```

```
        ActiveChart.Legend.Select
        ActiveChart.SeriesCollection(1).Name = "=""Vitesse convertie pour la télémesure"""
        Selection.Delete
    'Ajout des titres aux axes
      ActiveChart.SetElement (msoElementPrimaryCategoryAxisTitleAdjacentToAxis)
         ActiveChart.Axes(xlCategory, xlPrimary).AxisTitle.Text = "Temps en s"
         ActiveChart.ChartArea.Select
         ActiveChart.SetElement (msoElementPrimaryValueAxisTitleRotated)
         ActiveChart.Axes(xlValue, xlPrimary).AxisTitle.Text = "Vitesse convertie en m/s"
         ActiveChart.ChartArea.Select
End Select


    Next

'Placement des graphes
ActiveSheet.Shapes("Graphique 9").IncrementLeft -291.75
    ActiveSheet.Shapes("Graphique 9").IncrementTop 186.75
    ActiveSheet.Shapes("Graphique 8").IncrementLeft 68.25
    ActiveSheet.Shapes("Graphique 8").IncrementTop 186.75
    ActiveSheet.Shapes("Graphique 7").IncrementLeft -291.75
    ActiveSheet.Shapes("Graphique 7").IncrementTop 402.75
    ActiveSheet.Shapes("Graphique 6").IncrementLeft 69
    ActiveSheet.Shapes("Graphique 6").IncrementTop 403.5
    ActiveSheet.Shapes("Graphique 5").IncrementLeft -292.5
    ActiveSheet.Shapes("Graphique 5").IncrementTop 618.75
    ActiveWindow.SmallScroll Down:=-6
    ActiveSheet.Shapes("Graphique 4").IncrementLeft 68.25
    ActiveSheet.Shapes("Graphique 4").IncrementTop 618
    ActiveWindow.SmallScroll Down:=-27
    ActiveSheet.Shapes("Graphique 3").IncrementLeft 427.5
    ActiveSheet.Shapes("Graphique 3").IncrementTop 186.75
    ActiveSheet.Shapes("Graphique 2").IncrementLeft 428.25
    ActiveSheet.Shapes("Graphique 2").IncrementTop 402
    ActiveSheet.Shapes("Graphique 1").IncrementLeft 428.25
    ActiveSheet.Shapes("Graphique 1").IncrementTop 618.75
    ActiveWindow.SmallScroll Down:=9
    Range("M31").Select
End Sub
```

Appendix 5 : Stabtraj

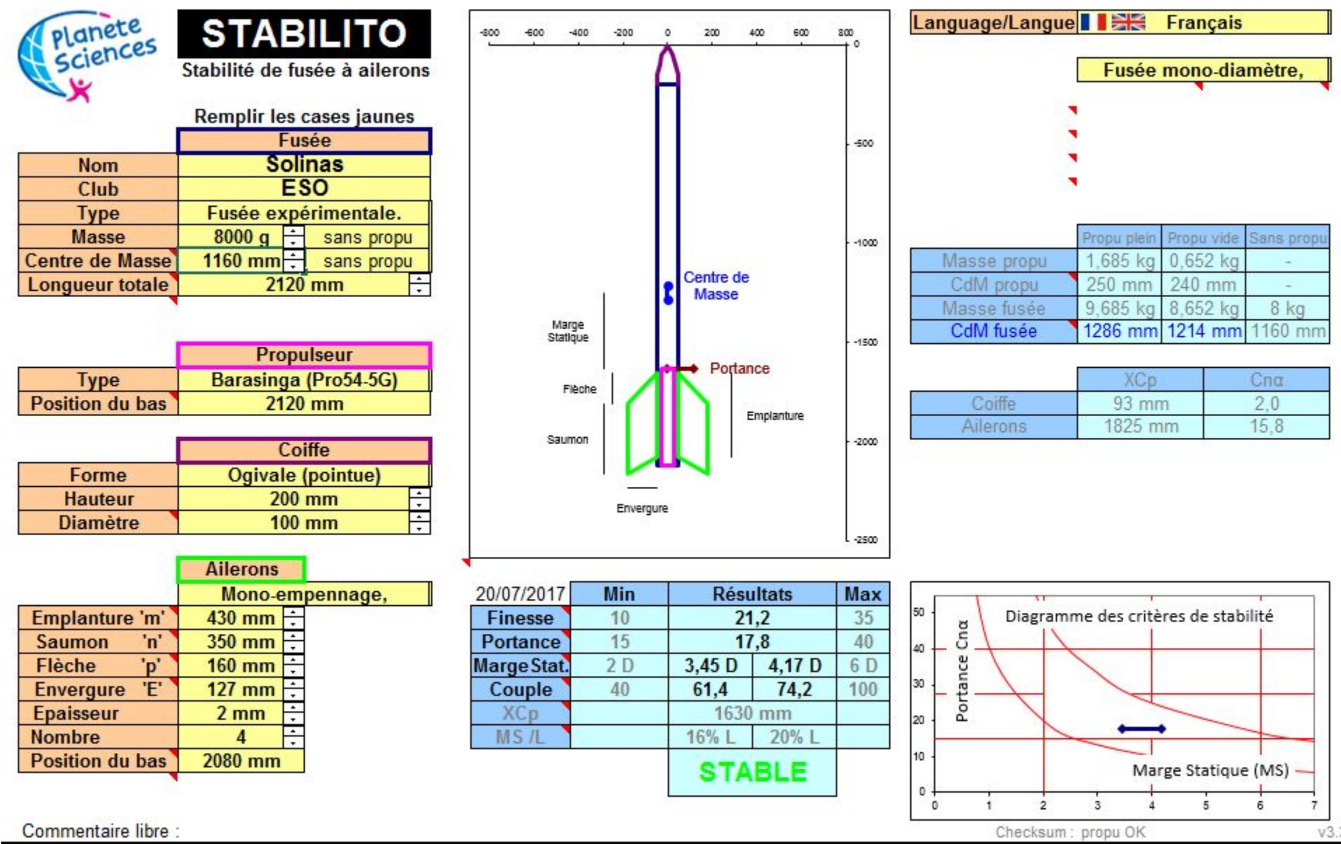
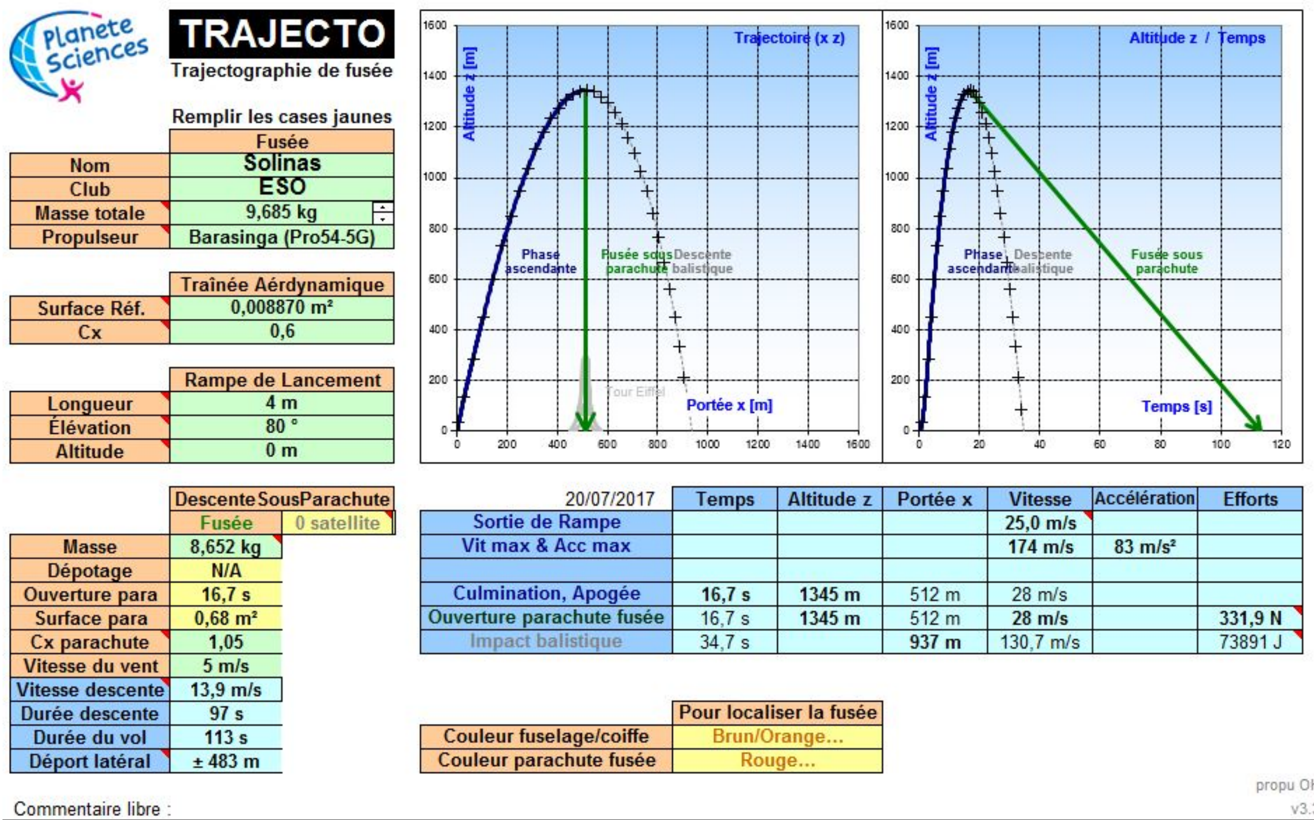


Figure 58: Stability features

Appendix 6 : Trajecto



	Fusée
Nom	Solinas
Club	ESO
Masse totale	9,685 kg
Propulseur	Barasinga (Pro54-5G)

	Traînée Aérdynamique
Surface Réf.	0,008870 m²
Cx	0,6

	Rampe de Lancement
Longueur	4 m
Élévation	80 °
Altitude	0 m

	DescenteSousParachute	
	Fusée	0 satellite
Masse	8,652 kg	
Dépotage	N/A	
Ouverture para	16,7 s	
Surface para	0,68 m²	
Cx parachute	1,05	
Vitesse du vent	5 m/s	
Vitesse descente	13,9 m/s	
Durée descente	97 s	
Durée du vol	113 s	
Déport latéral	± 483 m	

20/07/2017	Temps	Altitude z	Portée x	Vitesse	Accélération	Efforts
Sortie de Rampe				25,0 m/s		
Vit max & Acc max				174 m/s	83 m/s²	
Culmination, Apogée	16,7 s	1345 m	512 m	28 m/s		
Ouverture parachute fusée	16,7 s	1345 m	512 m	28 m/s		331,9 N
Impact balistique	34,7 s		937 m	130,7 m/s		73891 J

	Pour localiser la fusée
Couleur fuselage/coiffe	Brun/Orange...
Couleur parachute fusée	Rouge...

Figure 59: Trajectory features

Appendix 7 : Material list for C'Space

<u>C'Space 2017</u>

<u>Préparation caisse :</u>

Expérience

- Tube de Pitot (2)
- Tuyaux en plastique pour les tubes de Pitot (4)
- Capteurs de pression (4)
- AOP de secours (2)
- Jupes de secours (support AOP) (2)
- Seringue avec tube plastique (1)

Cartes électroniques

- Carte d'amplification (1)
- Carte de modulation (1)
- Minuteries (2)
- Arduino (1)
- Carte LED Arduino (1)
- Shield Arduino interrupteur (1)
- Shield Arduino carte SD (1)
- Câble blindé
- Supports piles 1.5V (2)
- Condensateurs pour carte modulation Thomas

Alimentations

- Batterie LIPO 3S (1) ➔ alimentation capteurs, AOP, Arduino
- Piles 9V (7) ➔ 2 pour le modulateur, 2 pour les deux minuteries, 1 pourle Kiwi, 2 de secours
- Piles 1.5V (6) ➔ 4 pour les deux minuteries, 2 de secours

Enregistrement des données

- Caméra (1)
- Carte micro-SD (2) ➔ 1 pour la caméra, 1 pour l'Arduino
- Adaptateur carte SD pour carte micro-SD (1)
- Kiwi (1) ➔ A RECUPERER A TOULOUSE

Sauvegarde et Cansat

- Cansat (1)
- Ressorts (2)
- Electroaimants (2)
- Crochet attache parachute
-

Parachute

- A DETERMINER ENCORE

Ailerons

- A DETERMINER ENCORE

<u>Sur la fusée :</u>

Bagues (9)

- Bague de maintien propu Alu / structure bas (1)
- Centrage propulseur Alu (2)
- Bague de poussée Alu (1)
- Bagues 3D parachute (1)
- Bagues 3D électroaimants pour porte (2)
- Bague structure haut Alu (1)
- Bague coiffe Bois (1)

Coiffe (1)

Treillis (4)

<u>A acheter sur place</u>

Peinture (mais peut-être fait après le vol, pas une priorité)

Scotch double face ou scrotch (scotch et scratch) ➔ fixation de spiles

Appendix 8 : Poster solinas

Here is a poster made to present the Solinas project during some ESO events. Some of the values described have changed since this moment.

Figure 60: Solinas poster

Appendix 9 : Flight chronology

Chronologie – Solinas – FX 29

EN TENTE CLUB

Electronique		
Fermer interrupteur minuteries (parachute et cansat)		
Vérifier LED rouge minuteries allumées		
Retirer les jack		
Vérifier LED jaune minuteries allumées		
Vérifier LED verte minuteries allumées au bout de 16 secondes		
Remettre les jacks		
Ouvrir interrupteur minuteries		
Allumer l'Arduino en fermant l'interrupteur rouge		
Vérifier LED orange carte alim Arduino allumée		
Lancer enregistrement sur carte SD en fermant le gros interrupteur Arduino		
Vérifier LED verte carte alim Arduino allumée		
Ouvrir le gros interrupteur Arduino		
Eteindre l'Arduino en ouvrant l'interrupteur rouge		
Cansat		
Introduire le Cansat en force		
Fermer porte		
Mécanique		
Vérifier la présence des goupilles sur la bague propu		

EN RAMPE

ESTACA Space Odyssey C'space 2017 1

/!\ Vérifier pendant toute la mise en rampe que les LED jaune ou verte des minuteries ne s'allument pas /!\

/!\ Vérifier pendant toute la mise en rampe que les LED rouge de l'Arduino ne s'allume pas /!\

First of all : Lire la chronologie	Vincent	
/!\ Rappeler la presence d'objets fragiles /!\	Vincent	
Introduire doucement la fusée en rampe		
Actionner interrupteurs minuteries, expérience (rouge puis gros interrupteur) (4 INTERRUPTEURS !)		
Vérifier 2 LED rouges minuteries (alim on)		
Vérifier LED verte Arduino allumée (début enregistrement)		
Etage propulsif		
Vérifier la présence des goupilles sur la bague propu		