Technical Project: CANSAT

MILESTONE 1: Technical specifications

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Background

The CanSat France competition is an annual competition open to students from all disciplines, including engineering schools, universities, IUTs, IUPs and BTSs. Its aim is to encourage student teams to design and build micro-satellites called CanSats. These teams, supported by Planète Sciences and CNES, take part in projects simulating scientific missions. The competition attracts students interested in engineering, aerospace and scientific research.

This year, our team will be taking up the challenge. In a context where interplanetary probes are being sent further and further out, passing through atmospheres of varying densities, these probes need to separate into two modules to slow their fall and send back valuable scientific data with little energy. Similarly, our CanSat will have to carry out several critical missions, like data collection, telemetry and information transmission, while integrating these systems into an extremely small space, equivalent to a can of soda (between 33cl and 100cl).

The main aim of the competition is to raise students' awareness of the challenges of space engineering while providing them with an immersive educational experience. Participants develop skills in design, manufacturing and project management by tackling real-life aerospace industry problems. By designing a miniature satellite capable of carrying out scientific missions, the teams taking part in the competition learn how to integrate complex systems in a restricted space, while demonstrating innovation and creativity.

The competition also encourages scientific experimentation, as the teams must collect and analyse environmental data. This reinforces their technical learning and their ability to solve concrete problems in a collaborative setting. For those who are not yet passionate about space, this competition also aims to arouse passions.

Student teams register with CNES via the dedicated website, and have one year to design, build and test their CanSat. The 2025 edition of the CanSat France competition will take place from 6 to 13 July 2025, on the 1st RHP firing range in Tarbes, in the Hautes-Pyrénées department.

State of art

To establish the state of the art for CanSat, we need to look at what is already being done in the various technologies that we are going to use to achieve our objectives.

We therefore need to look at what is being done in terms of altitude sensors, fall deceleration and battery autonomy in machines with objectives close to ours.

1. Altitude sensors

Being able to determine the altitude of our CanSat during the entire fall is one of the most important characteristics.

1.1. Pressure sensors

Pressure sensors are used in a very large number of machines and are extremely useful when it comes to determine an altitude. They also are relatively small which is very convenient as we have to fit them in a small volume.

Drones

Drones, use pressure sensors to determine their altitude (altimeter).

The TE's digital barometric pressure sensors **MS5607** and **MS5611** are used in drones and measures atmospheric pressure and then converts it into altitude.

- **Pressure sensor type:** Digital pressure and altimetry
- **sensor modules**
- **Pressure type:** Absolute
- **Output signal type:** 24-bit ADC
- **Pressure accuracy:** ± 1.5 mbar / ± 4 mbar
- **Supply voltage (V):** 1.5 - 3.6

Figure 1: MS5607

These sensors identify an air pressure of **1.5 mbar** (MS5611) and **4 bar** (MS5607) which correspond approximately to a lifting height of **10 cm** at low altitude, close to sea level. It also requires a supply voltage between **1.8 V** and **3.6 V** which is within the CNES specifications. Both sensors can be used on a PCB and can be found under 13 €.

There are of course several other pressure sensors such as the **BMP388** used in the **drone DJI Mavic Air 2**. It can be found under 10 € but is relatively less accurate than the **MS5607** and **MS5611** with an accuracy of 0.7 meter at low altitude.

Figure 2 : DJI Mavic Air 2

Weather balloons

Another machine that shares similarities with our project, and which also needs to determine its altitude, are the weather balloons.

For instance, the **Vaisala PTB330** is used in scientific research balloons for altitude and pressure measurements on NOAA (National Oceanic and Atmospheric Administration) missions.

Figure 3 : Vaisala PTB330

Figure 4NOAA Balloon

The problem with these sensors is that they meet **very demanding expectations** that are not our own. They still operate at altitudes of several kilometres and have a lifespan of several years. As a result, their price is extremely high (several hundreds of euros) and are **not interesting for our application.**

Limitations of a barometer

The accuracy of a barometer is influenced by several key factors. Firstly, temperature plays a crucial role, as variations in temperature can change the density of the air, affecting pressure measurements.

Humidity is also a factor. More humid air is less dense than dry air, which can distort readings. In addition, it is imperative that the barometer is regularly calibrated; without this attention, measurements can quickly become inaccurate.

Vibrations and physical shocks, particularly in the case of mercury barometers, can also affect accuracy. Finally, the positioning of the barometer is crucial: placing it near a heat source or in a draught can affect the results.

By taking these various parameters into account, it is possible to adjust and set the barometer to obtain accurate measurements in the desired conditions. This makes it possible to optimise its use according to the user's specific needs.

Overall, an altimeter similar to **drone's** pressure sensors seem very **well suited** to our application. They have the level of precision we are looking for, can be used on a PCB and are within our budget. Moreover, an altimeter can be associated with GPS and accelerometer for a better precision and more information about the CANSAT movements.

1.2. GPS

Another way of determining the altitude of an object is by using a **GPS**. GPS uses satellites to determine the position of an object on Earth, including its altitude. Devices such as smartphones, connected watches and dedicated GPS devices (such as those used in hiking or aviation) incorporate this technology.

Many GPS modules are currently on the market with similar performances.

The **Adafruit Ultimate GPS Breakout**, for instance, used on 3DR Iris+ drones can be found around $29.95:

- -165 dBm sensitivity, 10 Hz updates, 66 channels
- 5V friendly design and only 20mA current draw
- Breadboard friendly + two mounting holes
- RTC battery-compatible
- Built-in datalogging
- PPS output on fix
- Internal patch antenna + u. FL connector for external active antenna
- Fix status LED

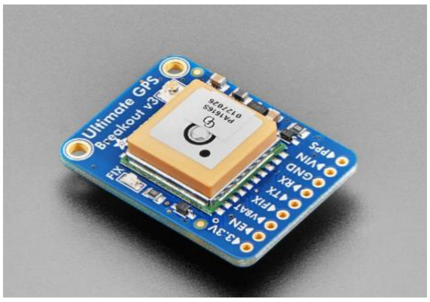

Figure 5 : Cirrus SR22

However, it is important to note that the altitude measured by a GPS may **not be as accurate as that obtained by barometric altimeters**. The weather, radio interference, satellite quality, Physical obstructions (trees, buildings, etc...) can compromise the accuracy of measurement.

Manufacturers' datasheets indicate an accuracy of **5 metres** with ideal conditions which is acceptable but not ideal for a drop of 120 metres. But if all the conditions are not met, accuracy can drop to 10 metres.

1.3. Accelerometer

We can use an accelerometer to determine the speed of our CANSAT.

The accelerometer measures variations in acceleration on the three axes (x, y, z). Vertical acceleration (z) is used to estimate altitude.

By integrating the acceleration measurements over time, we can obtain the speed. Once the velocity has been obtained, we can integrate again to obtain the position (altitude).

By knowing the initial position and velocity, you can adjust the integration results for greater accuracy.

They are used in many kinds of object such as Smartphones, cars, planes...

The Cirrus SR22, use sensors, including accelerometers, for advanced flight control systems and other navigation functions.

Figure 6 : Cirrus SR22

An example of an accelerometer module commonly used in aviation and other applications is the **ADXL345 (**found under 10 €):

- **Type:** Digital 3-axis accelerometer
- **Measurement range:** ±2g, ±4g, ±8g, ±16g
- **Interface:** I^2C and SPI
- **Resolution:** 13 bits
- **Applications:** Used in navigation systems, flight controllers and other on-board devices.

An example of a device incorporating the **ADXL345** accelerometer is the Parrot **AR. Drone 2.0 drone**. This drone uses several sensors, including the ADXL345, to stabilise its flight and improve navigation. It is also used in the iPhone 6 for movement and orientation features.

In many cases, accelerometers are combined with other technologies to improve the accuracy and reliability of measurements such as gyroscopes, barometer or GPS. It is because many factors can influence the measures made by an accelerometer:

- external vibration
- Temperature variation

- Alignment of the device in relation to the axis of gravity
- Electronic noise

To mitigate these influences, it is often necessary to implement filtering techniques, regular calibration and combination with other sensors to improve the overall accuracy of measurements.

In general, when using an accelerometer alone to estimate altitude, an accuracy of around **±10 metres** can be expected, but this can vary depending on the conditions of use and data processing methods.

For applications where greater accuracy is required, it is recommended that the accelerometer be coupled with other sensors, such as a barometer or GPS, to improve the reliability and accuracy of altitude measurements.

1.4. Conclusion

In conclusion, pressure sensors, like those used in drones, are proving to be the most suitable for our needs in terms of accuracy, size and cost. Although other technologies such as GPS and accelerometers exist, they have limitations in terms of accuracy or sensitivity to environmental conditions. Therefore, a combination of these technologies, in particular with pressure sensors, seems to be the best approach to ensure reliable and accurate altitude measurements in our application.

2. Means of slowing down the fall

Slowing down the fall of our CANSAT is essential as it need to descend to the ground with a speed between 2m/s and 15m/s and withstand the landing. Many machines need to slow down their fall or reduce their speed and many technologies are used to achieve this goal.

Figure 7 : Space x Reusable spaceships thrusters

Figure 8 : ULM's parachute

Figure 9 : Non-aerodynamism profile (spoiler)

Figure 10 : Helicopter and its propellers

Thus, we have a lot of technologies that solves our problem, but few are applicable to our CANSAT. Among the examples above, only the non-aerodynamism profile and the parachute would be applicable to our project, the others being too complicated or dangerous to implement.

A. <u>Parachutes</u>

There are many different types of parachutes, each designed to slow down the object carrying it to a greater or lesser degree depending on the mission.

There is for example the round parachutes, the cruciform parachutes, the Rogallo wings, ram air parachutes.

They each have different objectives. Some are designed to allow the load to glide more freely, others to give maximum control of the trajectory. But what's important to us is the parachute's ability to slow the fall of the CANSAT, and according to the literature it's the round and the cruciform parachutes fulfil the best this role. They are used to slow down returning satellites, slow down aircraft or slow down parachuted cargo.

Figure 11 : Nasa's spacecraft: Insight

Figure 12 : Breaking parachute

B. <u>Aerodynamism</u>

We can also take an interest in the aerodynamics of certain system's structure designed specifically to slow it down. This is the case with airbrakes on aircraft, but also with certain cars where the rear wing can move during braking to maximise air intake.

The Apollo capsules also had a fairly wide profile to slow the fall and arrival in the atmosphere.

Thus, we can draw inspiration from these models to design the structure of our CANSAT.

Figure 13 : Apollo capsule

3. Battery autonomy

For the battery there is several options we can consider:

- **Lithium-Polymer (LiPo)**

The Lithium-Polymer batteries have a high energy density, and they are also light and compact, which is useful for a CanSat project. Finally, Lithium-Polymer batteries can deliver high current, which is valuable for sensors and motors.

- **Lithium-Ion (Li-ion)**

The Lithium-Ion batteries have a good energy density, but not as good as LiPo. However, Lithium-Ion batteries have a long-life cycle and are safer and more reliable than LiPo, even though they are a bit heavier.

- **Nickel-Metal Hydride (NiMH)**

NiMH batteries are safer in case of overcharging and are tougher than both LiPo and Li-ion. However, they are heavier and have lower energy density.

- **Lithium-Iron Phosphate (LiFePO4)**

LiFePO4 batteries are safe and stable, with a good life cycle and performance at high temperature. However, they are also a bit heavier and have lower energy density.

Conclusion

In conclusion, pressure sensors, like those used in drones, seems to be the best way to determine the altitude of the CANSAT. They are proving to be the most suitable for our needs in terms of accuracy, size and cost. Although other technologies such as GPS and accelerometers exist, they have limitations in terms of accuracy or sensitivity to environmental conditions. Therefore, an altimeter is required, we could also imagine a combination of technologies with accelerometer and a GPS for a better precision and more data about speed and location.

To slow down our CANSAT during its fall, a parachute (round or cruciform) and a non-aerodynamic profile such as wings seems to be a suitable solution. Other technologies do not comply with the requirements of the subject or are not suited for the size of our project.

To ensure the autonomy of our CANSAT, we will choose a lithium battery. Depending on whether we want to prioritize weight or robustness, we will respectively choose between LiPo and Li-ion.

Environmental approach

In order to lead our project with an environmental approach, we chose to use recyclable and eco-friendly materials such as lightweight alloys, natural composite fibers, and recycled plastic. following the same idea, we also chose to make our CanSat as modular as possible so that most of the components can be reused and replaced easily.

For the atmospheric measurements, we opted to use a small particle sensor, allowing our CanSat to analyze the air quality according to altitude. Another aspect we considered is energy consumption. To manage this, we will use a rechargeable lithium-ion battery, known for its high energy density and good reliability but also for its lightweight.

Regarding the end-of-life cycle of our CanSat, since the launch altitude won't be so high, we will be able to recover the CanSat and sort all its components from electronics to composite. We should be able to reuse many of the parts, such as the various modules like the sensor, and the battery, as it can be recharged.

User stories and product backlog

User stories

User Story 1: Separation

As a head of the CanSat competition I want the CanSat to separate into two modules at an altitude of 50 meters in an autonomous way, so as to slow the probe's fall by reducing its weight.

SMART Goal: The CanSat must automatically separate in two modules at an altitude in the range of 47 and 53 meters.

User Story 2: Atmospheric conditions measurement

As a head of the CanSat competition, I want the CanSat to measure the altitude and the fine particles so I can have an overview of the atmospheric conditions of a designated location.

SMART Goal: The CanSat must measure the altitude and the fine particles every second during its fall.

User Story 3: Measure distance between modules after separation

As a head of the CanSat competition ,I want the CanSat to measure the distance between its modules so I can simulate a mission scenario in which several parts of a space probe separate to collect data from different points and get an overall view of their trajectory.

SMART Goal: The CanSat must measure the distance between its modules every second during its fall.

User Story 4: Data transmission

As a head of the CanSat competition I want the CanSat to send the collected data about the atmosphere and the measurement of the distance between the modules back to the operation center so I can visualize them in real time.

SMART Goal: Each data collected by the CanSat must be send each second to the operation center.

User Story 5 : Safe Landing

As a head of the CanSat competition, I want the CanSat and all the ejected elements to resist a fall of 120 meters and land at a speed between 2 and 15 meters per second, so that the CanSat, the embedded technology and the ejected elements will not break upon impact.

SMART Goal: The CanSat and all the ejected elements must resist a fall of 120 meters and land at a speed between 2 and 15 meters per second.

User Story 6: Dimensioning

As a head of the CanSat competition, I want the CanSat to have a basic volume of 1 liter 80mm diameter and 200mm height and weight maximum 1kg , so that the CanSat so that It can consume less energy be more easily transportable and match the release system dimensions.

SMART Goal: The CanSat must have a basic volume of 1 liter 80mm diameter and 200mm height and weight maximum 1kg.

User Story 7 : Autonomy

As a head of the CanSat competition, I want the CanSat to have a autonomy of 45 min, so that I can limit the number of times I have to recharge it.

SMART Goal: The CanSat must have an autonomy of 45 min.

<u>User Story 8</u>: CanSat Systems

As a head of the CanSat competition, I want the CanSat to have a maximum electrical voltage difference (Vmax-Vmin) is limited to 30 V , a pneumatic systems are limited to 10 bar and a recovery chain able to withstand a force of 20 N so that I can protect the CanSat and the people using it.

<u>SMART Goal</u>: The pneumatic systems are limited to 10 bars. The maximum electrical voltage difference (Vmax-Vmin) is limited to 30 V. The recovery chain must be able to withstand a force of 20 N.

Table 1 : Requirement Specific

Function	Function statement	Acceptance criteria	Requirement levels
FP1	The CanSat must separate in two modules.	Altitude of splitting	50 meters ± 3 meters
FP2	The CanSat must measure altitude	Altitude h	H ± 3 meters
FP3	The CanSat must measure the distance between its modules.	Distance D between the modules	D ± 3 meters
FP4	The CanSat must measure the fine particles.	Particle density ρ 0,3μg/m³	ρ ± 15 %
FP2	The CanSat must send the altitude measurement to the operation center.	Duration D between each data sent.	0s<D<1s
FP3	The CanSat must send the measurement the distance between its modules.	Duration d between each data sent.	0s<d<1s
FP4	The CanSat must send the fine particles measurement to the operation center.	Duration d between each data sent.	0s<d<1s
FC1	The CanSat must take maximum 5 minutes to reach the ground	Duration d	0min<d< 5min
FC2	The CanSat must weight maximum 1kg.	Mass m	M<1kg
FC3	The CanSat must have a basic volume of 1-liter 80mm diameter and 200mm height	Dimensions in mm	V<1L D<80mm H<200mm
FC4	The CanSat and all the ejected elements must resist a fall of 120 meters and land at a speed between 2 and 15 meters per second.	Speed vc in m/s	2m/s<vc<15m/s
FC5	The CanSat must have an autonomy of 45 min.		
FC6	Rotating or sharp components must be protected by fairings.		
FC7	Deployable elements must be deployed beyond the basic volume at the release end only.		
FC8	The transmission system must be able to send data to 130 meters	transmission distance Dt	Dt>130 meters

	Telemetry systems must comply with French regulations. Usable frequencies and HF emitted power must be as follows: • 433MHz band with a maximum power of 10mW • 868.5MHz to 869.2MHz band with maximum power of 25mW • Band 869.4MHzto869.65MHzwitha maximum power of500mW • 2.4GHz band with maximum power of 100mW • 5.8MHz band with maximum power of 25mW • The 144-146MHz band may be used provided that a licensed radio amateur is present during transmissions. • GSM frequency bands are authorized. • The 868.0-868.5MHz band is forbidden.		
FC9	Each team can attach a module to the drone. The mass of this module must weigh less than 380g	Module mass mm	mm<380g
FC10	Speed is almost zero at the moment of release.	Speed of release	vr is close to 0
FC11	Drops take place in wind conditions of less than 5m/s	Speed of wind vw	vw <5m/s

Table 2 : Gantt Diagram

ID	Task	Start Date	Due Date	2024					2025			
				S	O	N	D	J	F	M	A	M
1	**Milestone 1 : Technical Specification**	09/09/2024	23/09/2024									
1.1	Project Background and context	09/09/2024	20/09/2024									
1.2	Requirements Specifications	09/09/2024	20/09/2024									
1.3	Making the Gannt Diagram	09/09/2024	20/09/2024									
1.4	State of the Art	09/09/2024	20/09/2024									
1.5	Making the final report	09/09/2024	22/09/2024									
1.6	Proof Reading everything	09/09/2024	23/09/2024									
2	**Milestone 2 : Concept**	23/09/2024	22/10/2024									
2.1	Concept Brainstorming	23/09/2024	27/09/2024									
2.2	Kinematics diagram	27/09/2024	04/10/2024									
2.3	Energy chain diagram	27/09/2024	04/10/2024									
2.4	Pré-dimensioning calculation	04/10/2024	22/10/2024									
2.5	Sketches and diagram to explain how it works	04/10/2024	22/10/2024									
2.6	Start the CAO phase	04/10/2024	22/10/2024									
3	**Milestone 3 : Bill of material**	22/10/2024	18/11/2024									
3.1	Listing product components	22/10/2024	04/11/2024									
3.2	Listing raw materials	22/10/2024	04/11/2024									
3.3	Provider identification	04/11/2024	18/11/2024									
3.4	Identifiaction of material that can be supply by the school	04/11/2024	18/11/2024									
4	**Milestone 4 : Technical file**	18/11/2024	16/12/2024									
4.1	Details and assembly drawing	18/11/2024	25/11/2024									
4.2	Routing of all parts	25/11/2024	02/12/2024									
4.3	Wiring diagrams	02/12/2024	07/12/2024									
4.4	Software algorithm	07/12/2024	04/12/2024									
4.5	Calculation and simulation results	04/12/2024	09/12/2024									
4.6	Risk analysis	09/12/2024	13/12/2024									
4.7	Product qualification planning	13/12/2024	16/12/2024									
5	**Milestone 5 : Sub-assembly Qualification**	16/12/2024	03/02/2025									
5.1	Test Sub-assembly functions	16/12/2024	20/01/2025									
5.2	Update of the technical file	20/01/2025	25/01/2025									
5.3	Update of the product qualification	25/01/2025	03/02/2025									
6	**Milestone 6 : Integration Test**	03/02/2025	17/03/2025									
6.1	Test assembled product functions	03/02/2025	10/03/2025									
6.2	Update of the technical file	10/03/2025	12/03/2025									
6.3	Update of the product qualification	12/03/2025	17/03/2025									
7	**Milestone 7 : Final qualification test**	17/03/2025	25/04/2025									
7.1	Preparation of the presentation of a functionnal prototype	25/11/2025	25/11/2024									
7.2	Finalisation of the technical file	25/11/2025	25/11/2024									
7.3	Finalisation of the product qualification	25/11/2024	25/04/2025									

Sources

Capteur pression

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