# 1. Introduction

The CanSat competition organised by ESERO consists of teams building and launching a can at around 1km of altitude, using a rocket. The can is meant to contain the necessary equipment to measure both the temperature and pressure of the atmosphere. On top of that, each team is required to find a secondary mission which further enhances their project. Teams are expected to show great innovative skills to overcome the mission's challenges, such as the design of the can, building of antenna to collect data, and set up of different systems.

Can.net is made up of 5 members: Gabriel, Cillian, Aboubaker, Martin, and Ugo. We are 16-year-old students from the "Lycée Français Vauban Luxembourg", each in our penultimate year of High School. Gabriel and Martin are long established members of the Vauban Makerspace (MS20): they are more accustomed to projects like CanSat. Can.net got the idea to participate in this event thanks to Mr. Metzler, our technology teacher, but also thanks to past exposure to the project and Instagram accounts of previous CanSat competitors. We intend to go as far as possible in the competition, learning as much as we can (pun intended) and at least completing the primary mission.

Our secondary mission consists in determining our can's position through trilateration and tracing its trajectory. We have chosen this specific scientific subject for our secondary mission as we were greatly intrigued by our can's trajectory throughout its launch. However, we did not want to depend on satellites to locate our CanSat: we wanted to be as independent as possible and go as far as we could, without tasks already done for us. Indeed, we aim to make a project that can be fully recreated with as little third-party tools as possible. We found an alternative to GPS after watching a video about 'SoundThinking' in the U.S. (Source: « Wired » on YouTube, see video below if interested). This video addresses the use of sound and trilateration to locate gunshots. The idea is simple: we can pinpoint the location of a signal emitter by finding its distance relative to three distinct points, using the signal's strength (a weaker signal translates to a greater distance and vice-versa). We then realized we could use this same method with our CanSat to precisely locate it, given that it emits radio signals. With the help of special antennas, we will build a graph that determines the position of the Can. Although we aim not to use GPS, we will rely on it to verify our results.

In this report, we will present our missions' objectives, as well as the means we have put in place to complete them. This includes our different designs and systems, as well as our overall method, tests, and difficulties encountered.

[We Tracked the Secret Police Microphones Hidden Everywhere | WIRED](#) (1)
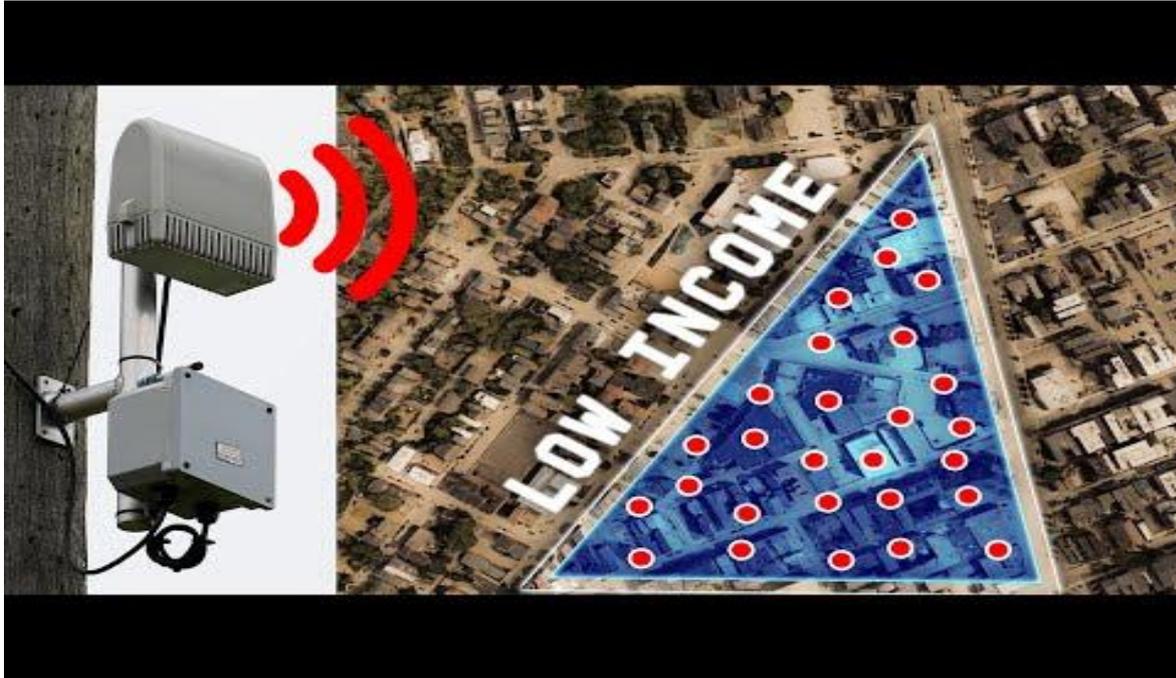
2. Project description

2.1   Mission overview

Primary Mission

The primary mission consists of loading our CanSat in a rocket. At 1km of altitude, the can should be ejected from the rocket, and a parachute should deploy to assure it descends safely.

The primary goal is real-time transmission as well as storage of temperature, pressure, and humidity data during this descent. This will be achieved using two Raspberry Pi Pico modules, temperature and pressure sensors, a turnstile antenna, and a computer to receive and process data. The yagi antenna is here only as a backup, as the turnstile is more effective.

Secondary Mission

Our objective is to track the CanSat's position along the X and Y axes using three ground-based antennas, while estimating the altitude (Z) through pressure sensors, already utilized in the primary mission. Direct visualization of the CanSat's position might be possible, depending on external factors such as weather conditions and 4G/5G signal strength.

Trilateration Methodology

To determine the CanSat's location, we will rely on two key techniques:

- **RSSI (Received Signal Strength Indicator):** By analyzing the signal strength received by each antenna, we can estimate the distance between the CanSat and the antennas.
- **ToF (Time of Flight):** By measuring the time it takes for signals to reach each antenna, we can further refine the position estimation. Ultimately, we

did not use this method. Although this method was promising, it would have been complicated to synchronise the different time stamps from the antennas. On top of that, we wanted to test an alternative to this widespread method.

Using three antennas, we obtain two possible intersection points in 3D space. The correct one will be identified by incorporating altitude data from the pressure sensor (see Figure 1). Additionally, we plan to compare our trilateration results with GPS data to evaluate the system's accuracy.

RSSI and Distance Relationship

The **Received Signal Strength Indicator (RSSI)** is a measure of the power level received from a radio signal. The relationship between RSSI and distance follows an approximate inverse power law, commonly modeled using the **log-**
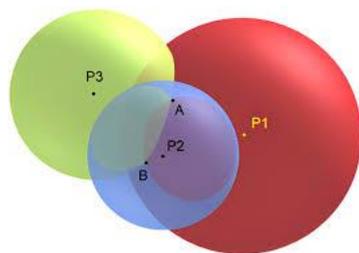
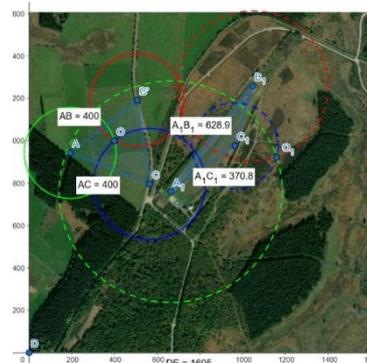Figure 2: The two intersections (A and B) of three spheres

Figure 1: Two potential locations for the three antennas, either at each summit of the equilateral triangle in the field or at each summit of the isosceles triangle on the landing strip.

distance path loss model:

$$d = d_0 \times 10^{\frac{RSSI_0 - RSSI}{10n}}$$

where:
- d is the estimated distance between the transmitter (CanSat) and the receiver (antenna),
- d_0 is a reference distance where the signal strength is known,
- $RSSI_0$ is the received signal strength at d_0,
- $RSSI$ is the measured received signal strength,
- n is the path loss exponent, which depends on the environment (e.g., free space, urban, or indoor conditions).
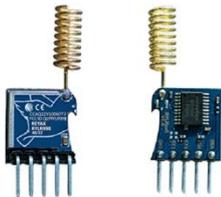
Potential Errors and Mitigation Strategies

The trilateration system may be subject to errors due to various factors:
- **Signal Interference**: External disturbances can cause antennas to misinterpret signals, leading to inaccurate position estimations
- **Weather Conditions**: Adverse weather, such as rain, may weaken or disrupt reception signals
- **RSSI Variability**: RSSI-based distance estimation is inherently imprecise due to fluctuations in signal strength caused by environmental changes and multipath effects.
- **Angle relative to antenna:** turnstile antennas are much more effective when the object is directly above them
- **Natural obstacles:** obstruction of signal can lower its quality

To mitigate these issues, we can:

- **Enhance signal strength** from the CanSat
- **Implement an encryption key** to reduce the impact of interference
- **Regularly calibrate the RSSI-distance equation** on the day of the launch, adjusting for real-time environmental conditions to ensure accurate calculations

| Key Equipment	Picture	Characteristics
BMP280 (Temperature and pressure sensor) *https://www.adafruit.com/product/2651*		Accuracy: ±1°C ±1hPa 3.3 or 5 V systems
Breakout RFM69HCW - radio Transponder (433 MHz version) *https://www.adafruit.com/product/3071*		-3.3V -50-150mA Good component for the price, and compatible with the system
Rasberry Pi-Pico (RP 2040) micro-controller *https://datasheets.raspberrypi.com/pico/pico-datasheet.pdf*		We have chosen this module as the price is good for the performance. On top of that, it is compatible with the system and some of our members are already accustomed to rasberry Pi-Pico modules.
Adafruit Ultimate GPS Breakout *https://www.adafruit.com/product/746*		-5V, 20mA -10 location updates/s Good component for the price, and compatible with the system
LoRa Transeiver module https://reyax.com/products/RYLR998		-2.3 to 3.6V -868-915 MHz -0.06-5.5 mA Accuracy - ±10 ppm Good component for the price, and compatible with the system

Other Components:

- 1 Yagi antenna as backup for the primary mission
- 3 omnidirectional Turnstile antennas built with the help of the radio amateur group of Thionville, to fulfill our secondary mission.
- 3D-printed can
- 3 computers for data collection

Data Transmission Method

The radio module operates on a **low-power RF communication protocol**, allowing for long-range data transmission while maintaining energy efficiency. The RFM69HCW transmits data using **FSK (Frequency Shift Keying) modulation**, where digital information is encoded by varying the carrier frequency. The transmission process follows these steps:

1. Data Encoding: Telemetry data are **formatted into packets**.
2. Packetization: Each packet includes a **header, payload (data), and checksum** for integrity verification
3. Modulation: The encoded data is modulated using **FSK** and transmitted at **432.5 MHz**
4. **Transmission:** The CanSat periodically emits signals
5. **Reception and decoding:** The packets received undergo **error checking (CRC validation)** to ensure data accuracy. If errors are detected, retransmission may be requested.

Figure 3: Three basic digital modulation formats are still very popular with low-data-rate short-range wireless applications: amplitude shift keying (a), on-off keying (b), and frequency shift keying (c). These waveforms are coherent as the binary state change occurs at carrier zero crossing points.
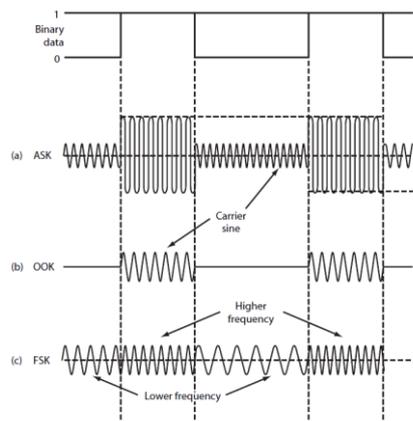
2.2 Mechanical design

We have elaborated multiple can designs as shown below and decided to keep the most recent one (number 4). The third design has incorporated fittings for the battery at the bottom and the PCBs. The PCB fittings are inclined to maximize the wall's width, assuring the can's sturdiness. At the top the can, we have included holes to attach the parachute, and for aeration. Aeration holes can also be found at the bottom of the can. Finally, the CanSat will be filled with soft material like cotton, foam, or sponge to absorb shocks and vibrations, and keep components in place. The last design only adds aeration holes to facilitate data collection. The can has also been 3D-printed and made of PLA. Here are its characteristics:

- height: 115mm
- width: 66mm
- thickness: 3mm

First Version
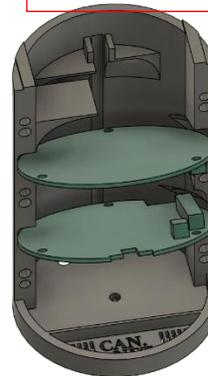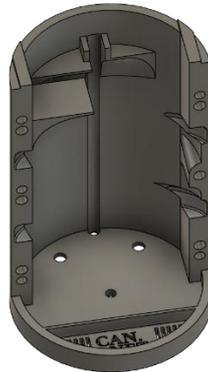
Horizontal PCB
Problem: Easy to break
(wall thickness 1mm)

Weak Battery Wall
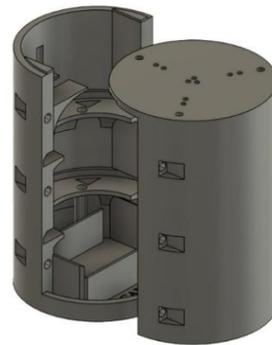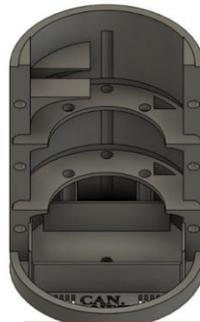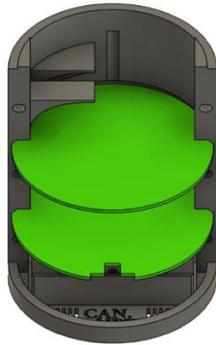
Radio Support Too Small
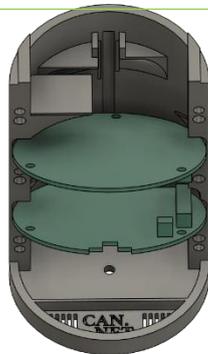
Second Version

Parachute Holes✓

Double holes for
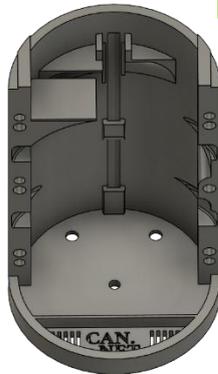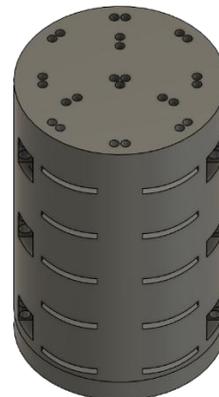zip ties ✓

Lean PCB ✓

Third Version

Radio support right size ✓

Wire guide ✓
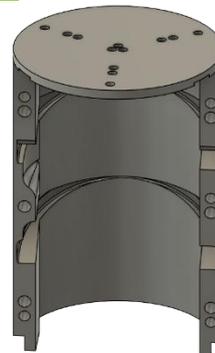
Interlocking parts ✓

Fourth Version

The parachute has been completed and consists of a circle made of red nylon ripstop. Its diameter is approximately 30cm and we pierced a hole of approximately 2cm in diameter. We then pierced 4 holes for eyelets. On top of that, we used nylon strings of 70mm.

Figure 4: The parachute attached to the can

Here are the calculations we used to calculate the area of the parachute:

$$\text{Add } \tfrac{1}{2}C_D\rho Av^2: \quad mg - \tfrac{1}{2}C_D\rho Av^2 = 0$$

$$mg = \tfrac{1}{2}C_D\rho Av^2$$

$$\text{Multiply by 2: } 2mg = C_D\rho Av^2$$

$$\text{Divide by } C_D\rho v^2: \quad A = \frac{2mg}{C_D\rho v^2}$$

2.3   Electronic design

The electronic setup includes:

- An emitter. This setup on breadboard shows the alimentation of the system, as well as the connections betwen the sensors, GPS, and radio emitter, to the rasberry pi module. We estimate our current battery is enough to supply the system for the whole mission, so we have not elaborated backup, which might lead to more technical issues.
- A receiver. This setup includes connections between the radio receiver and rasberry pi module, a lora module for the turnstile antennas to communicate live data.This module will be connected to a computer to interpret data, and the radio receiver to our turnstile antenna to correctly receive data.
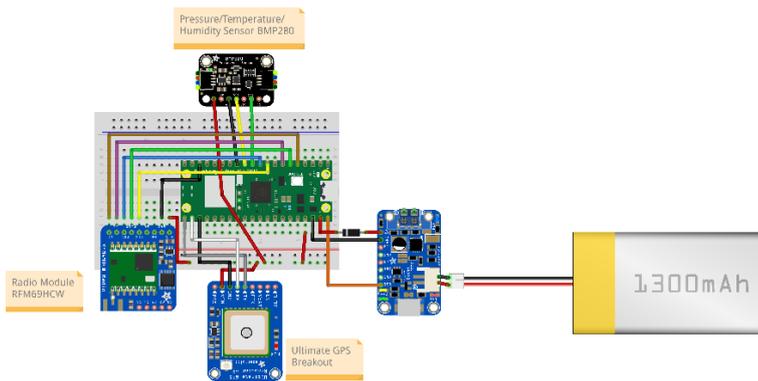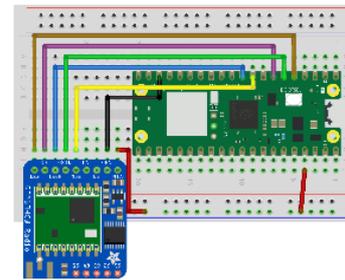
Figure 4: The emitter on breadboard

Figure 5: The receiver on breadboard

2.4 Ground station design

Primary mission
Our ground station will consist of 1 turnstile antenna (having the yagi as back-up: we realised the turnstile was simply more practical), receiver module, and computer to receive/store and exploit the can's data. However, it is important to note we will also store the data directly into the Cansat, in case we fail to receive a signal but manage to retrieve the can.

Secondary mission
For this mission's requirements, we require 3 omnidirectional antennas, each greatly spaced from one another, for the trilateration to work. We will try our best to exploit the data in real time. For this, we will need to couple each antenna with a computer. We are then using a LORA to transmit the data to antenna number 1 who then put all the antennas in relation by connecting all data to one turnstile.
Initially, our team reached out to Pierre-Marie Gayral, a member of the Thionville Amateur Radio Club, for some help regarding the ground station. Through a Zoom discussion, we learned about different types of antennas, their radiation patterns, and their suitability for tracking our CanSat. Mr. Gayral introduced us to two main types of antennas: the Ground Plane Antenna and the Turnstile Antenna, which are harder to construct.

Turnstile Antenna (https://alicja.space/blog/how-to-build-turnstile-antenna/)

The Turnstile Antenna is a type of antenna that is used for omnidirectional reception with both horizontal polarization and elevation polarization, making it well-suited for receiving signals from all directions. The Turnstile antenna uses two dipoles arranged in a specific orientation to create a circular polarization, which can help improve signal reception in some cases.

Key Consideration: While this antenna provides a good radiation pattern, its construction is more complex compared to a ground plane antenna, which may require more time and effort to build and align.

Figure 5: Our home-made turnstile antenna
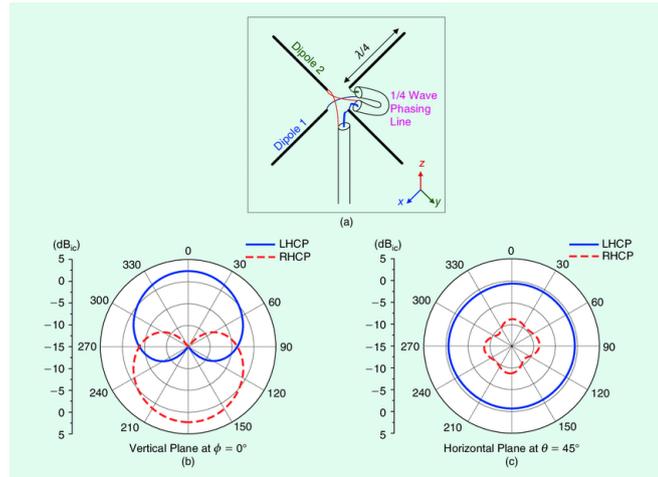
Antena Calibration:

We proceeded to calibrating the antennas before the launch by attaching our Cansat to a drone. Using the flight device, we elevated the can vertically over the antenna. Estimating height with Apple Measures, we associated different heights with their respective RSSI value. Finally, we created a calibration curve using the data. This process needed to be done on each separate turnstile, as RSSI value depended on the antenna's conception itself.

Example of calibration curve:
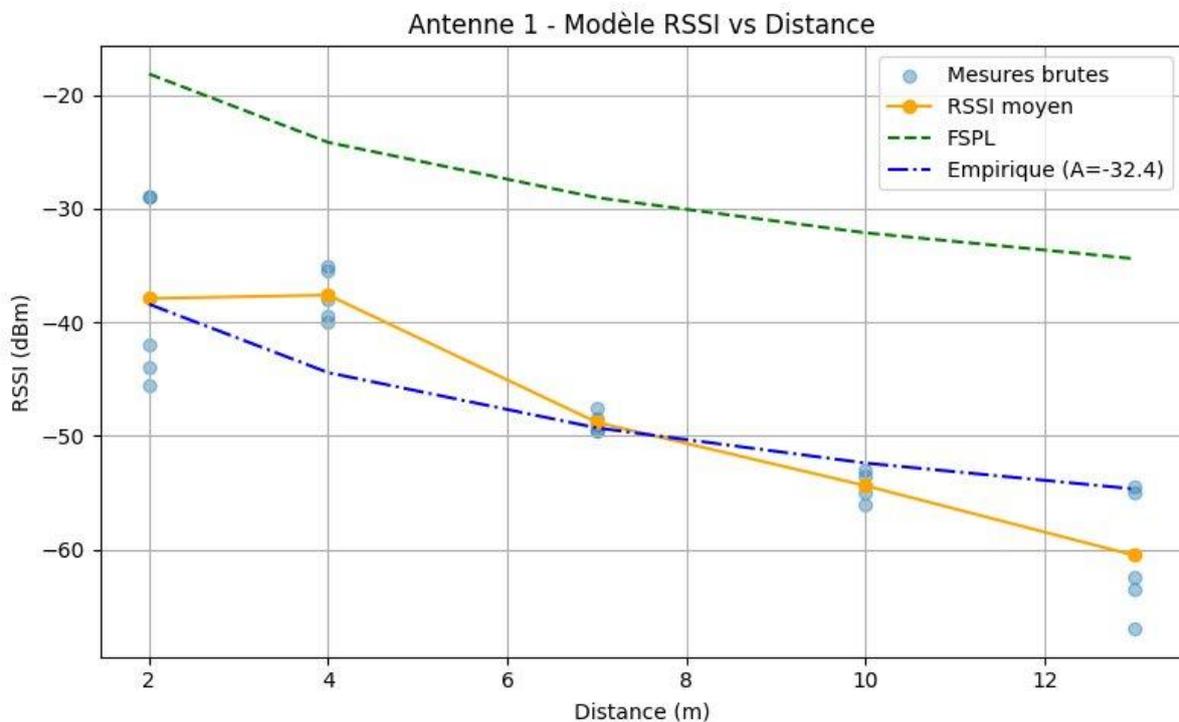
2.5 Software design

Primary mission

To put it simply, our code collects data from the sensors and sends them through a precise radiofrequency (432.5 MHz) with an emitter to our Turnstile antennas. In parallel, the data will be saved directly within the can.

Secondary mission

The can should be constantly emitting radio waves. These waves will be intercepted by three different antennas on the ground. Using the strength of the signal, the program will use a formula to determine the distance from each antenna and finally determine a relatively precise location through trilateration. For it to take height into account, this program will simply use the pressure data collected from the primary mission. The data of each antenna will then be sent to the antenna of base 1 using LoRa modules, and the data will be interpreted.

Formula for Distance Using Signal Strength (Path Loss Model):
The distance estimation is based on the **free-space path loss equation** (FSPL), which describes how a radio signal weakens over distance:

$$\alpha(dB) = 32.4 + 20 \log_{10} F \text{ (MHz)} + 20 \log_{10} D \text{ (km)} \quad \text{(ITU-R P.525-3)}$$

where:
- $\alpha(dB)$ = signal attenuation (path loss) in decibels,
- $F(\text{MHz})$ = frequency in megahertz,
- $D(\text{km})$ = distance between the CanSat and the antenna in kilometers.

Since the **RFM69HCW** operates at **432.5 MHz**, we can determine the signal wavelength λ using:

$$\lambda(m) = \frac{300}{F(\text{MHz})}$$

which gives:

$$\lambda = \frac{300}{432.5} \approx 0.694 \text{ m}$$

From the path loss equation, we can **rearrange** to solve for the distance DDD based on the measured signal strength:

$$D(\text{km}) = 10^{\frac{(\alpha - 32.4 - 20 \log_{10} F)}{20}}$$

Formula for Height using pressure:

$$h = \frac{Pa - Pb}{\rho \times g} = \frac{Pa - Pb}{1000 \times 9.81}$$

where:
- $\rho =$ volumic mass of air ($\approx$1204 kg/m^3 at 20° degrees Celsius)
- $g =$ the Earth's gravitational pull (9.81 N/kg)
- $Pa =$ Amospheric pressure at the can's height (Pascals)
- $Pb =$ Atmospheric pressure on the ground (Pascals)

Please note we will determine Pb before launch for more precise calculations.

Code within the can

```
Startup
└────── 🔁 Main loop:
├────── 📊 Read BME280 sensor:
│       └────── Temperature, Pressure, Humidity
├────── 💾 Write to CSV file:
│       └────── Add a line with the data + timestamp + counter
├────── 📡 Send message via RFM69:
│       ├────── Format: "Message {counter}! temp,press,hum,time"
│       ├────── Convert to bytes and send with ACK
│       └────── Display: ACK received or missing
├────── 🔢 Increment `counter`
└────── ⏱ 1-second pause (sleep)
```

Code on base 1

```
Startup
├────── ☑ Connection checks:
│       ├────── LoRa (REYAX RYLR998)
│       └────── RFM69HCW (SPI)
└────── 🔁 Main loop:
├────── 📡 Reception via RFM69:
│       ├────── If message received:
│       │   ├────── Parse sensor data:
│       │   │   (counter, time, temperature, pressure, humidity)
│       │   ├────── Get RFM69 RSSI
│       │   ├────── Write to:
│       │   │   ├────── `base1-sensors.csv`
│       │   │   └────── `base1-RSSI.csv`
│       │   └────── Update dictionary: `rssi_dict[counter]["Base1"]`
│       └────── If all RSSIs (Base1, Base2, Base3) available:
│       ├────── Write to `all-RSSI.csv`
│       ├────── Send to computer via UART
│       └────── Delete `counter` from dictionary
├────── 📶 Reception via LoRa:
│       ├────── If message received:
│       │   ├────── Decode message: (base, counter, RSSI)
│       │   └────── Update dictionary:
│       │   ├────── `rssi_dict[counter]["Base2"]` or
│       │   └────── `rssi_dict[counter]["Base3"]`
│       └────── If all RSSIs (Base1, Base2, Base3) available:
│       ├────── Write to `all-RSSI.csv`
│       ├────── Send to computer via UART
│       └────── Delete `counter` from dictionary
└────── ♻ Repeat indefinitely (until interrupted)
```

2.6 Recovery system

Our CanSat relies on four different and relatively simple systems that ensure its recovery.

The first one consists of a standard 85db buzzer provided at the meeting on the 15th of January. This buzzer will emit a constant sound allowing us to locate the can.

The second system is directly incorporated into our secondary mission, which consists of locating the can using trilateration.

Lastly, our last identification system is based on our parachute's color: their bright fluorescent red and blue color should make it easier for us to spot it. The inconvenience, however, is that this identification method only works at a very short range, to spot the can through foliage for instance, otherwise, it will not be of great use.

With all this, we are confident we will not, in fact, be sad! Overall, these 3 methods work in harmony to maximize chances of retrieval, while keeping risks of technical issues and general difficulties to a minimum. GPS and trilateration should give us a global idea of the can's position. The buzzer and bright colors will then stimulate our senses and help them collaborate to help locate the can, at closer range.

2.7 Testing

Primary Mission

Components

We have tested all the sensors, micro-controllers, receivers, and emitters on breadboard before soldering. We have concluded that our primary mission was operational for the emitter modules. Though, as time went by, we started experiencing problems with the receiver modules. We tried reconnecting the cables, changing breadboard, troubleshooting our code, but found no answer to the problem. We believe one of the components of the receiver was malfunctioning as our antenna received data from the emitter but cannot interpret them. As a result, we decided to replace the radio receiver, and the microcontroller, which gave us positive results. Concerning the GPS module, we did not manage to make it work, even at the time of launch. After doing research online, we realised it might be due to urbanisation that prevents the GPS from getting a proper lock with a satellite. However, the GPS did not work either in a rural environment, maybe due to malfunction. We also managed to test the buzzer indoors and outdoors. Initially, the buzzer's sound was relatively low, due to low voltage input. Consequently, we decided to up the voltage from 3V to 5V.

PCB/soldering

At the beginning, the wrong raspberry pi- Pico microcontroller was put on the PCB (it was malfunctioning on breadboard and didn't work on PCB either for an unknown reason). This greatly slowed the process, but we decided to get a new PCB as unsoldering the component damaged the original PCB. The soldering on this new PCB went smoothly, and everything worked correctly.

Antennas

The antennas were tested near the running track of Athénée. We spaced the emitter and receiver by approximately 200 meters. At first, the signal went through, but stopped after a while, which is when we detected the problem with the receiver. However, we still managed to evaluate the Turnstile's performance using a software named "SDR#", which indicated us a reading of −10 db (see video: Turnstile Test). We also tested the Turnstile from 550 m away.
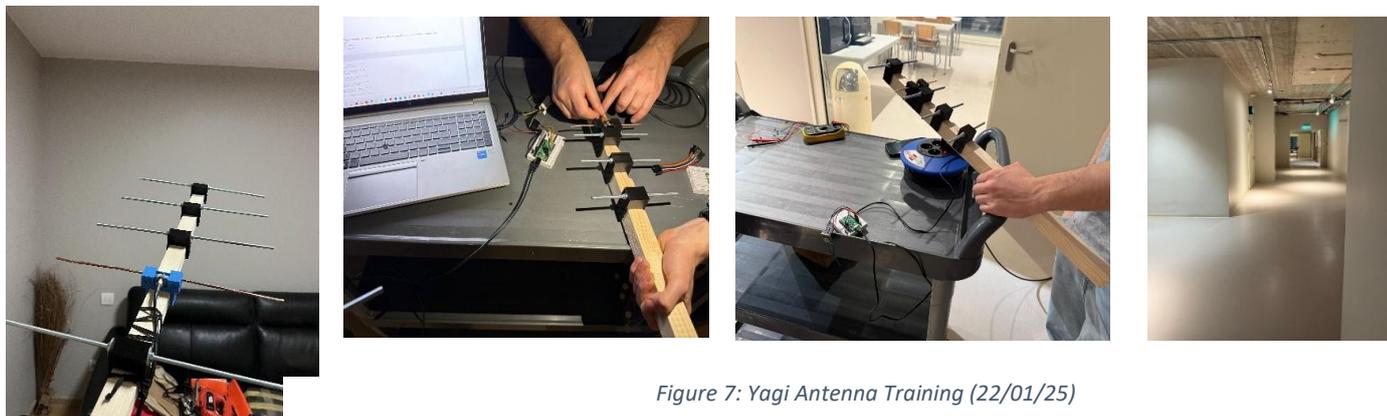

Figure 7: Yagi Antenna Training (22/01/25)

Figure 7: Our Yagi Antenna
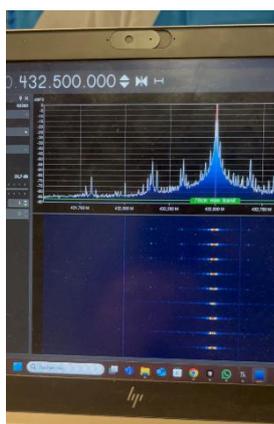
Figure 6: -10dB on SDR# for the Turnstile's performance

Figure 9: 550 meters test of the Turnstile in Luxembourg

To increase signal strength, we added a balun to the Yagi. *(Videos: Yagi Test)*

Regarding the turnstiles, members of the Radioamateur group of Thionville evaluated and approved each of them (Article of the Radioamateurs). However, we also decided to test them ourselves. We took our least performing turnstile, and tested data reception at 550m, placing the Can in an elevated position to simulate the launch.

Figure 8: Yagi Test in the street

Trilateration

For trilateration testing, we placed the antennas in an open field, spacing them around 100 meters apart. The idea was to use a drone to elevate the can, though lack of battery prevented us from doing so. Our solution was to simply walk around with the can, which gave us coherent values:
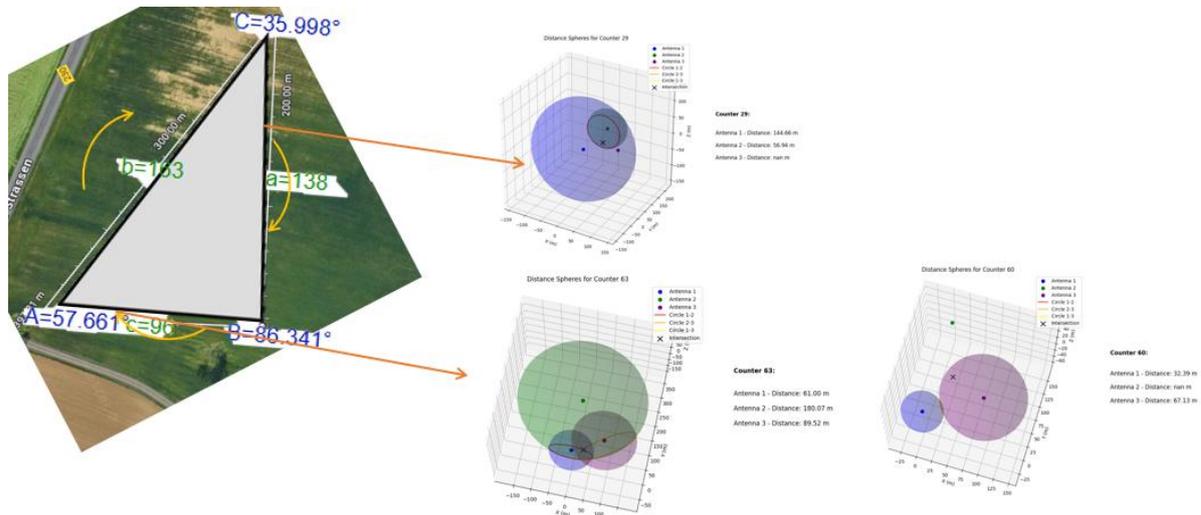
Parachute

To test our parachute, we first tested the strings' solidity by swinging the can around. On top of that, we tested air resistance by dropping the can from a 10 meter drop approximately and observed a slow in motion. A person was placed below to film the can. Moreover, we have realized that our parachute only used one piece of fabric, too many eyelets, and a very big center hole. To further optimize it, we will use 2 sheets of fabric, reduce the hole's size, as well as the number of eylets. We will continue to test our parachute, by attending the drop test organized on the 27th of March. (see video: [Parachute Test](#))

1. Requirements

We put on additional weights. Our can rely on 1 lithium battery of 3.7 Volts, 1300 mAh and a 5 volts converter and lithium battery charger, that convert the power of the battery to a 5 volts power source for the Raspberry. It also recharges the battery when the kit is powered by USB. Our can have a main, switch accessible from the bottom of the can, that will be openable. Our Cansat has a parachute that deploys. The parachute color is fluorescent red. We used nylon strings to attach our parachute to the can. Those strings are firmly attached to hooks on top of the cansat. The strings can withstand a force of up to 250 kilos or 2452 Newtons. Our parachute brings the descent speed to 12m/s. All our data is stored in the Raspberry Pico, in the form of a data table

3. Overall progress

3.1 Human resources

Team members and roles:

➢ **Gabriel:** Gabriel is a bike enthusiast and triathlete. He regularly indulges in activities such as climbing, swimming, running, and mountain biking. The discipline he gained from sports helps him stay focused on his tasks. On top of that, Gabriel has proven time and time again he detains critical thinking skills helpful in our task.

➢ **Ugo:** Ugo is a student passionate about science and Engineering. His BIA (Brevet d'Initiation à l'aéronautique) diploma reflects his interest in the matter. He is impatient to learn and make the project come true, yet composed enough to take all the necessary steps without rushing. His ability to analyze situations and problems has been crucial for the team so far.

➢ **Martin:** Martin, like the other members, is very dedicated in the project. Like Ugo, he aspires to be an engineer and shows great interest in science in general. This explains his past involvement in the « First Global Robotics Competition » and internship at the SES (Société Européenne des Satellites). Martin is probably the most well-versed member when it comes to coding and exploiting software, a skill that has not gone unnoticed.

➢ **Aboubaker:** Aboubaker is a division 2 basketball player. The sportsmanship and ability to learn strategies he acquired from basketball enables him to clearly see the objective and follow the rules.

➢ **Cillian:** Cillian takes on the role of our math specialist, a subject which he is very passionate about. He got second place in the « Olympiades de Mathématiques Belges » (OMB) preliminary round in Luxembourg.

Work repartition:

Our team has equally divided the work between all the members:

• Martin has been taking care of creating the Turnstiles Antennas, the codes for the second and primary mission, enhancing the signal received from our Yagi antenna, and creating our beautiful can

• Ugo helped Martin on the creation of the Turnstiles Antennas and has been working on the codes and on the modelling of the can with him

• Aboubaker helped build the Yagi Antenna and worked on the modelling of the can. His current task is soldering on the PCB

• Gabriel built the Yagi Antenna with Aboubaker and completed the parachute. He also is the courier of the team and almost has the fidelity card at Hornbach with all the times he went there.

• Cillian has been and is keeping the report updated at each new milestone achieved by the group. He oversees our Instagram. He takes care of all calculations.

Events (in order):
1st February: Making and finalization of the Yagi antenna during Vauban's open day, Gabriel and Aboubaker
10th February: Making the Turnstiles antenna, Martin
15th February: First test of the antenna, Ugo and Martin (it works!)

7th March: First model of then can, Martin
20th March: Finalization of the Turnstiles antenna, Martin
22nd March: Second model of the Can, Martin
24th March: Making of the parachute, Gabriel + Third model of the can, Martin
25th March: Start of the souldering on the PCB, Ugo, Aboubaker, Martin
28th March: Finalization of the parachute, Gabriel
1st May: Trilateration test in open field

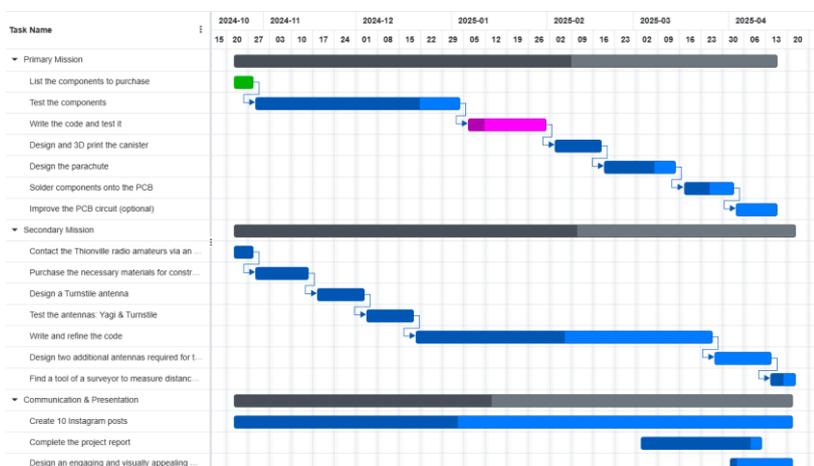**Instagram account posts/stories:** Everyone
Making of the report: Martin, Ugo and Gabriel

3.2 Planning

To manage our project's timeline effectively, the team utilizes **Notion**, a powerful organizational tool. Notion helps us keep track of tasks, deadlines, and progress in a structured and collaborative manner. Each member has assigned their name to a task and updates the team as regularly as possible. Moreover, we try to organize a weekly meeting to clarify points of uncertainty as well as our progress.
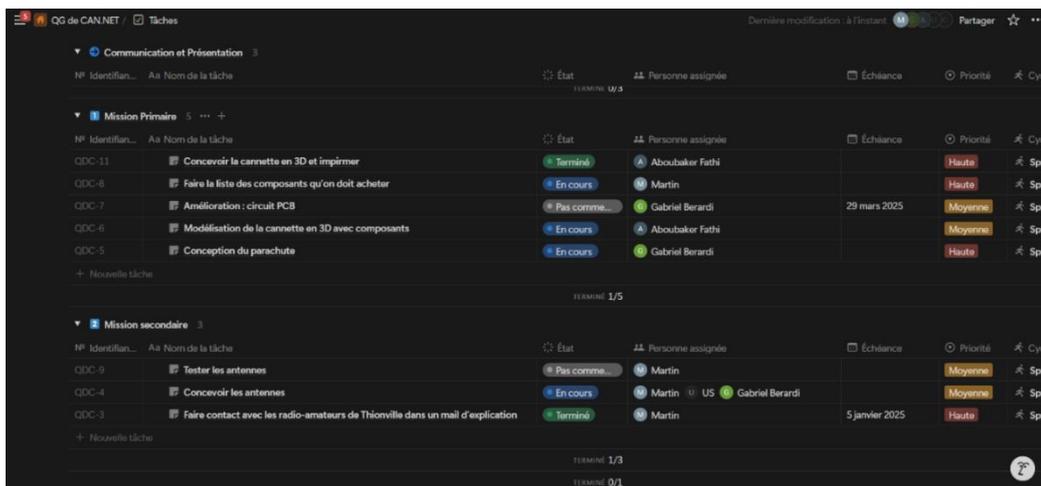
Gantt chart illustrating task progression over time.

3.3 Budget

Parts	Price	Origin	Date of purchase
CanSat Components			
Adafruit Electronics			
Ultimate GPS Adafruit	36,24€	https://www.reichelt.com/fr/fr/shop/produit/cartes_de_developpement_-_carte_de_breakout_gps_mtk3333-235482	25/01/25
DC 3V-24V Piezo Buzzer	$5,50€/3 = 1,83€$	https://www.amazon.com/3-Pack-3V-24V-Electric-Buzzer-Active/dp/B0761WSXDK	Received for free
Parachute			
Parachute Textil	34,99€	https://amzn.eu/d/acVu2Tr	Received for free
Paraloc Mamutec Polyester Rope Ø 3 mm, 20 m	8,95€	https://www.hornbach.lu/fr/p/corde-paraloc-mamutec-polyester-o-3-mm-20-m/8442210/	29/01/25
50 medium-sized eyelets	$50 \times 0,16€ = 8€$	In bulk at Hornbach	
15 flat washers	$0,031kg \times 21,45€/kg = 0,66€$	In bulk at Hornbach	
Ground Antennas			
Yagi Antenna			
Rough Spruce/Pine Batten 20x30x2000 mm	6,60 €	https://www.hornbach.lu/fr/p/tasseau-konsta-pin-epicea-brut-20x30x2000-mm/5485737/	29/01/25
1-meter threaded rod, DIN 976, M5, galvanized zinc-coated	$2 \times 0,85€ = 1,70€$	https://www.hornbach.lu/fr/p/tige-filetee-din-976-m5-electrozinguee-1-m/10544377/	
H07 V-U conductor, 1G2.5 mm², 20 m	10,38€	https://www.hornbach.lu/fr/p/conducteur-h07-v-u-1g2-5-mm-20-m-vert-jaune/5116020/	Received for free
Hex nut, Sencys, galvanized, M5, pack of 40	4,09€	https://www.brico.be/fr/quincaillerie/fixations-techniques/ecrous/ecrous-hexagonaux/ecrou-hexagonal-sencys-galvanise-m5-40-pieces/5367596	
Wide flat washer, Sencys, M5, pack of 40	7,99€	https://www.brico.be/fr/quincaillerie/fixations-techniques/rondelles/rondelles-plates/rondelle-plate-large-sencys-m5-40-pieces/5368786	

Turnstile Antennas			
PVC pipe, 40mm in diameter, 500mm in height	$3 \times 1,35€ = 4,05€$	https://www.hornbach.lu/fr/p/tube-ht-dn-40-500-mm/209767/	25/01/25
RTL-SDR V4 Dongle	31,18€	https://fr.aliexpress.com/item/1005005952682051.html	
CW 8500 Flux Gel - No Clean	18,67 €	https://www.reichelt.com/fr/fr/shop/produit/gel_de_flux_cw_8500_-_no_clean-112697	
SO 239 Female embedded UHF connector	1,72€	https://www.reichelt.com/fr/fr/shop/produit/connecteur_uhf_femelle_encastre_montage_a_bride-19218	
PL 259 UHF connector for a cable diameter of 4.5 mm	0,97€	https://www.reichelt.com/fr/fr/shop/produit/prise_uhf_pour_un_diametre_de_cable_de_4_5_mm-14692	
Cable type RG58 C/U	$2 \times 0,76€ + 4,50€ = 6,03€$	https://gigatek.be/fr/kabel-c-ble-coax-rg-59-75-ohm-b500--kobrg59	
SMA Male to SMA Female Cable RG58A/U	12,78€	https://amzn.eu/d/eUK25X2	
Stainless Steel Rods 4 mm x 100 mm	7,85€	https://amzn.eu/d/7TrxGDK	
Stainless Steel Round Rods 4 mm x 400 mm, Pack of 5	$(3 \times 16,31€) \times 0,9 = 44,04€$	https://amzn.eu/d/73RTc5X	29/01/25
SMA cable and 5 pieces adapter kit	12,78	Amazon	
LAVMHAB Stainless Steel Rods	7,85	Amazon	
Crimping tool	12,50	Hornbach	
Eyelet box	10,09	Hornbach	
3D Printed Objects			

Creality, Ender-3 V2			
Yagi Support Total 3.69€	**Material Cost** $2 \times 63.2g \times 10^{-3}$ $\times €18.03/kg$ $= 2.28€$ **Electricity Cost** $2 \times 7.9h$ $\times 0.350kW$ $\times €0.255/kWh$ $= 1.41€$	Example of calculations For a 72.64g 3D print of the can using Bambu Lab X1 and blue PLA: 1. **Material Cost**: Weight: $0.07264\ kg$ PLA cost: $€18.03/kg$ $Material\ Cost = 0.07264\ kg \times €18.03$ $/kg = €1.31$ 2. **Electricity Cost**:	28/01/25
Turnstile Support Total 6.61€	**Material Cost** $4 \times 56.7g \times 10^{-3}$ $\times 18.03€/kg$ $= 4.08€$ **Electricity Cost** $4 \times 7.08h$ $\times 0.350W$ $\times 0.255€/kWh$ $= 2.53€$	Power consumption: $0.11\ kW$ Printing time: $2.65\ hours$ (2h39min) $Energy\ used = 0.11\ kW$ $\times 2.65\ hours$ $= 0.2915\ kWh$ Electricity price: $€0.255/kWh$ $Electricity\ Cost$ $= 0.2915\ kWh \times €0.255/kWh$ $= €0.074$	10/02/25
Bambu Lab X1		3. **Total Cost** = Material Cost + Electricity	
Can	$3\ versions$ $= 3 \times 1.38$ $= 4.14€$	$Cost = €1.31 + €0.074 = €\mathbf{1.38}$	24-25-26/03/25
Total Prize (only paid material + shipping cost)	3D Printed Objects: 3.69+6.61+4.14=14.44€ <u>Total:</u> **501.61€**		

For more info on all the equipment bought, see the: Invoices

3.4 Outreach

In order to communicate our work to our entourage, Can.Net has primarily opted for social media. We have created an instagram account in which we try to actively post, update, and interact with our followers. Furthermore, we do not hesitate to share our projects with those curious enough at social and scientific gatherings such as the « Makerfest ». Finally, our involvement with the "Club Radioamateur Thionville" has led to an article being published about our project (see link below).
https://f8kgy57.wordpress.com/2025/01/21/la-trilateration-vous-connaissez-le-club-f8kgy-a-ete-sollicite-par-jerome-metzler-professeur-au-lycee-vauban-luxembourg-pour-le-choix-optimal-du-type-dantenne-et-le-traitement-du-signal/
Instagram: c4n.n3t (don't forget to follow!)

As of now, we have 70 followers and 15 posts. We have accumulated 720 views in the last 30 days and 143 likes.

We have also created our own website: c4nn3t.eu
An article is also to be published on our school website: https://www.vauban.lu/

4. Scientific results

Primary mission results:

The graphs indicate temperature and pressure were constant during takeoff (around 28.4 degrees Celsius, and 955 hPa), since it was relatively quick, and the can was not exposed to outside air. Temperature then slowly decreased over time, as air entered through the can's aeration holes (which confirms our prediction). Pressure on the other hand, decreased at higher altitudes, before increasing again as it neared the ground (which again confirms our predictions). Using this pressure and time, we managed to calculate the can's vertical speed (blue) and vertical acceleration (red). Therefore, we can observe that the can accelerated during launch, before decelerating when the parachute opened and keeping a constant fall speed until landing.
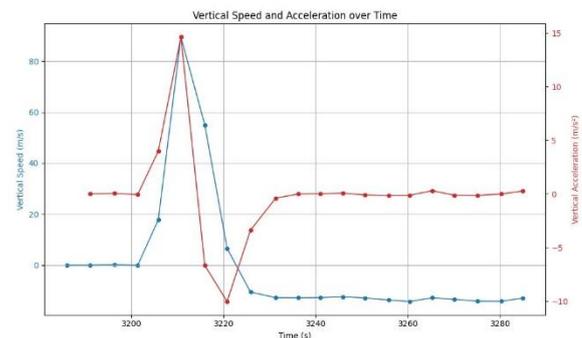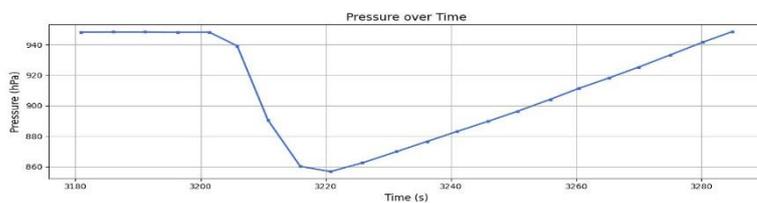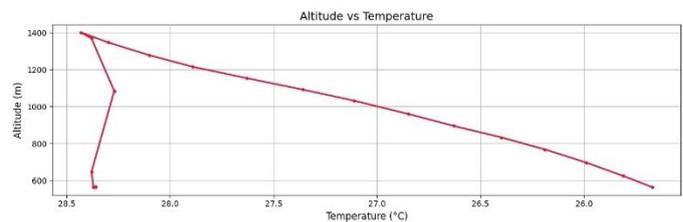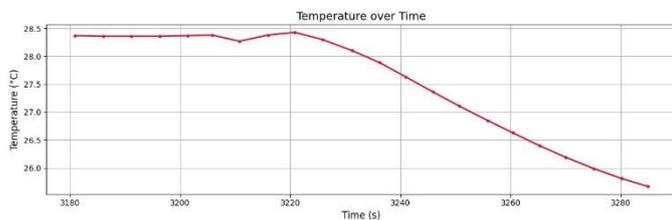
Secondary mission results:

The trilateration data that has been received, however, we believe the data is not reliable. Indeed, the overall trajectory obtained does not match the trajectory of the rocket, nor does it match the theoretical trajectory of the can. The results are non-coherent. We believe this could be due to bad RSSI signals, that do not match our calibration. As mentioned in part 2.1: signal Interference, weather conditions, RSSI variability, angle relative to antenna, natural obstacles. On the other hand, this proves that the data has correctly been collected and that the antennas do work. This means that to obtain a precise trajectory, we only need to change our method of calculating the distance between the can and antennas. For example, we could include time of flight in our calculations, although this comes with other complications such as time synchronization. time.
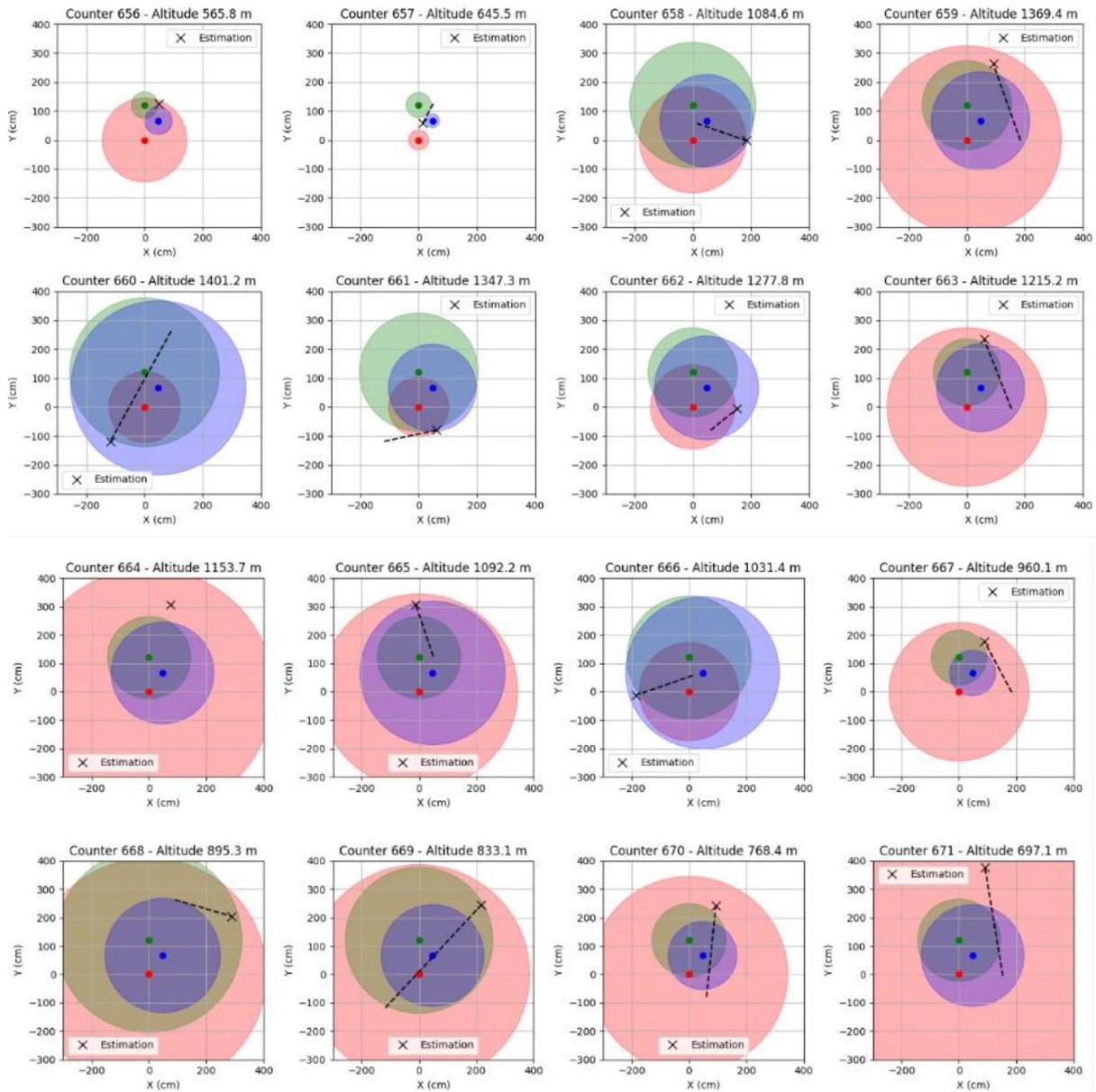
Problems encountered:

On launch day, we had to deal with many unexpected problems. For example, we had to react quickly to protect our components from unexpected rain. It was also important for us to react quickly when faced with a broken parachute. Luckily, we had the necessary material to create a new one on the spot. Furthermore, we encountered a memory problem while running our code, which would not have saved any data if the problem hadn't been spotted on time. Overall, we learned it was important to try to plan such events, by protecting exposed components from bad weather for example, or even packing necessary equipment in case of an inconvenience.

5. Discussion

CanSat is a great project that enabled us to enhance our research and practical skills. The mission requirements greatly stand out from what is normally taught in our school, forcing us to look for information and help on our own. Furthermore, the project was a great initiation to electronics for many of the members, introducing them to notions like soldering. Furthermore, we enjoyed being introduced to the world of engineering through this immersive experience that pushed us to learn how to achieve a goal, on a budget with deadlines and restrictions. To improve our secondary mission results, we could simply change the method for distance calculations. For instance, simply taking flight time into consideration could help create precise values (although the technical aspects that follow are also quite complex). We plan to improve our project to the maximum, even after the end of the competition.

6. Conclusion

We faced some challenges such as a lack of equipment (like for the antennas), faulty equipment (like the receiver), manipulation errors (like putting the wrong micro controller on the PCB), and complexity of manipulations (like with the turnstile antennas' build). From this, we learned that we need to plan more in advance, communicate correctly, keep track of faulty components, and make sure that we have everything we need before proceeding with our tasks. We have also learnt crucial skills and enjoyed learning more about the engineering world. Overall, we are proud of what we have achieved: primary data was received flawlessly, and trilateration could be more precise simply by changing methods. To conclude, this competition along with the things we learnt are unforgettable, and we couldn't be happier to have participated in CanSat 2025.

References

1. **WIRED.** We Tracked the Secret Police Microphones Hidden Everywhere. *YouTube.* [Online] December 19, 2024. [Cited: December 30, 2024.] https://www.youtube.com/watch?v=USNJ2eOme8E.

2. **Marie, Jacky.** La trilatération vous connaissez ? *f8kgy57.* [En ligne] 01 01 2025. https://f8kgy57.wordpress.com/2025/01/21/la-trilateration-vous-connaissez-le-club-f8kgy-a-ete-sollicite-par-jerome-metzler-professeur-au-lycee-vauban-luxembourg-pour-le-choix-optimal-du-type-dantenne-et-le-traitement-du-signal/.

Annexes

Invoice name	Invoice Amount (EUR)
Hornbach - boite à oeillets, boulons	€10,09
Hornbach - pince à sertir	€12,50
Amazon.de - Câble SMA + Tiges d'acier	€24,12
Hornbach - bout de bois, rondelles (Yagi)	€25,91
Hornbach - domino électrique, pinces	€28,40
Ali-Express - RTL-SDR Blog V4	€32,19
Amazon.com - Reyax RYLR998	€51,44
Gigatek - Câble coax RG 59	€6,03
Hornbach - Serre Fils	€6,55
Gigatek - Câble coax RG 58	€6,62
Amazon.com - Reyax RYLR998, USB for UART	€61,38
Hornbach - bâton rond (support Turnstile)	€63,77
Reichelt - Ultimate Breakout GPS, Flux, Connecteurs	€64,55
Hornbach - vis à cylindre, colliers de serrage	€8,29
Fishing World - fil de pêche	€8,50
Hornbach - boite à oeillets	€8,95
Hornbach - tube pvc, ... (Turnstile)	€82,32
Adafruit - SMA to uFl, GPS antenna	€60,42
TOTAL (EUR)	**€632,13**

For more info on all the equipment bought, see the: Invoices