CanSat Portugal 2025

CANssini – D. Inês de Castro Secondary School, Alcobaça

1. Team organization and roles

Our team, led by the Physics and Chemistry teacher, António Martins, is composed of six students whose roles are the following:

Name	**Age**	**Role**
Alexandre Lopes	18	Programming
Francisco Dias	18	Soldering
Martim Nogueira	19	Graphic Design and Public Relations
Pedro Alexandre	18	3D Modelling and Printing
Rodrigo Valério	18	Antennae
Teodora Martins	18	Parachutes

It is worth noting that this is not the distribution of tasks originally outlined in our presentation video and document. These roles have shifted over the course of the project to better align with our team's needs.

2. Description of the project

2.1. Project Summary

Our primary mission consists, like all others, of collecting pressure and temperature data and transmitting it in real time to a ground station through telemetry, as well as estimating altitude using these values. Besides temperature and pressure, we have also chosen to measure relative humidity to better describe atmospheric conditions throughout our CanSat's descent. For our secondary mission we have chosen to take pictures both in the visible and far infrared spectrums in order to create a topographic and thermographic map of the surface below the CanSat. The algorithms behind the creation of these maps have been implemented by ourselves.

2.2. Expected Results

During the CanSat´s fall, through the data received by the temperature and pressure sensor, we can foresee the variations of the variables related to the atmosphere, according to its typical behavior.

Altitude: The CanSat should quickly reach its terminal velocity. Therefore, we expect, for most of the fall time, a linear decrease in altitude.
Atmospheric Pressure: According to the barometric equation, the pressure should increase throughout the fall, due to the increasing weight of the column of air on the sensor.
Temperature: The temperature is expected to increase slightly during the descent, following the mean vertical thermal gradient of the troposphere, which is approximately 6.5 °C per 1000 m of descent.
It is worth noting that these conditions are standard and lack consideration of local phenomena.

Our secondary mission's goal is to obtain a topographic and a thermographic map of the island of Santa Maria. We hope to create a point cloud from which we can make out the shape and dimensions of the terrain around the CanSat's launch. As an example of the kind of output this would ideally produce we give the following image of the Euryalus Castle archeological site in Syracuse, a point cloud obtained by an aerial photogrammetric survey conducted by R. Valenti *et al*. In our case, many of the points will have not just color but also temperature data associated to them.

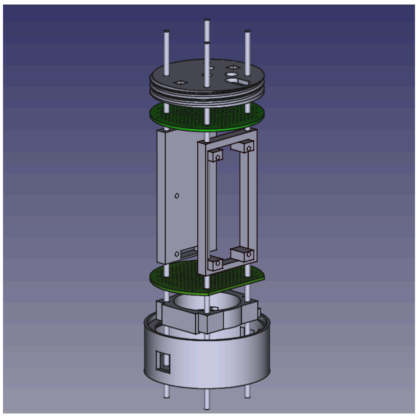
2.3. Project Details

2.3.1. Materials and structural design

The PTRobotics Cansat kit was an essential part to support the components used, when it comes to storing all the electronic devices in the three different stages, aligned with its functions and characteristics:
The first stage is placed at the bottom, essentially because of the sensors that it contains:

- Optical camera;
- Thermal camera;
- Pressure and temperature sensor (PT sensor).

The second stage is the central one. It is where the microcontroller, power supply and GPS module are placed.
The third, topmost stage contains the radio communication module and GPS module antenna.

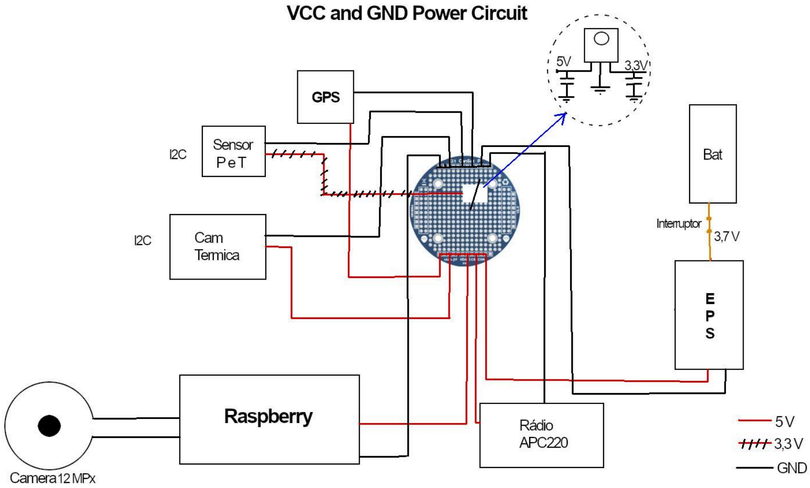


Since some components are too big to be placed and welded horizontally, two different support structures were printed to hold the microcomputer, the GPS module and the power regulator in place. These supports were then slid onto the thread rods, as shown in the figure.
Due to the sensors' fragility, all the components in the first stage are mounted to a common support and protected by the CanSat's base.
A thin case was 3D printed to protect from impact and dust. The parts were printed using PLA filament by an Elegoo Neptune 4 with a fill rate of 50%, as to provide resistance and the necessary weight.

2.3.2. CanSat Components

Our CanSat will use a pressure and temperature sensor (Bosch BME280 PCB) a camera for high-resolution photographic recording (Raspberry Pi HQ Camera - M12 mount), a wide-angle lens (Raspberry Pi SC0947), a wide-angle thermal camera module (MLX90640) and a GPS module. (Ublox NEO-7M GPS). These components will then be connected to a microcomputer (Raspberry Pi Zero 2 W). The communication system between the satellite and the ground station is established with the APC220 Radio Communication Module.

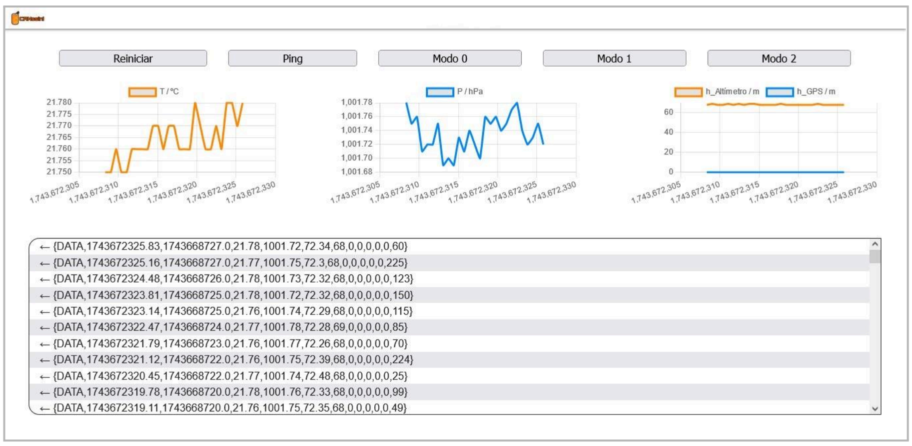
When it comes to power, the system will run off of a 3,7 V, 4200 mAh battery. This battery will be connected to a power amplifier and charger, model name MP2636, which will charge the battery and output a voltage of 5V. The following figure represents the CanSat block diagram.



2.3.3. Software

For this project, we have written three distinct pieces of software, all of them in Python:

- A program for the ground station computers which reads, stores and displays incoming data so that we can more easily monitor the progress of our mission as well as change between the different operating modes of our CanSat.
- The CanSat's main program running on the Raspbian operating system which was itself configured to suit our missions' requirements;
- An interactive notebook implementing the structure from motion technique.



Team CANssini's ground station dashboard

The CanSat has been programmed with three different modes: a "Mode 0" that will be used during ascent which does not take pictures of any kind and emits data at a slower rate of just over once per second, a "Mode 1" which behaves the same but takes pictures and was designed for the first part of our descent and a "Mode 2" that also takes pictures but emits data at a much faster rate of around three to four times per second. The CanSat will begin in "Mode 0" and switch to "Mode 1" automatically as its altitude reaches 500m so that it can begin taking photographs shortly before release. If something were to go wrong and this shift does not occur due to some type of failure with the temperature and pressure sensor or the altitude calculations then we can trigger it manually from the ground station. "Mode 2" will then be activated manually midway through descent as a demonstration of our CanSat's ability to receive, act upon and respond to commands sent by the ground station.

2.3.4. Recovery and Landing System

The team decided to use a circular parachute. Having in mind all the forces applied to the system during the fall, we have gotten the following terminal velocity formula:

$$v_t = \sqrt{\frac{2mg}{\rho C_d A}}$$

Meaning: m - mass (of the system); g – gravitational acceleration ;
ρ - air density (1,225 kg/m^3) ; C_d - Drag coefficient (≈0,8 in a circular parachute);
A - Parachute area (πr^2)
The radius of the parachute can be obtained with the following formula:

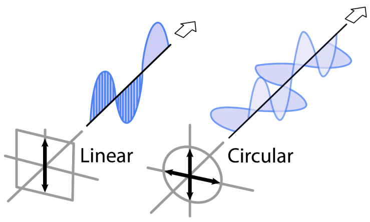
$$r = \sqrt{\frac{2mg}{\pi\rho C_d v_t^2}}$$

With this formula, and keeping in mind the terminal velocity must have a value between 8 and 11 m/s, two parachutes were built, with radii of 17 and 18 cm.

2.3.5. Ground support equipment

In order to receive the information of the sensors of the CanSat we had to build an antenna. After consulting a local radioamateur, we concluded that the most adequate choice was the helical antenna, due to its **polarization**.

Polarization is a property of certain electromagnetic radiations that are restricted in the direction of vibration.
The wave is linearly polarized if the electric field propagates in only one direction and it is circularly polarized if the electric field propagates in a two-axis plane (XY).



The power that the antenna extracts from the received wave, known as the Polarization Matching Factor (PMF), depends on the alignment between the polarization of the antenna and received sign.

$$PMF = \cos^2 \Psi_P$$

In which, Ψ_P, is the angle between the direction of the polarization of the antenna and the polarization of the signal.

For Ψ_P = 0º ⇒ PMF = 1 – Maximal Power

For Ψ_P = 90º ⇒ PMF = 0 – Zero Power (with the exception of the reflection from the ground)

We can secure a reliable gain - measured in decibels (dB) - with circular polarization, given the fact that the alignment is consistent (45º) and that its PMF will always be 0.5.
The loss of signal power due to mismatched polarization between the transmitting and the receiving antennae can be calculated by the expression:

$$PMF_{dB} = 10 \log PMF$$

So it means that the polarization loss will be 3dB.

To assure that we are able to capture the signal from the satellite, we agreed that we needed to build another antenna. This time, we opted for a ¼ wavelength one for its simplicity, efficiency and, foremost, because it is a non-directional antenna, which means that we don't have to point it at the satellite.

In order to obtain the gain and the length of the various constituents of the antennae, we resorted to simulators. The results of which will be featured in the appendix to this paper.

2.3.6. Energy Autonomy

Battery used

Voltage: 3,7 V

Capacity: 4200mAh = 4,2Ah

Available energy: E = 3,7 V x 4,2 Ah = 15,54 Wh

Power consumption

P = I x V

Component	Current (mA)	Voltage (V)	Power (W)
Raspberry Pi	250 mA - 350 mA We'll consider 350 mA	5 V	0,35 x 5 = **1,75 W**
Pressure / Temp. Sensor	0,7 mA	3,3 V	0,0007 x 3,3 = **0,0023W**
HD Camera	250 mA	5V	0,25 x 5 = **1,25 W**
Thermal Camera	18 mA	5V	0,018 x 5 = **0,09 W**
GPS	45 mA	5V	0,045 x 5 = **0,225 W**
APC220 Radio System	42 mA	5 V	0,042 x 5 = **0,21 W**

Total Power = **3,53 W**

Battery life calculation

$$Battery\ life\ (h)\ = \frac{Energy\ (Wh)}{Total\ Power\ (W)} = \frac{15{,}54}{3{,}53} = 4{,}4\ h$$

The battery will power the system for **4,4 hours.**

Note:

- This is a maximum load scenario — since the cameras won't be working all the time, that is, they will be taking pictures at a determined rate, the battery life may increase.
- We didn't take into account the efficiency of the MP 2636 amplifier, which might be around 90%, possibly reducing the real time.

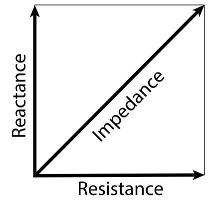
3. CanSat Testing and Calibration

3.1. Testing to the impedance of the antennae

In the Rohde & Schwarz FPC1500 device we optimized the value of **impedance** to 50.0 Ω (Ohm), which is the standard impedance for coaxial cables. This matching of the impedance between the antenna and the coaxial cable enables the maximal transfer of power, resulting in a better efficiency, because it minimizes reflections and signal loss.

Impedance is described as the vector addition of:

1. **Resistance** - the opposition to the current flow.
2. **Reactance -** the opposition that comes from capacitors and inductors in AC circuits.

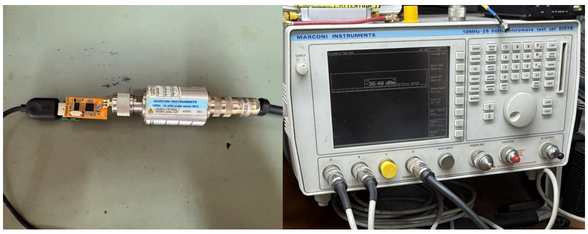


In the appendix, there are the figures corresponding to the smith chart, VSWR and return loss.
The values of the impedance for the frequencies in the range we are going to use are the following:

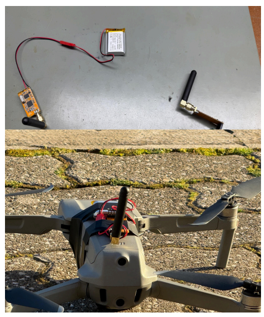
M1	430 MHz •	49.39-j0.23 Ω
M2	433 MHz •	49.20-j0.51 Ω
M3	435 MHz •	48.85-j0.25 Ω

3.2. RF testing

We performed a trial to measure the RF power of the APC220 Radio Module. The power obtained was 35,49 dBm.
The equipment used was the measuring device "Marconi Microwave Test Set 6203A "
and the "Marconi Instruments 6913" probe.



3.3. Simulation of bilateral radio communications in the laboratory.



We tested the bilateral communication, operating the transmitter and receiver in loop mode. Two tests were conducted, one C where the transmitter and the receptor were close to each other, while the other was carried out using a drone that operated at a maximum altitude of 30 meters within a 500-meter radius.
Our tests didn't reveal any problem whatsoever regarding communication.

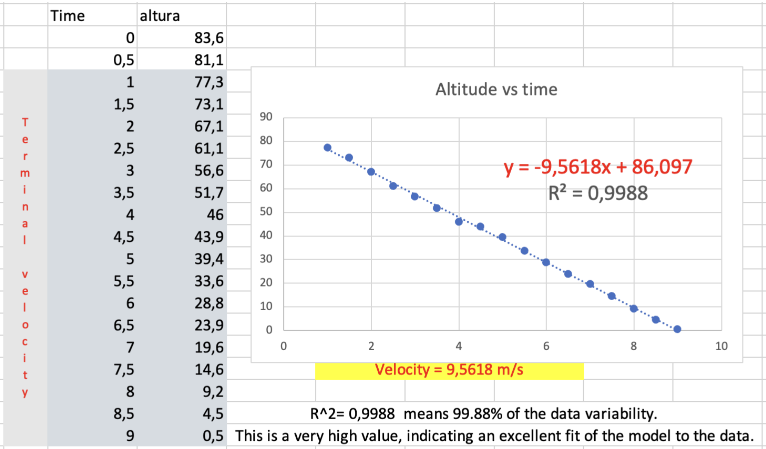
3.4. Wind loading and Landing precision testing

With the aim of designing the ideal parachute, some tests on circular parachutes were carried out on March 23. The tests were made at an altitude of 30 meters with the help of a drone, using:

- 1 circular parachute with a radius of 18 cm with 8 cords;
- 1 circular parachute with a radius of 18 cm with 16 cords;
- Chassis with a mass of 330 grams;

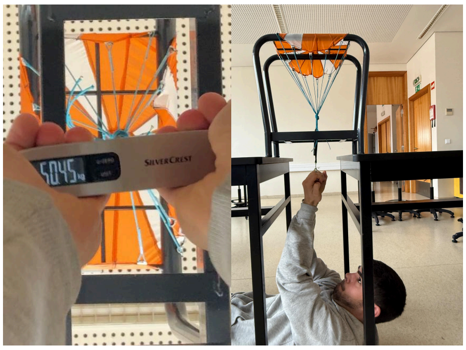
- A pressure sensor and a radio transmitter to send altitude information to the ground station every 500ms.

A detailed analysis of the fall videos allows us to conclude that the parachute becomes more stable when it is equipped with 16 cords.



Time	altura
0	83,6
0,5	81,1
1	77,3
1,5	73,1
2	67,1
2,5	61,1
3	56,6
3,5	51,7
4	46
4,5	43,9
5	39,4
5,5	33,6
6	28,8
6,5	23,9
7	19,6
7,5	14,6
8	9,2
8,5	4,5
9	0,5

In order to study the fall velocity, we used a spreadsheet where we graphically represented the fall height over time. Through linear regression, we obtained the velocity of 9,562 m/s and 8,115 m/s for the first and second test, respectively.



3.5. Parachute Traction Force Testing

The parachute was tested to be able to support, at least, 500 N of traction force. The following images show how the trail was carried out.

3.6 CanSat Acceleration Test

In order to realize the acceleration test, we connected the CanSat to a cord of 1.30 meters of length and set the satellite on a circular movement. We seeked to have a constant velocity, so that the acceleration could be calculated by the product of the radius times the square of the angular velocity. Considering the relation between angular velocity and frequency, we have:

$$a_n = r\,\omega^2 \;\Leftrightarrow\; a_n = 4\,\pi^2 f^2 r$$

With a radius of 1,30 m and to an acceleration of 20g, the frequency is equal to:

$$f = \sqrt{\frac{20 \, X \, 9.8}{4\pi^2 X \, 1{,}30}} \Leftrightarrow f = 1{,}95 \text{ Hz}$$

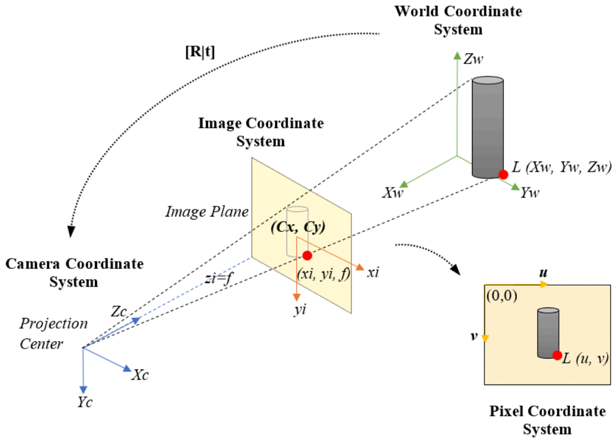
In the trial we made, we attained a frequency of around 2,3 Hz, which implies an acceleration of 27,7g.
The video can be consulted using this link: https://youtu.be/7cVcUySmHf8

4. Innovation

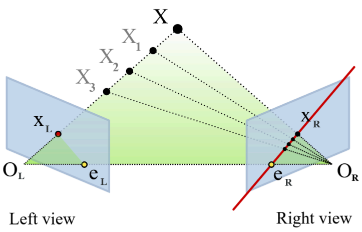
We believe our project's most innovative aspect lies in the usage of photogrammetry, so we will give a brief overview of our method.
To create a model of the environment we must first model the cameras themselves. We model our cameras' projection of 3D objects onto the image plane as a pinhole camera's. In this model 3D points are projected to the image plane according to the following formulas:

$$x' = \frac{fx}{lz} \qquad y' = \frac{fy}{lz}$$

Where (x, y, z) is the point's coordinates in the camera's own referential (i.e. the z axis is perpendicular to the image plane and its origin is the "pinhole"), f is the focal length of the camera and l is the pixel size. Any given pinhole camera can thus be modeled knowing solely its focal length to pixel size ratio and its referential which is itself defined by its origin and its orientation.



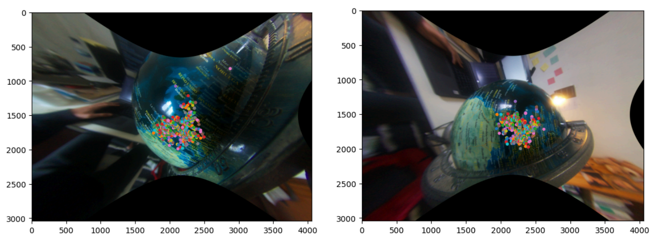
This is, of course, not an accurate model by any means as the fisheye lens we used deviates from it significantly by introducing what is called barrel distortion. This distortion can, fortunately, be quantified and corrected so that our final image looks as though it is simply a non-rectangular image taken by a pinhole camera. The following images show the before and after of this undistortion procedure:



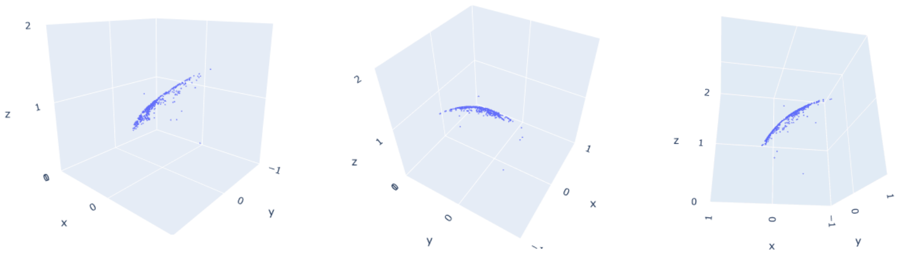
From several of these images we can then extract information about the camera at the moment they were taken. This is achieved through the study of epipolar geometry (see diagram to the left). Knowing how enough points have been projected to the image planes allows us to determine the cameras' relative position and orientation. Using this information we can perform triangulation and determine points' coordinates.

It goes without saying that we must also be able to identify when points in different images match for this to be possible. To this effect, we used the SIFT algorithm.

The following two images of a globe are example inputs where only some points of interest have been highlighted in color:



The reconstructed positions of these points can be plotted in a 3D scatter plot where the unit of length is the length of the camera's displacement between the taking of the pictures. In them one can clearly identify the globe's curvature.



5. Dissemination

As soon as our qualification for the final of the CanSat Portugal contest became known, the team started thinking about the promotion and dissemination of the project to all of the local and academic community. We achieved this through the creation of the following:

- A blog;
- A Facebook group
- An Instagram page,

Where the evolution of the project was posted and documented.

The project was also highlighted in local media outlets, such as:

- "Região de Cister" Newspaper;
- "Cister FM" Radio;
- Newsletter of the Agrupamento de Escolas de Cister (AECister).
- Project dissemination at school during the 'Open Lab Days' activity.

6. External Support

Throughout the development of this ambitious project, we've gotten various supporters and collaborators. We highlight the following:

- **Radioamateur Paulo Delgado CT2GUR:** He has had a tremendous role in the development of this project. He has helped in the creation and maintenance of the antennae, as well as with electronics (R&D), thanks to his expertise in the area. In his laboratory we were able to test and measure the efficacy of the antennae we created, using adequate equipment, through which it was possible to measure the Return Loss/SWR and the impedance of the antennae and the coaxial cables. The insertion losses of the coaxial cables (pigtails) were also measured. Besides, he has given us countless suggestions, whether related to improving the project, or by indicating other people and entities willing to help and collaborate with the project.
- **Agrupamento de Escolas de Cister and the Alcobaça City Council:** Financing all the CanSat equipment.
- **Nuno Virgílio from Cloudbase Portugal:** Donation of the fabric for the construction of the parachute;
- **INED. Publicidade e Design:** Donation of sweatshirts to wear at the final;
- **Caixaltur (Caixilharia de Alumínios de Turquel)**: Donation of aluminium for the construction of the reflector for the helical antenna.
- **HRCD (Helder Delgado):** Donation of copper tubes for the construction of the antenna.

- **AJ TECHNOLOGY (or AJTEC)**: Donation of the GPS antenna and a pressure and temperature sensor. The small size of these components made the assembling process much easier.

7. Budget

Amount	Component	Unit price
1	PTRobotics Cansat Kit (without Arduino)	120 €
1	Raspberry Pi Zero 2W	19,99€
1	Micro SD card	5,75 €
1	Raspberry Pi HQ Camera	59,90 €
1	Raspberry Pi SC0947 Lens	29,90 €
1	Ublox NEO-7M GPS Module	12,50€
1	Adafruit MLX 90640 110º Thermal Camera	101.00€
1	MP2636 Power Amplifier and Charger Module	12,18 €
1	3.7V 4200mAh Li-Po Battery	19,14 €
1	Power Amplifier and Charger, MP2636	12,18 €
2	Antenna connector - Female N panel solder connector with square base	3,16 €
2	Antenna connector - Female N panel weld connector with nut	1,53 €
1	3D Printing Filament	2,78€
1	LED	0,45€
1	Switch	1,13€
3	Resistances	0,12€
1	Single-wire wire kit	15,52€
1	Tin roll	7,95€
Total		**430,11€**

8. Appendix

Link: https://canssini.pt/2025/04/20/appendix/