Critical Design Review

(CDR)

Team: EcoMaros

School Name & City: Bolyai Farkas Elméleti Líceum, Marosvásárhely

Date: 2/16/2025

Video link: https://youtu.be/EJZ_LCFnJKg

Table of contents

1. INTRODUCTION

1.1. Introduction of the team

Our team is a dynamic group of three dedicated students from the Bolyai Farkas Elméleti Líceum. Together, we bring diverse yet interconnected skills to the CanSat project, building on a history of successful collaborations, such as participating in an international Erasmus project. The team is guided by their experienced mentor, Veres Péter, whose expertise in electronics and automation plays a crucial role in ensuring the project's success.

Our mentor, Veres Péter is an engineer and amateur astronomer who provides vital technical support throughout the project. His extensive background in electronics and automation is key in guiding the team through testing and troubleshooting processes. He dedicates approximately **8–10 hours per week** to offering technical advice for our team and helping resolve challenges, ensuring that every phase of the CanSat project meets the competition's requirements and rules, while also maintaining high standards of reliability and precision.

Veres Ákos leads the team as the group coordinator and is in charge of the hardware and software aspects of the CanSat. He is responsible for writing and debugging our CanSat's and Ground Station's code, integrating circuits and sensors, while also developing and maintaining the team's website. His work is vital for accommodating the project's strict size and weight requirements while maintaining functionality and reliability, taking into consideration the safety of our surroundings. Ákos invests roughly **10-15 hours per week** in hardware development and integration, continuously innovating to address technical challenges as they arise during testing.

Bedő-Tar Zerind oversees the design and overall appearance of our CanSat. His creative vision ensures that the satellite is not only aesthetically pleasing but also functionally robust, with careful attention to weight distribution and structural integrity during both launch and landing phases. He's also responsible for the visibility of the satellite, ensuring an easier recovery after the successful mission. In his additional role as social media manager, he manages the project's online presence, engaging with the community and promoting our project to a broader audience. This includes status updates on our official Instagram and Facebook accounts, blog posts on our website and physical interactions with friends and schoolmates. He allocates about **5 hours per week** to visual design tasks and social media activities, ensuring that both the physical and digital presentations of the project are top-notch.

Koszta Gianluca-Krisztián is responsible for the design and implementation of the parachute system that guarantees the safe descent of our CanSat. He performs detailed aerodynamic testing and calculations to optimize flight performance and to meet the competition's specifications. He documents every technical and design aspect of the project. This thorough documentation is essential for clear communication and future reference. The majority of our team's published images and posts exist thanks to his restless efforts, following our tasks during every step of the competition. Krisztián dedicates approximately **5-6 hours per week** to developing the parachute system, conducting aerodynamic tests, and preparing comprehensive project documentation.

1.2. Mission objectives

In addition to its primary objective, our CanSat incorporates a secondary mission focused on environmental protection and visual data gathering. This mission was chosen to address two key areas: improving air quality through precise environmental monitoring and documenting landing and atmospheric conditions via visual recordings. Together, these efforts contribute valuable data for environmental research and community well-being, our team's ultimate objective.

The first component of our secondary mission involves the collection of air quality data during the CanSat's descent. Our sensors are designed to measure various atmospheric parameters, including pollutant concentrations and temperature variations, which are critical indicators of air quality. The rationale behind this mission is to provide actionable insights into local pollution levels and to support broader initiatives aimed at reducing harmful emissions. By gathering and analyzing this data, the project seeks to:

- Measure and Examine: Monitor pollutant levels and ambient air conditions, offering a snapshot of environmental health during the mission.
- Expected Outcome: Produce reliable data that can be used to assess the impact of air pollution and inform strategies for cleaner air and improved public health.

Complementing our environmental measurements, the CanSat is also equipped with a side-mounted camera to capture quality video recordings of its surroundings during descent. This visual data serves two primary purposes:

- Landing Documentation: To verify and document the performance of the landing and recovery systems by recording the descent and touchdown.
- Environmental Context: To provide additional insights into the local environment, correlating visual observations with sensor data.

For the CanSat launch to be considered successful with respect to the secondary mission, the following objectives must be achieved:

- Accurate and Reliable Data Collection: The onboard sensors must consistently capture precise air quality metrics throughout the mission, automatically saving the measured data onto the onboard SD-Card.
- Effective Visual Documentation: The camera must record high-resolution videos that clearly document both the landing process and the surrounding environment, using it’s dedicated SD-Card as storage.
- Integrated Analysis: A thorough analysis combining sensor readings and visual data should provide a comprehensive overview of the environmental conditions during the mission.

2. CANSAT DESCRIPTION

2.1. Overview of the mission

The CanSat is designed to be launched on a rocket, reaching an altitude of approximately 1,000 meters. At this altitude, the satellite will be ejected from the rocket and will descend under the controlled deployment of a parachute system made out of ripstop nylon, ensuring a landing speed of up to 10 m/s. During its descent, the satellite will perform measurements related to both its primary objective (using the onboard temperature and pressure sensor) and its secondary mission—which includes environmental protection (through air quality monitoring with an air quality sensor) and visual data collection (using an onboard camera). Telemetry data will be transmitted in real time to the Ground Station using the radio communication module, while also getting stored to the SD-card along with other values such as package number, date, time, temperature, accelerometer and gyroscope data. Our CanSat is expected to remain active for at least six hours to ensure it's flight readiness during the competition. (Figure 1)

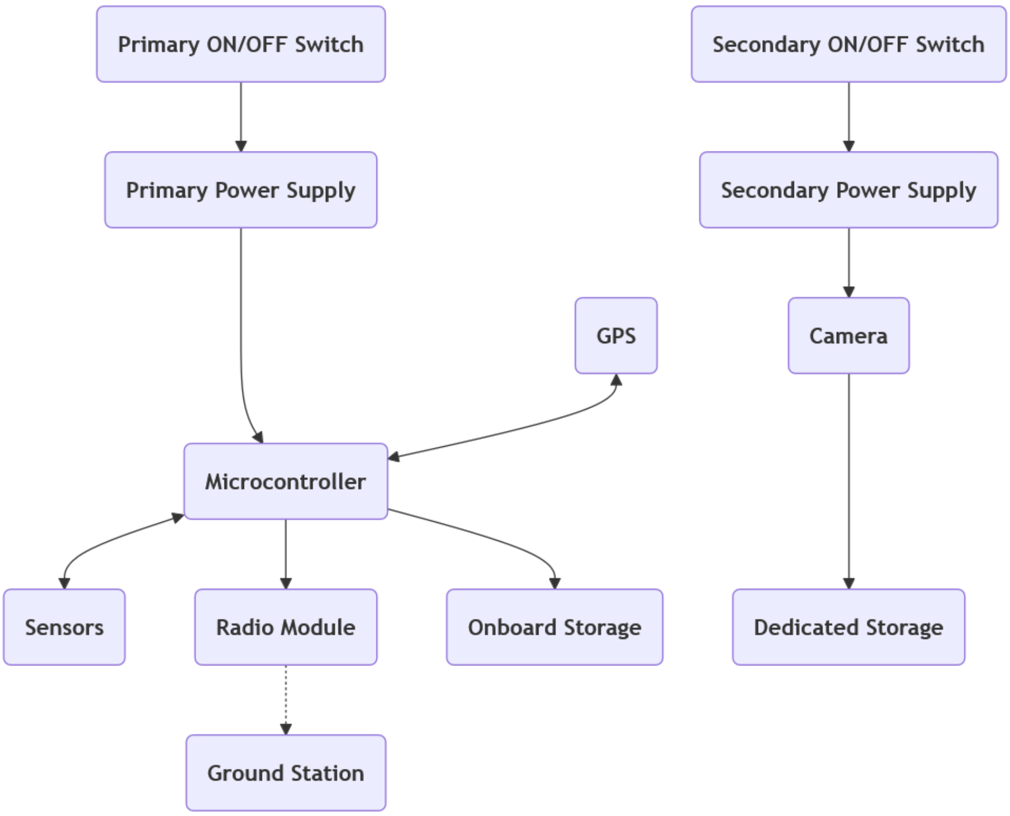


Figure 1

2.2. Mechanical/structural design

Our CanSat is built using bright orange PLA 3D printed plastic, chosen for its excellent balance of lightweight properties, durability, and ease of fabrication. This material not only provides high impact resistance but also offers the benefit of rapid prototyping, allowing for quick design iterations. We have optimized the print settings (high infill percentage, rounded corners and edges) to ensure the structure is both rigid and capable of withstanding high-stress conditions during launch, descent, and landing. Our design also includes screw holes on the body of the satellite. This integration allows us to use small screws and fasteners to securely attach all internal modules and circuit boards. This method not only provides a firm assembly but also reduces the reliance on adhesives, ensuring each component remains tightly fixed throughout the mission.

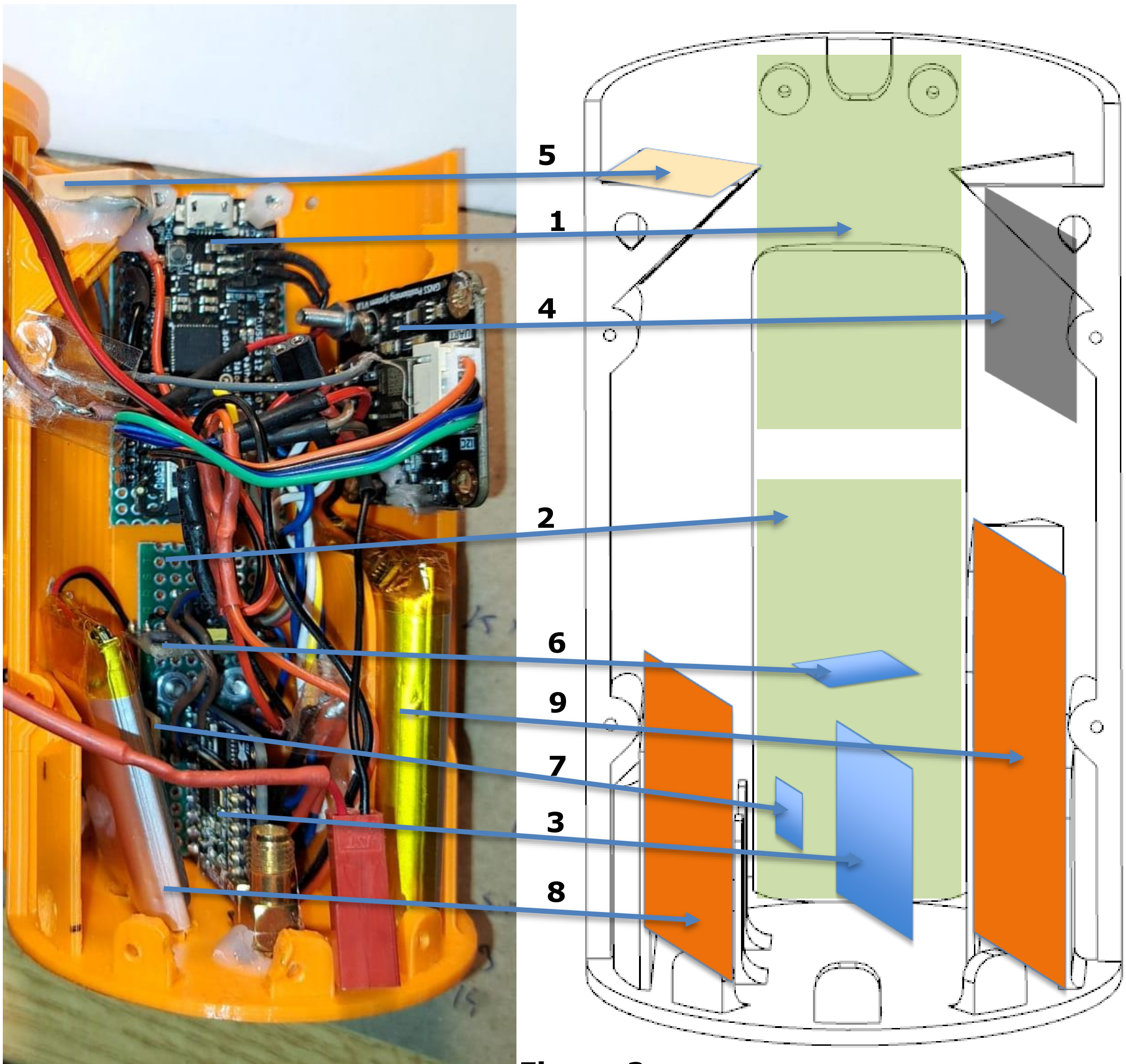


Figure 2

Cansat Hungary

1. **Feather M0 Adalogger with SD-Card support**. It serves as the central processing unit. It reads sensor data via the I2C bus, logs critical information to the SD card, and manages power distribution effectively—all while operating on minimal energy. It features an integrated connector for a 3.7V LiPo battery and an onboard USB charging circuit, simplifying the power management. This means you can easily power and recharge the unit, which is crucial for mission reliability.
2. **Motherboard** used to interconnect all used boards: Radio module, gyroscope, accelerometer, temperature and air quality sensors.
3. **RFM69 HCW Radio Module** used as digital radio module to communicate with the Ground Station at 868 MHz, transmitting telemetry data.
4. **DFRobot Gravity GNSS GPS Module** receiver for GPS positioning and altitude data.
5. **GPS Antenna**
6. **MPU6050 Gyroscope and accelerometer sensor** measures acceleration and gyroscopic movement on all three axis.
7. **BMP280** temperature and pressure sensor, used for primary mission objective.
8. **LiPo 3.7V 1000mAh Battery Pack** used to power the onboard camera used for secondary mission.
9. **LiPo 3.7V 2000mAh Battery Pack** used as main power source for all the other components of our CanSat. (Figure 2)

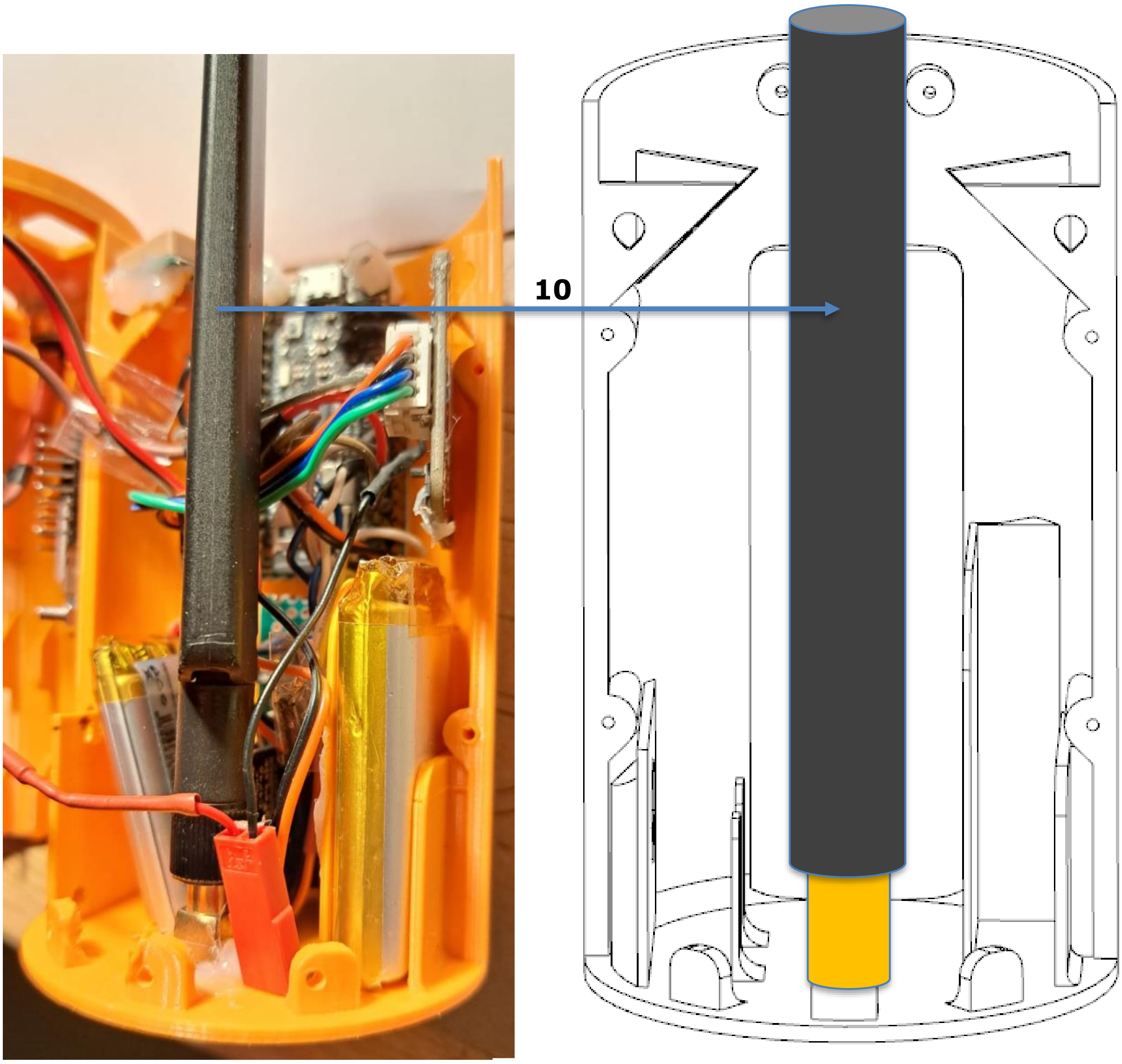


Figure 3

10. 868MHz RF Dipole Antenna with 5dBm gain used to communicate with the Ground Station. (Figure 3)

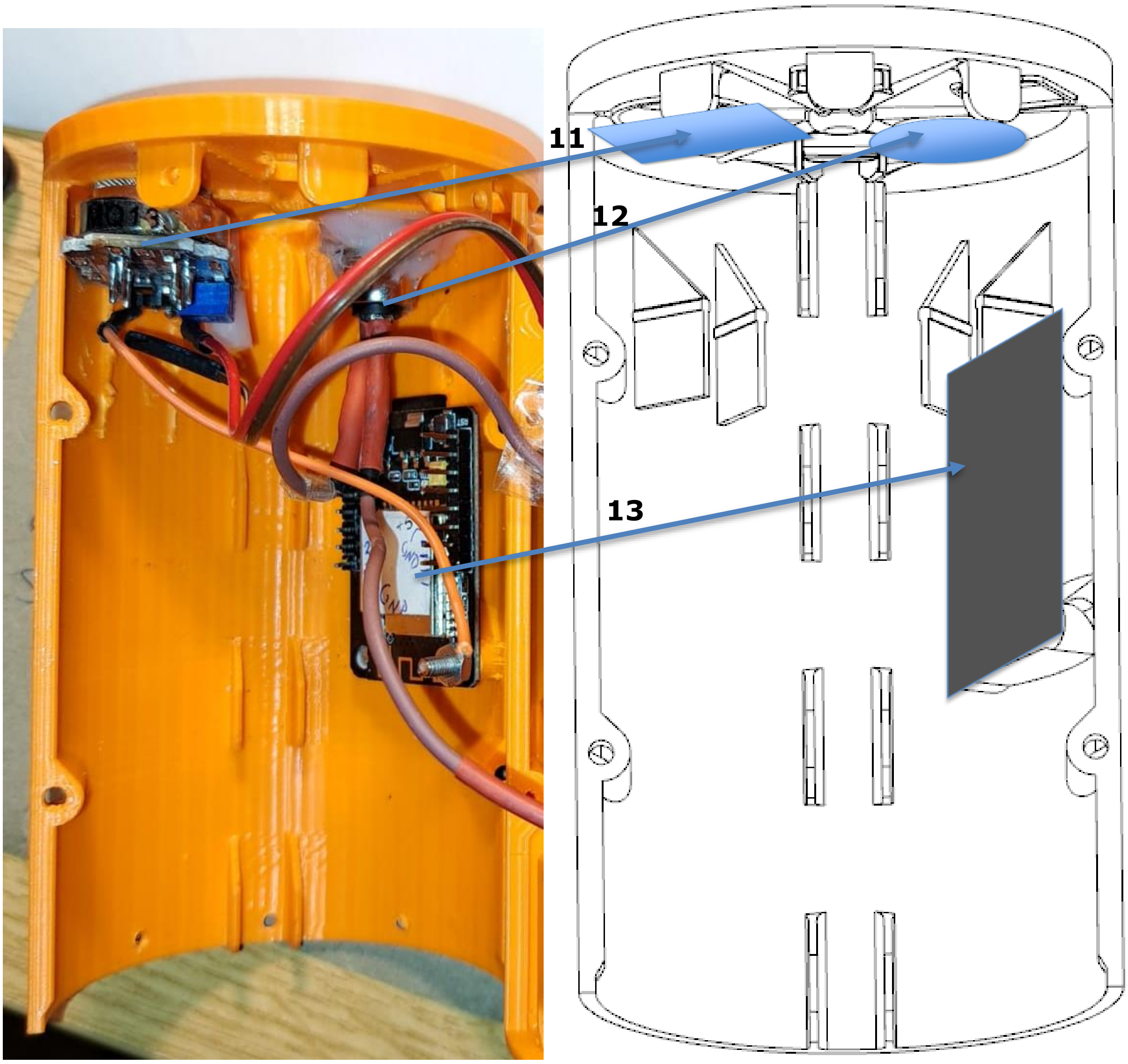


Figure 4

11. MQ135 Air Quality Sensor part of our Secondary Mission, used to detect a range of harmful gases such as ammonia, nitrogen oxides, alcohol, benzene, and smoke. We plan on using it for air quality monitoring and environmental pollution detection.

12. Master Power ON/OFF Switch

13. AI-Thinker ESP32-CAM used as a standalone unit, part of our Secondary Mission Target. It uses motion detection to capture and store live video, with included SD-Card. (Figure 4)

2.3. Electrical design

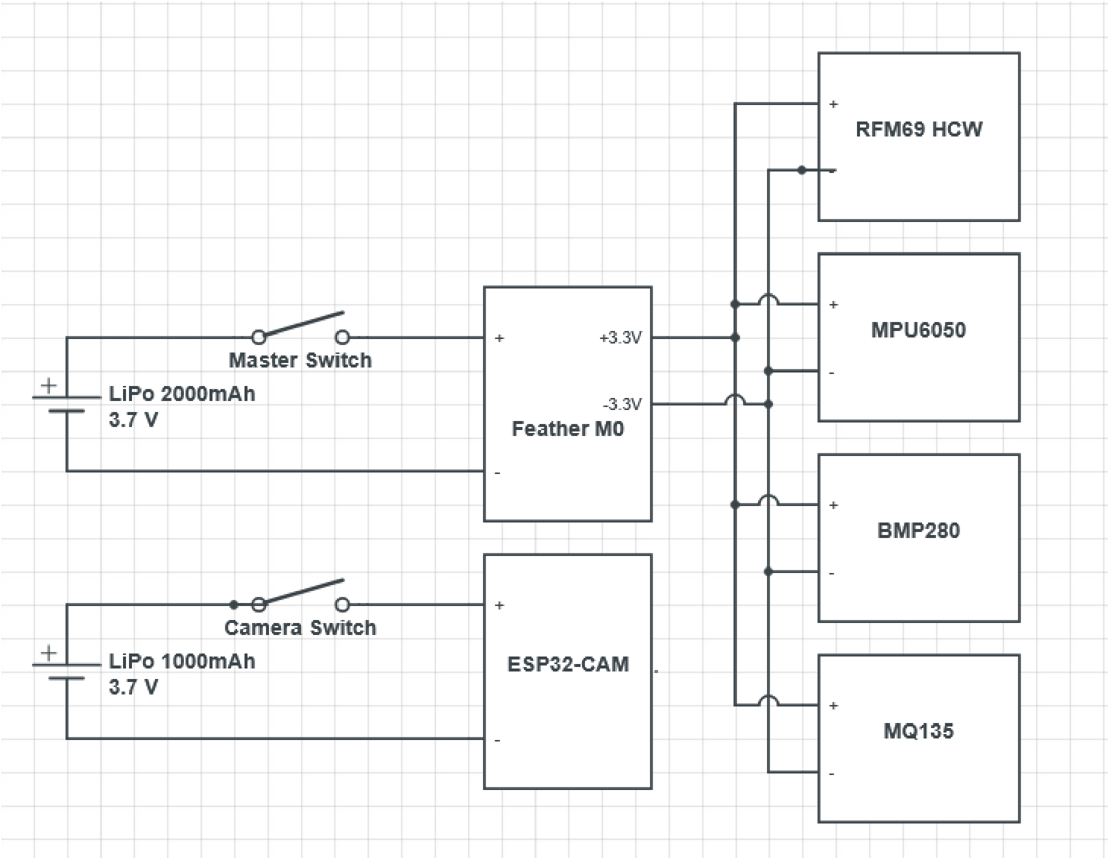


Figure 5

Component	**Power consumption (mA / mW)**	**Component**	**Power consumption (mA / mW)**
Adafruit Adalogger Feather M0 (3.7V)	14 / 51.8	ESP32-CAM (3.7V)	150 / 555
BMP280 (3.3V)	0.6 / 1.98		
MQ135 (3.3V)	29 / 95.7		
Adafruit RFM69HCW 868MHz (transmitting) (3.3V)	110 / 363		
MPU6050 (3.3V)	18 / 59.4		
DFRobot Gravity GNSS (3.3V)	40 / 132		
Total	**210.6 / 703.88**		**150 / 555**

Table 1

CONCLUSION: For the boards and sensors we chose the LiPo 3.7V 2000mAh Battery Pack and for the onboard camera we installed another LiPo 3.7V 1000mAh Battery Pack. Both of them are capable of supplying enough power for the set minimum mission time of 4 hours. (Figure 5 & Table 1)

RFM69HCW digital radio has an RF output power in 50 ohms, programmable with 1dB steps: Max 20dBm. Capable of using high speed FSK modulation, up to 300 kb/s. Can be used in Packet mode or in Continuous mode. Due to mission characteristics we will use it in Packet Mode. The packet (sensors and GPS data collected) is automatically built with preamble, Sync word, and AES 128bit encoding. The reverse operation is performed in reception.

We have chosen to use it just in transmitter mode from the CanSat to Ground station - to send Telemetry data. The packages are sent 5 times each second. Frequency usage will be determined on launch date with 100kHz scalability. We have tested it on 867.1 MHz as well on 867.5 MHz, with different RF power from 15dBm to 20 dBm reaching fair level of receiving enough packages of data. (Figure 6)

The Ground Station uses the same radio module on the same frequency, only in Receiver mode. With a personalized PC software we will follow telemetry with RSSI value live and manually orientating the antenna toward the CanSat maintaining the highest level of RSSI.

Conclusion: This module is capable of transmitting the amount of telemetry data needed in desired time frame with enough radio power to satisfy our mission's goal.

```
#define RF69_FREQ 867500000
```

```
rf69.setTxPower(15, true);  // range from 14-20 for power, 2nd arg must be true for 69HCW

// The encryption key has to be the same as the one in the server
uint8_t key[] = { 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08,
                  0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08};
```

Figure 6

2.4. Software design

The EcoMaros CanSat software is designed as an integrated system to manage all aspects of data handling—from acquisition to storage and transmission. Written in C++ using the Arduino IDE.

1. Initialization phase: When powered on, the software initializes all components, including the camera, GPS, sensor calibration, communication links, and onboard memory.
2. Flight mode: Once the initialization phase is complete, the satellite runs in "Flight mode" until shutdown.

In Flight mode the CanSat is in constant communication with our Ground Station through it's radio module and antenna, sending strings of telemetry data every ~200 milliseconds. Simultaneously, the satellite measures a set of different values using it's sensors with one decimal accuracy (except the latitude and longitude data, which require 6 decimal places), and saves it into a datalog text file created on the SD-Card. Each line, the data values are separated using commas, so the previously mentioned datalog.txt file can be reformatted into an Excel CSV file, making Post Data Analysis much less time consuming. Even if the radio communication breaks up, the CanSat will continue to save data to it's SD-Card, while checking for possible reconnection with the Ground Station. The side camera is equipped with a motion sensing routine that prevents the recording of static videos, making Post Data Analysis easier to conduct. (Figure 7)

After touchdown, data such as temperature and air quality are continuously measured and saved onto the board's SD-Card, further contributing to data visualization and comparative analysis, while maintaining radio communication with the Ground Station for easier recovery (See section 2.6 for further details).

After multiple calculations, assuming that the CanSat will be measuring and saving data for 4 hours, the result will be a 7 Mb data file, containing all the recorded data (104 characters / reading, 5 readings / second, x60 / minute, x60 / hour, x4 / 4 hours = 7.488.000 characters).

$$\mathbf{104 \times 5 \times 60 \times 60 \times 4 = 7.488.000}$$

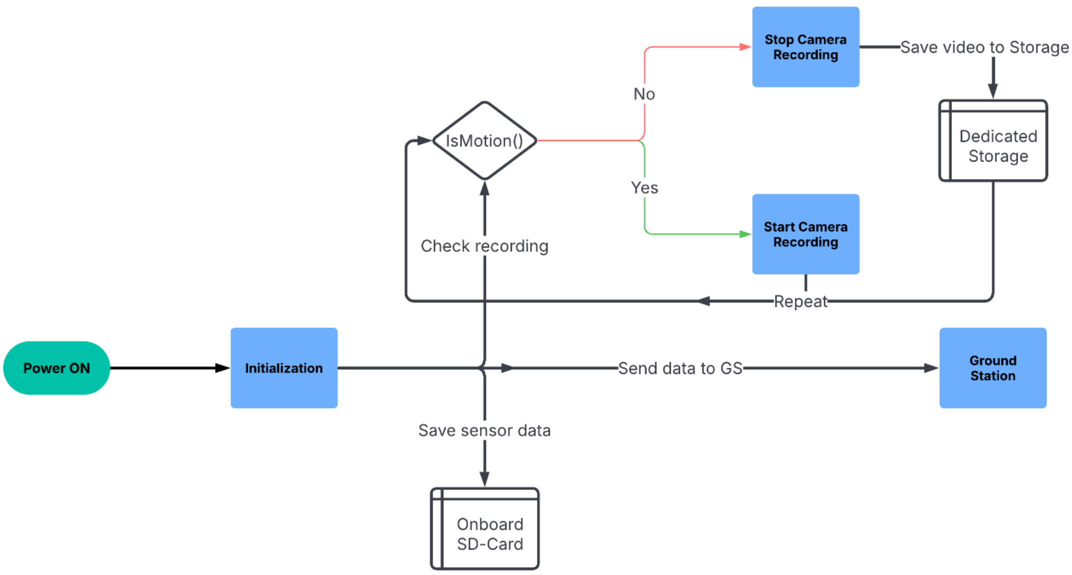


Figure 7

2.5. Recovery system

The recovery system of our CanSat is a parachute-based passive descent system, designed to slow down the descent and ensure a safe landing.

The parachute is a lightweight, dome-shaped canopy made from durable synthetic fabric. It consists of multiple stitched panels in orange and white, ensuring visibility during descent. The seams are reinforced to provide structural integrity during deployment.

The parachute is attached to the CanSat using elastic cords that are securely looped through reinforced holes at the top of the canopy. These cords are fastened to the main body of the CanSat using a metallic hook placed in the middle of our satellite's roof, ensuring a stable and controlled descent (under development). The attachment method prevents excessive swaying and helps maintain a predictable landing pattern.

Once the CanSat is released from the rocket, the parachute unfolds due to air resistance and the force of gravity. As the parachute inflates, it creates drag, significantly reducing the falling speed. The controlled descent ensures a soft landing, minimizing impact forces on the CanSat's internal components.

Based on our most recent tests and calculations (Parachute Version 3.0), we estimate the descent duration to be under 100 seconds, with a descent rate of 7.5 m/s. depending on altitude, parachute size, and atmospheric conditions.

$$G = m * g \;(force\ of\ gravity)$$
$$F_d = 0.5 * c_d * \rho * v^2 * A \;(drag\ force)$$
$$d = d_1 - d_2$$
$$A = \frac{1}{4} * \pi * d^2$$
$$G = F_d$$
$$m * g = 0.5 * c_d * \rho * v^2 * A$$
$$v^2 = m * \frac{g}{0.5} * c_d * \rho * v^2 * A$$

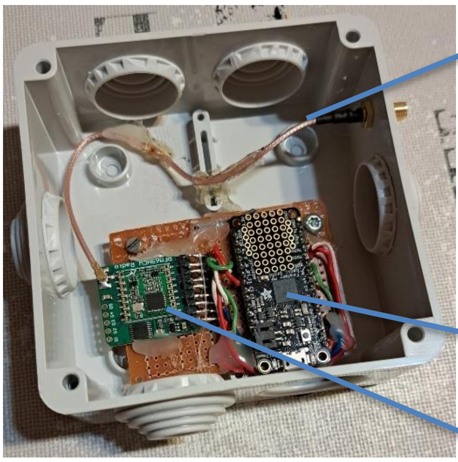
$$m = 0.34\,kg \;(mass\ of\ CanSat)$$
$$g = 9.81\frac{m}{s^2}$$
$$c_d = 0.78 \;(drag\ coefficient\ of\ parachute)$$
$$\rho = 1.225\frac{kg}{m^3} \;(air\ density)$$
$$A = 0.124\,m^2 \;(total\ area\ of\ parachute)$$
$$d_1 = 0.4\,m \;(full\ diameter\ of\ parachute)$$
$$d_2 = 0.04\,m \;(top\ hole\ diameter\ of\ parachute)$$
$$v = \sqrt{56.144} = 7.5\frac{m}{s} \;(descent\ rate\ of\ CanSat)$$

Parachute resistance test (50N)

&

Real flight test (26m)

2.6. Ground station



Antenna Connector

Adafruit Feather
Basic Proto

RFM69 HCW
Radio Module

Figure 8

Figure 9

Our Ground Station consists of an Adafruit Feather Basic Proto microcontroller, communicating with the laptop via USB. It has an RFM69 HCW Radio Module attached to it, using a 5-element YaGi antenna to listen to the satellite's telemetry transmissions. (Figure 8 & 9)

We have developed a computer interface using Serial Studio JSON scripting to continuously monitor telemetry data in real time received from our CanSat. It measures the RSSI value, helping to orientate the ground antenna towards the direction of the satellite. It has a crucial role in recovering the CanSat after touchdown, visualising the flight path based on received telemetry data. (Figure 10)

Figure 10

3. PROJECT PLANNING

3.1. Time schedule of CanSat preparation

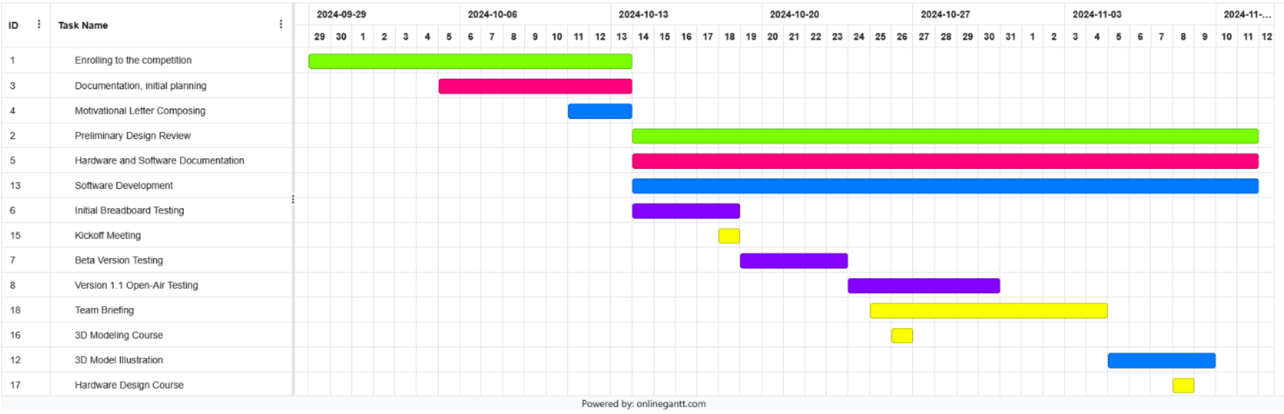


Figure 11

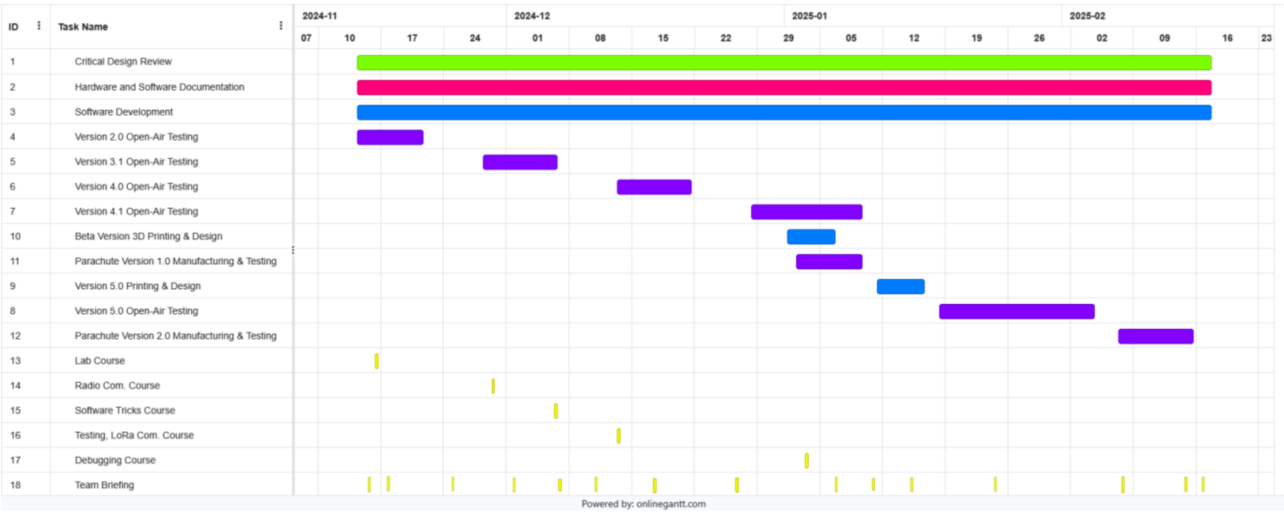


Figure 12

3.2. Resource estimation

3.2.1. Budget

Components	Price (EUR)
Adafruit Adalogger Feather M0	19.00
BMP280	9.50
MQ135	12.38
Adafruit RFM69HCW 868MHz + antenna	11.38 + 3.60
ESP32-CAM	18.10
DFRobot GNSS GPS 1.0	17.05
8 Gb SanDisk Micro SD	8.56
4 Gb SanDisk Micro SD	4.75
LiPo 3.7V 2000mAh	12
LiPo 3.7V 1000mAh	8
3D materials + printing	75
Master Switch	1
MPU6050	4.7
TOTAL	**205.02**

Table 2

3.2.2. External support

During our journey, our team was lucky to receive support from multiple outside sources. **Haraszti Werner**, the CEO of **Lico Mecatronic S.R.L.** provided us the materials and tools needed for 3D printing the CanSat, donating six pieces of high-quality circuit boards, two of which we integrated into the final CanSat body, leaving the remaining 4 for testing purposes. **Fuccaro Miklós** offered individual assistance in designing the satellite's body, helping our team create the perfect match for our mission by providing professional 3D design coaching using the AutoCAD software.

3.2.3. Test plan

After many tests and unsuccessful attempts we have reached where we're confident that our CanSat can fulfil both the Primary and Secondary Missions. The best communication results we have obtained in clear LOS at a distance of 3.7 km, with 15dBm TX power set, at 867.5 MHz frequency (all other frequencies worked also fine).

However, the parachute and drop tests are still undergoing, with additional changes to be made in the future regarding the parachute.

4. OUTREACH PROGRAMME

At **EcoMaros**, our outreach strategy is designed to actively engage the community and key stakeholders through our official channels. We ensure that our platforms are regularly updated with fresh content ahead of the CDR submission date.

4.1. Existing Platforms and Future Plans

- Website**:** Our official website (ecomaros.space) serves as the central hub for all EcoMaros project details, progress updates, and press releases. We plan to enhance this platform with interactive blogs and multimedia content as our project evolves.
- Instagram: Our Instagram page (www.instagram.com/ecomaros.cansat) is actively maintained with behind-the-scenes images, project milestones, and updates. Moving forward, we aim to deepen our community engagement through regular posts and interactive stories.

Additionally, EcoMaros has developed a unique project logo, which is a key element of our branding and outreach materials.

4.2. Summary of Outreach Activities

Platform URL	Outreach Activities	Media Coverage	Presentations/Exhibitions
ecomaros.space	- Regular EcoMaros project updates - Press releases - Blog posts	- Active outreach to local media	- Presentations at local tech events and conferences
instagram.com/ecomaros.cansat	- Frequent posting of project milestones - Sharing behind-the-scenes content - Showcasing our designed logo	- Monitoring social engagement for media interest	- Exhibition at local tech fairs (excluding school events)

5. REQUIREMENTS

Characteristics	Quantity (unit)	Requirement	Eligible (Yes or No)
Height of the CanSat	114 mm	115 mm	Yes
Mass of the CanSat	340 g	300 – 350 g	Yes
Diameter of the CanSat	65 mm	66 mm	Yes
Length of the recovery system	65x40 mm	66x45 mm	Yes
Flight time scheduled	<100 s	120 s	Yes
Calculated descent rate	7.5 m/s	5 - 12 m/s	Yes
Radio frequency used	867.5 MHz	868 MHz	Yes
Power consumption	210.6 mA 150 mA	210 * 4 h 150 * 4 h	Yes
Total cost	205.02 Eur	500 Eur	Yes

On behalf of the team, I confirm that our CanSat meets all the requirements set out in the official guidelines for the 2025 Hungarian CanSat competition.

Signature, place and date:

Veres Péter

Marosvásárhely, 02.16.2025