Critical Design Report

Team Name: CoderDojo Oradea Space Robotics
Organisation: CoderDojo Oradea
Country: Romania

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Contents

1 Introduction

1.1. New progress statement for the team profile

CanSat Developement

Mechanical design During our design phase, we've been evaluating two distinct can models using Autodesk Fusion. The initial model incorporates a lid positioned at the can's base, showcasing reliability and efficiency, albeit with certain constraints. The primary benefit of this bottom-lid configuration is its straightforward access to the can's interior, facilitating assembly and upkeep. Nevertheless, a drawback is the necessity for a swivel mechanism to attach the parachute, introducing additional weight and complexity. Moreover, this design complicates the rapid exchange of parachutes, potentially causing delays in practical scenarios.

Conversely, our second prototype features a lid on the can's top, streamlining the parachute's replacement without the swivel, thereby lightening the load and simplifying the design. This top-lid approach enhances access and maintenance ease. However, it presents a challenge in assembly, requiring components to be fitted through the upper opening.

Electrical design In late January, our team initiated the development of the payload, opting to use Python for programming, with a choice between ESP32 or Raspberry Pi RP2040 as the hardware platform. After thorough research and comparison of both options, we settled on the ESP32 for its superior features.

Initially, the Raspberry Pi 2040 (Pico) was considered, but it ultimately failed to meet our requirements for connectivity interfaces.

Recently, we embarked on a project focused on integrating two ESP32 microcontrollers. We chose the ESP32 for its enhanced computational power and wireless functionality, aiming to develop a powerful and flexible system that aligns with our project goals.

Module	Sensor	I2C Bus	I2C Address	Manufacturer
Altimeter	LPS25H	1	0xB8	STMicroelectronics
IMU	MPU-9250	2	0x68 - 0x69	TDK InvenSense
Environmental Sensor	BME688	2	0x76 - 0x77	Bosch
Temperature Sensor	MCP9808	1	0x18	Microchip Technology
Ambient Light Sensor	VEML6075	1	0x10	Vishay Semiconductors
GNSS / GPS Module	Quectel L76	2	0x20 - 0x21	Quectel

Table 1: Sensor modules with their respective I2C addresses and manufacturers

To gather the required components, we began sourcing them from suppliers like Mouser and TME.

Recovery System For our team's inaugural payload deployment, we opted for a parachute with a hemispherical shape. However, we ultimately chose a hexagonal model for our recovery parachute.

In an effort to refine our parachute design, we experimented with a hexagonal parachute variant that more closely resembled the hemispherical model. To inform our design process, we utilized resources found online, such as Nakka-Rocketry.net, to construct a parachute model and develop a new test board equipped with additional IMU and communication modules. These enhancements enabled us to achieve a descent velocity of 6 to 9 meters per second, marking a successful adaptation.

As we prepared for our next mission, it became evident that new parachutes were necessary. The parachutes from previous missions were showing signs of wear and tear, posing a risk to the mission's success.

To address this, we began crafting prototype parachutes while awaiting delivery of essential materials from a German supplier. We selected Nylon Ripoff Cordura fabric for its 50 grams per square meter weight, procured from extremtextil.de, due to its renowned durability and high resistance to abrasion. This choice was pivotal in ensuring the parachute's performance and longevity in challenging conditions, contributing to a robust mission strategy.

During our test phase, we developed and tested two parachute designs, each optimized for different weather conditions: one smaller for windy environments and another for calm conditions. This approach ensures our readiness for various atmospheric scenarios. Detailed diagrams of these parachutes are available for review in the Annexes B.

Ground Support Equipment As our team gets ready for the next flight, we realized how important it is to have a reliable and effective base station to keep track of our payload. To make sure our base station would work, we used two different plans.

Our first step was to find a new use for our old base station, which uses LoPy technology from Pycom. The members of our team had used this system before on other flights (CanSat), and it had proven to be very reliable and effective. We were sure that using this tried-and-true platform would give us a strong base station system and a backup plan in case we ran into any problems.

As our second step, we started making a new base station based on the Raspberry Pi. This change was made because we wanted to use and try new technological solutions in order to build a more advanced and flexible system that could meet the growing needs of our project. This also fit with our decision to use the ESP32 for the payload, which led us to try out the Pico as well. We chose the Raspberry Pico because it has better processing power, more connectivity choices, and more flexibility, all of which we thought were important for achieving our mission goals.

Sensor testing

Our team has advanced in the development and testing of the payload and individual sensors. We've performed targeted tests on acquired sensors, including for pressure, temperature, humidity, UV, and GPS functionalities.

- **Pressure Sensor:** We validated this sensor by comparing its pressure readings under varying conditions with a reference sensor, ensuring accuracy (we exposed the used sensor to a pressure change and compared the results with a reference device. We placed both sensors in a sealed container with a known volume of air and measured the pressure change with a manometer or a barometer). The test was considered positive when both sensors showed the same pressure without measuring errors.
- **Temperature Sensor:** This sensor underwent a 24-hour test to confirm its temperature readings matched those of a reference sensor, verifying its reliability (we placed both sensors in the same location and monitored their temperature readings at regular intervals for 24 hours). The test was considered positive when both sensors showed the same temperature without significant deviation.
- **Humidity Sensor:** We assessed this sensor in a controlled humidity environment, comparing its readings to a reference to ensure precision (we placed the target sensor and the reference device in a humidity chamber where the humidity was increased or decreased to a specific level, and the readings were compared). The test was considered positive when both sensors showed the same humidity level without significant deviation.

- **UV Sensor:** We exposed this sensor to UV light, comparing its UV index readings with a reference sensor to confirm its effectiveness. The test was considered positive when both sensors showed the same UV index without significant deviation.
- **GPS Test:** The GPS module's location accuracy was verified by comparing its data with a known location, ensuring its precision for mission requirements. We recorded the location data collected by the GPS module during this time and compared it to the actual location using a separate reference system.

1.2. Detailed project status

Our team is thrilled to share that we've made big steps forward in the building of our payload. The prototyping process has begun, which allows us to thoroughly test how each sensor works. Also, we've made different payload case designs to test how durable they are, and all of them have done great under tough conditions. Now that we have chosen the key parts and materials, our attention turns to putting them together in the best way possible so that the payload design exceeds other designs. As we move forward, we highlight how important it is to keep testing and making changes. The final PCB assembly and testing phase is scheduled for the coming weeks, which will ensure that the payload's electronics work at their best.

2 Introduction

2.1. Purpose of the mission

Our CanSat mission aims to integrate multiple sensors for atmospheric and motion analysis, investigating cosmic ray interaction with the atmosphere into one small module. The sensors will measure pressure, temperature, humidity, UV intensity, CO/CO2 levels, and detect muons. By deploying diverse sensors on our small CanSat, we can address important topics, such as environmental degradation, air quality, and high-energy physics, while also our knowledge about satellite technology and climate issues, physics and a broad range of other sciences. Our goal is to foster curiosity of our world, while also providing insights for both the scientific community and our team.

2.2. Team organisation and roles

2.2.1. Team name

The team name CDOSR stands for Coderdojo Oradea Space Robotics. Coder Dojo is a community programming club that offers free, volunteer-led coding sessions for youth aged 7 to 17 to foster programming skills. CDOSR is a division within CoderDojo which is based in Oradea and is comprised of passionate rocketry enthusiasts.

2.2.2. Team composition

The Space Robotics team of CoderDojo Oradea consists of a team leader and five members who are all between the ages of 15 and 18. Although they attend different high schools from Oradea, they are all members of the CoderDojo Oradea community.

Each team member has a primary role that they diligently fulfill and secondary roles that can be a place to learn from other memebers, promoting equality and providing a pleaseant enviroment for everyone.

Andrei Ţigan

- **Contribution:** Responsible with mechanical design, programming and work coordination among team members.
- **Field of Work (Role):** Team leader and software advisor. Coaching and coordinating the team.

David Cherecheș

- **Contribution:** Responsible for programming the research module, analyzing the data received from the payload, and managing the team's public image.
- **Field of Work (Role):** Software design, data analysis, outreach planning.

Daria Fologea

- **Contribution:** Responsible for the flawless functioning of the recovery system, monitoring and controlling the CanSat and ground station. Assist with data analysis and interpretation, using software tools to analyze the data transmitted from the payload.
- **Field of Work (Role):** Recovery system, ground station, data analysis and interpretation.

Alin Lupău

- **Contribution:** In charge of mechanical and rocketry designs and contributing to programming tasks.
- **Field of Work (Role):** Software design and high-level programming, Mechanical design.

Andrei Bogdan Costea

- **Contribution:** Circuit/electrical design. Responsible for the schematics and sensor footprint design for the payload (CanSat).
- **Field of Work (Role):** Electronics design & integration.

Mark Trefi

- **Contribution:** Responsible for the mechanical design, including wiring, layout and schematics, outreach planning, and public relations management, like graphic design and website management. He will also contribute by creating digital simulations and models of the CanSat.
- **Field of Work (Role):** Mechanical design, outreach projects, and computer modeling.

2.2.3. Team's Activity:

The team has developed a 6-point action plan to ensure effective progression in the CanSat and its payload (CanSat) design and development process, including:

1. Effectively work together on the project by using the skills and knowledge of each team member and giving each person clear jobs and responsibilities based on their interests and skills;
2. Establish a clear plan and timeline for the design, development, and testing phases of the CanSat;
3. Regularly communicate and meet to discuss progress, challenges, and potential solutions:

4. Leverage a multitude of resources, particularly those available online, to bolster the team's advancement and growth;
5. Continuously test and evaluate the CanSat design to ensure it meets competition requirements and performs as expected;
6. Seek feedback and input from mentors and advisors to enhance the design and development process.

2.3. Mission objectives

"Exploring the cosmos is not just about reaching for the stars; it's about inspiring the dreams of those who will one day touch them." - Unknown

The mission objective for the CDOSR team is to conduct a detailed atmospheric analysis at an altitude of approximately 200 meters, primarily focusing on collecting atmospheric pressure, temperature data, and flight dynamics data using an Inertial Measurement Unit (IMU). This mission is designed to lay the groundwork for future, more extensive exploratory initiatives. In its primary role, the CanSat will meticulously record and transmit vital atmospheric data, including pressure and temperature, alongside critical IMU data capturing the acceleration and gyroscope readings, essential for understanding the CanSat's behavior during flight.

In addition to these main goals, the CanSat also has a very broad secondary mission. This involves measuring other environmental factors like humidity, UV light strength, carbon monoxide/dioxide. Furthermore, this mission takes an innovative step into cosmic research by detecting muons, enhancing our exploration of space's mysteries.

2.3.1. Missions description

The CanSat's **primary mission**, following its release and during its descent, is to measure air **temperature** and air **pressure**. It will transmit this data to the ground station at least once every second. The data collected will be analyzed using the barometric formula to determine the CanSat's altitude.

The secondary mission of the CDOSR team ambitiously expands on its primary goals by incorporating the measurement of diverse environmental parameters. This includes humidity, UV light intensity, carbon dioxide levels, and cosmic particle detection, alongside the core telemetry data. The mission comprises several key tasks:

- **Enhanced Atmospheric Analysis:** Our CanSat will meticulously record atmospheric data at varying altitudes, focusing on temperature, humidity, and pressure. The aim is to construct a detailed atmospheric profile, providing valuable insights into atmospheric science and climatology.
- **UV Light Intensity Monitoring:** The CanSat will detect and record the amount of UV radiation at different altitudes during its descent. This data will be used to create a profile of the UV radiation intensity along the descending path. This information will help identify areas with high levels of UV radiation and raise awareness of the risks of skin damage and other health problems.
- **Advanced Cosmic Particle Research:** Delving into the field of high-energy physics, the CanSat is set to detect and study muons. This endeavor will not only enhance our knowledge of cosmic rays but also deepen our insight into the fundamental processes of space.

- **Air Quality Assessment:** The mission includes a thorough analysis of air quality, measuring carbon monoxide and other pollutants at various altitudes. This data will be instrumental in identifying pollution sources and aiding environmental policy-making concerning air quality.

2.3.2. Measurements, investigations and tests

Our mission emphasizes environmental monitoring by continuously tracking UV light intensity and carbon monoxide/dioxide levels throughout the CanSat's flight. This includes data collection and understanding the implications of these environmental factors at different altitudes. Our mission software is tailored for analysis, converting raw data into meaningful insights using graphical representations, detailed tables, and focused numerical analysis, providing an "X-ray" of the atmosphere.

A core objective of our mission is to detect muons with our CanSat. Muons are heavy elementary particles created when cosmic rays collide with gases in the Earth's upper atmosphere. Despite their short average lifespan of 2.2 microseconds, muons travel through the atmosphere, losing energy as they interact with various elements. This phenomenon, used in fields like Egyptology to discover hidden rooms in pyramids, is a fascinating subject of study. Although theory suggests that only about 0.003 percent of muons should reach the Earth's surface, approximately 10,000 muons strike every square meter of the Earth's surface every second. Investigating this discrepancy illustrates time dilation due to their high velocity, as proven by Einstein's theory of special relativity.

We will employ real-time transmission for certain data using a LoRaWAN network, while storing data collected at higher frequencies on flash memory and a microSD card for post-touchdown analysis. Our team emphasizes transforming collected data into a coherent narrative through various methods, including visual representation with charts and graphs, generating tables for variable comparison, and conducting numerical analysis.

The CDOSR team's secondary mission involves measuring atmospheric data and air pollution at different altitudes. This mission is vital for environmental and technical reasons, as the CanSat operates in a dynamic environment with rapidly changing atmospheric conditions such as temperature, humidity, and pressure. We also aim to conduct technical evaluations and material tests, balancing real-time transmission of UV and air quality data with detailed post-mission analysis of muon data.

Additionally, we are testing new materials, such as lightweight Cordura nylon for our parachute, correlating its performance with atmospheric data during descent. The microcontroller at the core of our CanSat will undergo rigorous performance evaluation by processing various atmospheric and cosmic data in real-world conditions. Lastly, our mission serves as a testbed for a modular sensor design, evaluating the efficiency of different sensor combinations and the feasibility of a unified processing core.

2.3.3. Research expectations

The CDOSR team aims to gain insights and knowledge from measuring atmospheric data and air pollution at different altitudes.

The team aims to optimize the CanSat's design and operation by measuring temperature, humidity, and pressure at different altitudes to ensure its survival and successful mission completion.

As the altitude increases, the atmospheric conditions undergo significant changes. The team expects a decrease in temperature of around 6.5 °C per kilometer, which is approximately the value of the vertical thermal gradient in the troposphere under standard conditions[1]. Moreover, using both linear and exponential Stevin's law[2], the team should detect a decrease in air pressure of approximately 12 hPa per 100 meters. As a consequence, there should be also a slight decrease in relative humidity since it is directly proportional to the air pressure. These insights will help the team to design and optimize the CanSat's systems to withstand the changing atmospheric conditions during the mission.

The team aims to gather data on UV radiation and air pollution at various altitudes to identify pollution sources and raise awareness of associated health risks.

The team aims to gain insights into data collection, transmission, and analysis for future space projects. We will equip the CanSat with specialized sensors to capture and analyze high-energy particles, particularly muons. The insights gained will be invaluable for future projects involving cosmic research and particle physics.

Overall, the CoderDojo Space Robotics project team expects to gain valuable insights and knowledge from the secondary mission of measuring atmospheric data and air pollution at different altitudes, contributing to the broader goal of promoting environmental sustainability and advancing space-related technology.

2.3.4. Objectives for a successful mission

The below objectives are to be achieved on launch day and post-launch analysis:

- ✓ Successful launch
- ✓ Live data transmission and telemetry
- ✓ Successful parachute deploy
- ✓ All systems nominal (reliable sensor and location data)
- ✓ Descent rate between 5-10 $\mathrm{m\,s^{-1}}$
- ✓ Landing confirmation
- ✓ Recovery of the can
- ✓ Data analysis
- ✓ Generating reports

In conclusion, the primary mission of the CanSat project is to measure and transmit atmospheric data such as temperature, pressure, and altitude, while the secondary mission includes additional measurements such as humidity, UV radiation, air pollution, telemetry data and muon detection.

Collecting atmospheric data is crucial for our space project, as it offers vital insights into the environment the CanSat encounters, influencing its design optimization and supporting sustainability. Understanding atmospheric variables like temperature, pressure, humidity, and UV radiation is key to ensuring the CanSat's effective operation and preventing damage to its components.

The data gathered at various altitudes will not only help us fine-tune the CanSat's design for enhanced performance but also allow for a successful mission outcome.

3 CanSat description

3.1. Mission Overview

The CoderDojo Space Robotics project team will execute the mission by designing and constructing a CanSat that will launch and deploy from an altitude of approximately 1000 meters. During the CanSat's descent, it must maintain a speed between 5 and 10 meters per second, while it simultaneously collects and transmits key environmental data. This data will include temperature, pressure, spatial positioning, and UV radiation levels. In addition to these, the CanSat is uniquely equipped to detect muons. All of this data will be transmitted in real-time to the ground station and stored onboard. After landing, the CanSat will signal its coordinates using a buzzer, activating the recovery system.

These key elements will play an essential role in accomplishing the mission objectives. Here is a brief explanation of each element:

- **Sensor System**: A sensor system is critical to the mission's success as it helps to measure various parameters that are important for the experiment. The sensor system can measure parameters such as temperature, pressure, inertial performance, UV, and light intensity. These measurements will provide valuable data for the post-launch data analysis.

During the descent, the CanSat will record, store, and transmit the following data:

- ❏ Humidity and air temperature
- ❏ Barometric pressure
- ❏ GPS Location
- ❏ Magnetic field
- ❏ Orientation
- ❏ Position in space using a gyroscope
- ❏ UV Index

- **Microcontroller**: The microcontroller is responsible for controlling the various subsystems of the CanSat. It provides a reliable and efficient way to control the CanSat's functions, making it a crucial part of the overall system.
- **Telemetry System**: The telemetry system is responsible for sending data back to the ground station. It uses GSM and RF modules to transmit data, which can be analyzed in real time by the mission team. This system helps to ensure that the mission objectives are met and that the data collected is of high quality.
- **Recovery System**: The recovery system is essential to ensure the CanSat is safely returned to the ground. It consists of audible alarms that alert the ground station to the CanSat's location. This system will help to prevent damage to the CanSat and ensure that the data collected during the mission is preserved.
- **Post-Launch Data Analysis**: Post-launch data analysis is essential for interpreting the data collected during the mission. It allows the mission team to evaluate the success of the mission and determine whether the mission objectives were met. This analysis can help to inform future missions and experiments.

Figure 3.1: Base block diagram for the CanSat and the ground station.

Several onboard devices will make the mission possible, the key ones being:

- MicroController (ESP32 Wroom or Raspberry Py PR2040)
- Data transceiver (LoRa)
- Humidity and temperature sensors
- GPS (L76GNSS)
- Navigation sensor
- High-performance batteries
- SiPM (Silicon photomultiplier) detector for muons
- Altimeter

3.2. Mechanical/structural design

For the mechanical design, several factors have been considered to ensure the payload's robustness and easy maintenance:

- **Component Protection**: The payload's structure will be designed to protect the components from any external impact or shock during the launch and landing.
- **Resilient Structure**: The payload's structure will include some shock-absorbing systems to reduce the impact force during landing, thereby preventing damage to the payload and its components.
- **Easy Removal of Batteries and Radio Transmitters**: The batteries and radio transmitters will be positioned in a way that allows for easy removal in the event of any malfunction, or for recharging and testing purposes.
- **Easy Access to Components**: The design of the payload's body will facilitate easy extraction of the components for maintenance or replacement in case of malfunctions.

By considering these factors, the team aims to create a robust and reliable payload capable of withstanding the mission's harsh conditions and delivering accurate data.

The payload's structure uses a combination of Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS). These lightweight 3D printing materials provide strength, durability, and exceptional design flexibility. This composition allows the can to endure the stresses of launch and landing while maintaining an aerodynamic shape. Additionally, the can is designed with a removable bottom or top section, facilitating easy access to its internal components for maintenance and repair without dismantling the entire structure.

The design ensures durability during launch and landing, distributing and absorbing high levels of stress and force. The aerodynamic design minimizes air resistance, helping achieve maximum altitude during launch.

Figure 3.2: Payload can with parachute cords attchement places.

The payload is composed of several major components, including a few PCB boards that house all the necessary modules. The battery pack, which is the largest and heaviest component, is located at the bottom of the payload and contains one or two 18650 battery modules placed in a horizontal position (one battery) or vertical position (for two batteries). The upper part of the can houses the PCB layers, interconnected with mezzanine connectors, which are fixed in place using screws and glue.

	CanSat Characteristics (description)	Figure (units)
	Total weight of the payload	300 g
	Diameter of the payload	66 mm
	Length of the recovery system, including parachute	Max. 60 cm
	Flight time scheduled	120 s
	Calculated descent rate of the payload	$8\,\mathrm{m\,s^{-1}}$
	Radiofrequency used for communication	868 MHz (LoRa)
	Power consumption of the payload	450 mA

Table 2: Main features of the CanSat

The case of the payload will be fitted with inserts on the interior to reinforce its structural strength. To ensure secure closure, the lid is designed to be fastened tightly with screws that fit into specific holes in the cap, requiring a screwdriver to open it. Moreover, the case will have strategically positioned holes to facilitate ideal camera placement and ensure adequate airflow within the can.

3.3. Electrical design

The electrical design of our payload relies on the use of custom-made PCBs due to the limited space available in its interior. We have developed custom PCBs designed using Autodesk's EAGLE software to ensure that all the necessary components fit properly.

Using custom PCBs provides several advantages for the CanSat project. Firstly, it allows for a better fit of all the components in the limited space available. This can increase the overall efficiency of the payload by reducing the size and weight while still accommodating all the necessary components. Secondly, custom PCBs can also help to reduce the risk of damage to the components during the launch and landing phases of the mission. By integrating the components into the PCB design, they are better protected from shocks and vibrations. Finally, designing custom PCBs allows for greater flexibility and customization in the CanSat's design, making it possible to optimize its performance and tailor it to specific mission requirements.

3.3.1. Electrical Interface

The electrical interface of the CanSat is designed to ensure a robust and reliable connection between its various electronic components. The microcontroller, an ESP32, serves as the central hub for the electrical interface, supplying power and data connectivity to the array of sensors, transmitters, and other components on the Sensor and Communications Boards.

The compact form factor of the payload's mainboard is tailored to accommodate the ESP32 microcontroller. This component is chosen for its adequate computing power and integrated wireless communication capabilities, vital for the mission. To ensure compatibility and flexibility, multiple connection types are established between the microcontroller and other components, including UART, I2C, SPI, and other necessary digital inputs and outputs.

The environmental sensors, measuring atmospheric pressure, temperature, humidity, and UV index, are integrated onto the same PCB as the microcontroller to streamline data line connectivity, utilizing I2C connections for efficient communication. The Silicon Photomultiplier Sensors (SiPM) for muon detection communicate via the SPI/UART protocol. All data collected by the sensors are logged onto an onboard SD card and transmitted to the base station.

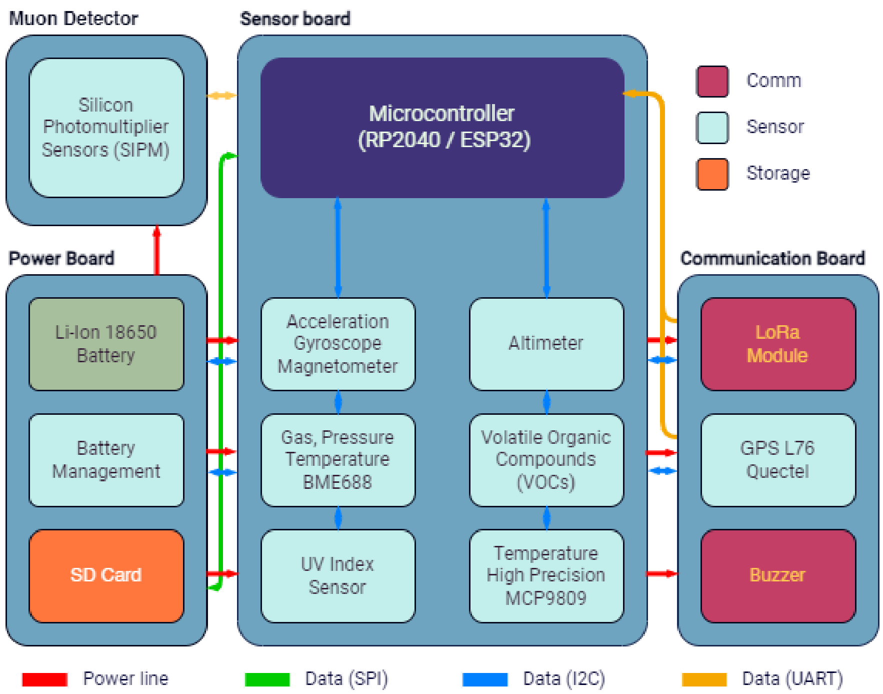


Figure 3.3: The Cansat block diagram with power and data lines.

Component	Voltage	Protocol	Other Information
ESP32-S3-Wroom or Raspberry Pi 20400	3.3 V	I2C, I2S, SPI, PWM, UART, USB	Dual-core μProcessor
LPS25H	3.3 V	I2C	Altimeter
MPU-9250	3.3 V	I2C	MEMS Module, 6-Axis Gyroscope, Accelerometer, Magnetometer
BME688	3.3 V	I2C	Air Quality Sensor, Humidity, Pressure & Temperature Sensor
MCP9808	3.3 V	I2C	Temperature Sensor
VEML6075	3.3 V	I2C	Ambient Light Sensor
Quectel L76	3.3 V	UART, I2C	GNSS / GPS Module
micro SD	3.3 V	SPI	Memory Card Connector
LoRa Module	3.3 V	UART	Lora Modulation, 868 MHz
Power Switching Regulators	3.3 V		High Efficiency Buck-Boost Converter
Low-dropout regulator	3.3 V		Voltage regulator, 868 MHz
Muon detector	25 V		Silicon Photomultiplier Sensor (SIPM)

Table 3: Electronics Component Information

The power system is centered around a Li-Ion battery, managed by a battery management system to ensure optimal performance and safety. The microcontroller and low-power sensors are energized by a 3.3 Volt line from the Power Board. In contrast, the muon detector module, requiring a different voltage line, will be adequately supported by the power system design. The battery pack's voltage range, from 3.6V to 4.2V, is compatible with the system requirements. Voltage regulation is achieved through the use of buck-boost converters and low-dropout regulators, ensuring that all components receive the correct voltage. These converters are rated to deliver up to 2A of continuous current, enough to power the entire system without risk of overloading any component.

The operational time of the payload (for the single battery case) can be estimated with the given formula:

$$\text{Time} = \frac{\text{Battery capacity} * \text{Voltage}}{\text{Power consumption}} = \frac{3400\,\text{mA} * 4.2\,\text{V}}{4.63\,\text{W}} = 3\,\text{h05min}$$

The duration of 3 hour is applicable when the payload's electronics operate at full capacity. With a dual battery system, this operational time significantly extends to well over 6 hours.

Component	Voltage	Current	Power	Mass
ESP32	3.3 V	40 – 240 mA	0.132 – 0.792 W	2.15 g
LPS25H	3.3 V	6 mA	0.0198 W	0.8 g
MPU-9250	3.3 V	3.9 mA	0.012 87 W	2.1 g
BME688	3.3 V	3.9 mA	0.012 87 W	1.7 g
MCP9808	3.3 V	0.2 mA	0.000 66 W	0.9 g
VEML76075	3.3 V	0.12 mA	0.0004 W	0.8 g
Quectel L76 (GPS)	3.3 V	25 mA	0.0825 W	0.5 g
micro SD	3.3 V	0.2 mA	0.000 66 W	1.6 g
LoRa Module	3.3 V	40 mA	0.132 W	4.15 g
Power Switching Regulators	3.3 V	800 mA	2.64 W	0.7 g
Low-dropout regulator	3.3 V	100 mA	0.3 W	0.6 g
Muon detector	25 V	0.02 mA	0.5 W	7 g
Buzzer	3.3 V	30 mA	0.09 W	3.15 g
Total Power			4.63 W	26.15 g

Table 4: Power consumption for the Major Electronics Components

3.3.2. Power budget

The payload is powered by a rechargeable Lithium-Ion battery pack with a 3.6 Volt output, supplying power to all of the components, with a maximum discharge of 8A. With an estimated power consumption of approximately 1.25 A, the battery pack's 3400 mA h (single battery) or 6800 mA h (dual batteries) capacity provides ample power for the entire mission. To ensure the payload has sufficient power throughout the mission, the battery is designed to provide over 3 hours of power supply to the system, even in the most power-consuming conditions. Moreover, after landing, the payload is programmed to switch to a lower power consumption mode, allowing for an extended battery life.

3.3.3. RF Link

The RF link is an essential component of any mission. It allows for real-time data transmission from the payload to the ground station, enabling the team to monitor the mission's performance and collect valuable data during the flight.

In our payload, we have chosen to utilize a single RF module, the LoRa communication module, to maintain a robust and reliable communication link. This module is responsible for transmitting vital data parameters such as GPS coordinates, temperature, pressure, altitude, and gas sensor readings back to the base station. It interfaces with the microcontroller via the UART protocol and is powered by a 3.3V supply. The current consumption of the LoRa module typically ranges around 100-150mA. It operates on the 868MHz frequency band, which is optimal for long-range transmission with low power consumption.

This approach simplifies the communication architecture, reducing potential points of failure and ensuring the payload maintains consistent communication with the ground station throughout its mission. The inherent redundancy of the LoRa network protocol also provides robustness against interference, contributing to the overall success of the mission and the integrity of the data collected.

3.4. Software design

The CanSat's software has two main purposes. Firstly, it is designed to acquire and log data from various sensors. This includes communication with the hardware equipment and additional processing such as compensation, data manipulation, and various calculations to give the raw data some meaning. Secondly, the software is responsible for logging the acquired data onto onboard persistent storage and transmitting it to the ground station. The software is programmed to execute all of these tasks autonomously, in real-time with a high-speed performance, without the need for human intervention. The software has two main parts: initialization and operating mode.

3.4.1. Boot-up sequence

During the initialization phase (boot-up), the system initializes by setting up various parameters and values to ensure proper functioning, and the software sets up the connected hardware, including sensors and data transmission devices, following a static set of instructions. Once the devices are set up, a startup message is sent on the data transmission channel to indicate that the system is online, and any errors encountered during this phase are logged.

3.4.2. Runtime and data management

After the initialization phase, the program enters the main loop, where it reads each sensor at a predefined period and processes the information. This loop spans almost the entire duration of the mission. Once the payload lands, the main loop is stopped, and the recovery loop starts. During this loop, only positional data is read, logged, or transmitted, and the recovery helper system is activated.

3.4.3. Sensor interrogation

The payload will collect various data from the sensors, with sensors being fetched every 150ms-250ms to maximize raw data throughput. Communication with the sensors is possible through the communication protocols described in section 2.3. To optimize efficiency and reduce the time spent on device communication handover, each sensor is strategically allocated to one of the two

I2C buses provided by our selected microcontroller. This utilization of dual I2C lines allows for simultaneous data acquisition from multiple sensors without the need for bus arbitration, thereby enhancing the overall performance of our system.

Data Interface	Components
USART/UART	Radio link module GNSS module
I2C	Accelerometer, Gyroscope, Pressure, Humidity, Temperature, CO_2/CO sensor
SPI	Micro SD memory card
Analog	UV light sensor Muon detector (Sipm)

Table 5: Data interfaces used in CanSat with their corresponding components.

3.4.4. Data Gathering and Storage

To ensure data integrity and mitigate the risk of data loss, all logging will be conducted on the SD card. The data will be recorded in CSV format, which will include a timestamp for each reading to facilitate straightforward processing after retrieval. In addition to logging, data will be transmitted in real time via the LoRa communication module, enabling continuous monitoring of the payload's status and environmental readings. This dual approach of storing and transmitting data ensures that we maintain a comprehensive dataset for analysis post-mission while also keeping track of the payload's performance during its flight.

The data gathered includes:

- X, Y, and Z-axis readings from a gyroscope, magnetometer, and accelerometer (only logged);
- Temperature readings (in Celsius) from the temperature sensor (transmitted and logged);
- Barometric pressure readings (in Pascals) and relative humidity readings (in percentage) from the BME688 sensor (transmitted and logged);
- UV Index readings (transmitted and logged);
- Altitude readings (in meters) calculated from the barometric pressure sensor (transmitted and logged);
- Muon counts from the SIPM module;
- Main battery voltage readings (in volts) (transmitted).

The SD card is equipped with ample storage capacity to house all the collected data, including sensor readings and any images captured during the mission. The microcontroller communicates this data to the ground station in binary format, which not only conserves bandwidth due to the small size of the data packets but also promotes data security through the potential use of encryption prior to transmission. The efficiency of the data packet size contributes to a stable connection, ensuring smooth data transfer without issues. Even with a transmission rate of once per second, the cumulative data sent remains well below the 1 Mb mark, ensuring that storage and bandwidth resources are effectively utilized.

3.4.5. Programming Language and Development Environment

The microcontroller is the central component of the CanSat, responsible for managing all the peripherals connected through various media access and wire protocols. Each device requires specific commands and data retrieval procedures. Furthermore, every operation involving an external device must adhere to strict time constraints. For instance, a query to the temperature sensor must be processed before the next packet is sent across the wireless link to the ground station.

To ensure that these strict timing requirements are met, the CanSat firmware is based on a real-time operating system (RTOS). RTOS is ideal for mission-critical applications where I/O calls and system calls must be executed within a specific timeframe, and where errors must not cause the system to stop running. The ESP32 comes with FreeRTOS, which is the open-source de-facto standard for embedded applications. C

We will be using Git extensively to keep track of changes to the codebase. This allows us to easily roll back to a previous version if a new feature breaks the code. With Git, we can collaborate on the codebase and track changes made by different team members, ensuring a smooth and efficient development process.

Additionally, we are planning to develop a custom software application that will run on the ground station. This application will receive the telemetry data from the payload and interpret it, visualizing the information on real-time graphs. The software will extract sensor data such as acceleration, GPS coordinates, pressure, and more from the raw data packets, allowing us to monitor the payload's performance and the environmental conditions it encounters. The software will also log the data to ensure that no valuable measurements are lost.

3.5. Recovery system

Our recovery system was designed to slow down the descent rate of the payload, nose cone and body tube to a safe and controlled speed of which may vary depending on weather conditions (we will discuss it a bit later on). The payload's recovery system ensures a safe and controlled descent to the ground via a deployed parachute after reaching maximum altitude.

3.5.1. Parachute

The key element is the hemispherical parachute. This type is ideal since our mission involves only atmospheric descent, not targeted landings. The parachute deploys right after the payload is released from the helicopter, attaching to the can at six points to minimize rotation. Six durable, lightweight ropes (1 gram/meter) connect the parachute to the payload. A ball-bearing swivel is recommended to prevent line entanglement. We will use colorful nylon for visibility.

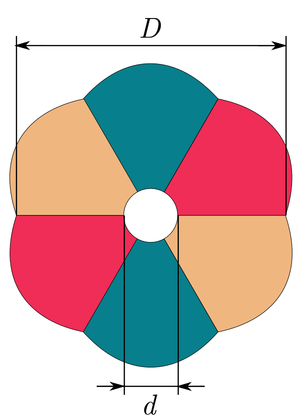


Figure 3.4: Parachute design.

In addition, we have two secondary recovery systems: GPS for descent tracking and a loud buzzer activated upon landing when sensors detect no movement. The bright colors of the can and parachute will aid in locating the payload.

Our parachute system is designed for both prolonged descent (6 m/s) for atmospheric analysis in good weather and rapid descent (9 m/s) in poor weather. Calculations for descent rates factor in time to ensure successful recovery.

For the values in Tables 6 and 7, we used the following formulas:

$$S = \frac{2mg}{C_d \rho v^2}, \qquad D = \sqrt{\frac{4S}{\pi}}, \qquad SLL = 1.15 * D, \qquad d = D * 10\% \tag{1}$$

Parameter	1st Parachute	2nd Parachute
Surface	0.0834 m^2	0.0370 m^2
Diameter 1 (D)	0.3259 m ≈ 32.6 cm	0.2173 m ≈ 21.7 cm
Diameter 2 (d)	3.26 cm	2.17 cm
Suspension Lines (SLL)	37.5 cm	25 cm

Table 6: Surface and diameter for the Payload's parachutes

Parameter	3rd Parachute	4th Parachute
Surface	0.0444 m^2	0.0197 m^2
Diameter 1 (D)	0.2380 m ≈ 23.8 cm	0.1587 m ≈ 15.8 cm
Diameter 2 (d)	2.38 cm	1.58 cm
Suspension Lines (SLL)	27.37cm	18.17 cm

Table 7: Surface and diameter for the nose cone and body tube's parachutes

To calculate the dimensions required for the parachute, we considered the following constant parameters, including physical constants and canopy parameters (Table 8).

Parameter	Value
g - gravitational acceleration	$9.81\,\mathrm{m\,s^{-2}}$
ρ - air density	$1.225\,\mathrm{kg\,m^{-3}}$
v - descent velocity	6 and 9 $\mathrm{m\,s^{-1}}$
m - Payload mass	$0.15\,\mathrm{kg}$
m - nose cone and body tube mass	$0.08\,\mathrm{kg}$
C_d - Drag coefficient	0.8
n - number of gores	6

Table 8: Constant parameters and their values

The hemispherical parachutes with 6 gores and an additional spill hole of diameter d = 10% of the canopy's diameter, D on the top, is our preferred primary recovery system due to its high drag coefficient per area, which allows for a lightweight parachute. This spill hole helps with air transition along the parachute, preventing oscillations during descent.

3.6. Ground support equipment

The ground support equipment for the mission includes receiver equipment and data visualization/logging components. Multiple devices, such as omni-directional antennas and a laptop, are used to capture radio signals and telemetry data from the Payload. The software processes and presents the data in an easily understandable format, facilitating analysis and decision-making. Data is stored in CSV format for compatibility with various analysis tools. The transmitter frequency for data transmission is 868.1 MHz. This ground segment software maximizes the Payload's performance by processing real-time data and offering advanced functionality.

4 Project planning

Effective project planning is crucial for our mission's success. Our team established milestones, such as acquiring resources and selecting components, ensuring a comprehensive plan. Our timeline covers all project phases, including design, construction, launch, and testing, with allocated resources and regular progress checks. We considered external factors like competition deadlines and launch availability. With our detailed timeline and milestones, we're confident in the success of our CanSat project.

4.1. Time schedule of the CanSat/Payload preparation

To obtain a comprehensive understanding of our project's timeline, please refer to the milestones in Appendix A.

By achieving these milestones, we will ensure the success of our CanSat project and meet our project goals and deadlines.

5 Risks analysis and mitigation

The risk analysis section of the project plan is vital, identifying potential risks to mission success and outlining mitigation strategies. It summarizes major risks and steps taken to address them:

- **Communication failure**: Critical for mission success, factors like interference, distance, and line of sight affect communication quality. Mitigate risks through system checks, tests, and deployment procedures, including onboard self-diagnostics and LED confirmation.
- **Power limitations**: Payload power generation and storage are limited. Ensure power-efficient design and sufficient power for mission completion.
- **Environmental factors**: Payload faces various environmental challenges like temperature, humidity, and vibration. Design for resilience and verify mission objectives through endurance, high G-force simulation, and landing tests.
- **Technical issues**: Prototype development board to catch design mistakes early. Identify and prepare contingency plans for potential technical challenges.
- **Budget constraints**: Ensure project feasibility within budget constraints, prioritizing mission objectives accordingly.

5.1. Resource estimation

To ensure that the project is completed successfully within the given budget and timeframe, it is crucial to perform a thorough estimation of the required resources. This includes identifying the necessary materials, equipment, and team members needed to complete the project, as well as the associated costs and time requirements.

By performing a detailed resource estimation, the project team can effectively plan and allocate resources to ensure that the project is completed on time, within budget, and to the desired quality standards.

Below is a breakdown of the resources required for the CanSat project:

- Materials and components:
  - ❏ Identify and list out all the required materials and components, including a microcontroller, sensors, batteries, antennas, radio modules, lightweight printable plastics, and other miscellaneous parts
  - ❏ Cost of materials can vary depending on the quality and quantity of components required
- Tools and equipment:
  - ❏ Various tools and equipment required, such as multimeters, 3d printers, oscilloscope, soldering station, and other miscellaneous parts

- Software:
  - ❏ Programming microcontrollers, designing 3D concepts, and analyzing data collected by the sensors
  - ❏ Using open-source software can significantly reduce the costs associated with software for the project.
- Manpower and build time:
  - ❏ Online tools and weekly meetings are used to ensure accuracy
  - ❏ Estimated effort of 630 hours for the entire project.
- Testing and validation:
  - ❏ Essential step to ensure the project performs as expected
  - ❏ May include the use of specialized equipment such as a drone or rocket
- Shipping, transport, and logistics:
  - ❏ Shipping and logistics costs may need to be factored into the project's budget
  - ❏ May include shipping materials and components and travel costs for team members to attend the competition
- Miscellaneous costs:
  - ❏ Other costs that may need to be considered when estimating resources for the project

In conclusion, it is evident that a successful project outcome is heavily reliant on a proper estimation of resources required to complete the project. Neglecting the factors such as materials, components, tools, equipment, software, testing and validation, shipping and logistics, and other unforeseen costs can lead to budget overruns, delays, and ultimately failure to achieve project objectives.

5.1.1. Budget

We conducted thorough research to ensure that our budget aligns with the ideal specifications for our CanSat. This involved finding the most efficient and lightweight components without compromising performance, as well as maximizing battery life. By carefully considering each part, we aimed to optimize our budget and ensure that we could achieve our project objectives.

However, building the CanSat is just a part of the project. Therefore, our budget covers the entire project from start to finish, which can be divided into four main parts:

- **Hardware parts**: all the necessary mechanical and electronic/electrical parts required to build both our custom development board and final payload. The cost estimation includes the purchase of a microcontroller, sensors, batteries, antennas, radio modules, lightweight printable plastics, and other miscellaneous parts.
- **Publicity and Branding**: covers the creation of custom t-shirts to promote our team and the event. In addition to custom t-shirts, we will also invest in creating promotional materials such as flyers, posters, and banners that showcase our team and the mission. These materials will be distributed both digitally and in person to help increase awareness of our project and the competition. Additionally, we will allocate a portion of our budget towards branding efforts such as website design and social media management to maintain a consistent and professional image for our team. Investing in Publicity and Branding will help us build a strong reputation within the community and attract potential sponsors and supporters to our cause.
- **Emergency Funds**: a contingency budget to cover any unforeseen costs that may arise during the project.

Below is a table that outlines all the anticipated expenses associated with the CanSat mission. This includes the costs of the components used to construct the CanSat, as well as any supplementary materials, equipment, and personnel necessary to complete the mission.

The components required for the project will be purchased from various suppliers such Optimus Digital, Cleşte.ro, Mouser, TME, Adafruit, and JLCPCB. It is worth noting that the team did not receive any kits from the organizers, and as a result, the team members did all the design and construction of the payload.

Category	Cost Item	Cost €
Hardware Parts (deductible) (134€)	ESP32 (μC)	6
	LPS25H - Altimeter	25
	MPU 9250 - IMU Sensor	5
	BME688 - Barometric Pressure	10
	MCP9808 - Temperature Sensor	5
	VEML6075 - UVA UVB UV Sensor	5
	Quectel L76 - GPS	10
	Power Switching regulators, LDO	4
	micro SD	6
	Buzzer	1
	SMA Connectors	2
	Radio module	10
	Parachute material	20
	Battery	25
Consumables (non-deductible)	PCB components (RLC, diodes)	10
	Parachute cords	5
	Antennas	10
	3D printer filament	15
Publicity & Branding (100 €)	T-Shirts	65
	Flyers & stickers	10
Emergency Funds	Miscellaneous	100
	Total	**349**

Table 9: Foreseen costs for the CanSat mission.

5.1.2. External support

The successful execution of the CanSat mission relies on the assistance and resources given by different organizations, departments, and companies. We are fortunate to have received sponsorship or in-kind support from the following entities:

- **Fundaţia Comunitară Oradea** has generously provided facilities where we can conduct our activities;
- **Depozitul de Tricouri** has agreed to provide customized T-shirts for each team member, which will help us promote our team and the event.

5.2. Test plan

The mission's success hinges on thorough pre-launch testing. This plan outlines tests to ensure the payload meets objectives and functions under various conditions, categorized into mechanical, software, communication, power, integration, ground station, battery charging, launch, and post-mission tests. The goal is to ensure accurate data collection and transmission, and survival during launch and landing. Annex G provides a testing roadmap with general ideas for each test.

Specific tests on electronics and structure are crucial to verify sensor functionality and structural integrity under launch, landing, and environmental conditions (see Annex H). Endurance tests assess the payload's ability to withstand harsh conditions, such as falls, vibration, shock, and prolonged G-forces during transport, providing insights into its performance limits (see Annex I).

By conducting these tests, the team ensures the CanSat is fully functional and mission-ready.

5.3. Time management

To keep the project on track and meet our timeline, we have divided the process into several phases, each with specific tasks and durations. We have completed the ideation phase and are currently in the design and prototyping stages. The upcoming phases include various testing campaigns and construction runs. The exact details of the testing phase will be determined as the project progresses, leading up to the final phase, which culminates in the competition.

We estimate a total of 630 man-hours needed for the entire project and have already invested 330 hours. The Gantt chart automatically updates as we advance through the project, allowing us to monitor progress and adjust our plans as necessary to ensure timely completion. By using this tool, we can stay on schedule and achieve our desired outcomes.

To ensure that we complete all necessary tasks on time, the following is a summary of our timeline. For a more detailed timeline, please refer to the Gantt chart provided in the Appendix.

- Team formation: 11.10.2023 - 19.11.2023
  - Think of feasible mission objectives and requirements
- Ideation: 11.10.2023 - 28.04.2024
  - Documentation writing (PDR, CDR, FDR)
  - Mission refinements
- Design the Rocket and Payload: 03.01.2024 - 19.05.2024
  - Mechanical structure
  - Electrical system
  - Software
  - Recovery system
  - Ground support
- Prototyping: 22.01.2024 - 17.04.2024
- Testing (prototype): 01.04.2024 - 30.04.2024
- Build the CanSat: 08.04.2024 - 15.05.2024
- Launch Campaign: 29.05.2024 - 02.06.2024

6 Data Analysis and Outreach

There is a lot of useful information in the mission data that can provide valuable insights into various aspects of the mission. As a result, data analysis is an important step in making sense of the data that has been gathered, drawing useful conclusions, and making informed decisions. Outreach is an important part of the data analysis process, in addition to looking at the data for internal use. The analysis's results can be shared with more people, such as partners, the scientific community, and the public, through outreach. In this part, we'll talk about our data analysis and outreach efforts, focusing on the different tools and methods we used to look at the data and get the word out.

6.1. Data Analysis Plan

The mission data plan lays out all the steps we will take to gather, process, and analyze the data that the mission creates. Several Python tools are used in the plan to make sure that the data is properly collected, processed, and displayed. The data plan is made up of four parts: collecting data, processing data, visualizing data, and statistical analysis.

- **Data acquisition**: The data acquisition component of the plan utilizes a Python library to collect and store data from the CanSat sensors in real time. The library is designed to communicate with the devices on the payload and is used to keep track of data while the CanSat is in the air.
- **Data processing**: The data processing component of the plan involves a Python library that processes and cleans the raw data collected by the data acquisition software. The library is used to filter out any noise or errors in the data and organize it into a format suitable for analysis. To achieve the mission objectives, a range of statistical techniques and models will be employed to filter out noise and errors in the data. This will ensure that the data is accurate and reliable for further analysis.
- **Data visualization**: The data visualization component of the plan employs Python libraries to create visual representations of the data, such as easy-to-understand graphs and charts. These visualizations can help to quickly understand the data and identify patterns or trends.
- **Statistical analysis**: The statistical analysis component of the plan uses Python libraries to perform statistical analyses on the data, to identify any significant relationships or patterns in the data, such as the relationship between pressure and altitude.

6.2. Outreach Program

Our outreach program has two primary objectives. The first is to promote the interrelated STEM disciplines, Science, Technology, Engineering, and Mathematics, and highlight their distinct but interconnected nature. These four fields are essential in shaping the future of technological advancements and scientific discoveries, and we aim to inspire the next generation to pursue careers in STEM-related fields.

The second objective of our outreach program is to popularize the space sector and space exploration. We aim to educate the public about the importance of space technologies and how they impact our daily lives. Through our outreach efforts, we hope to inspire the public to take an interest in space exploration and encourage the pursuit of careers in the space industry.

The team has made a detailed plan for raising awareness of the CanSat project and getting people involved. Different actions are included in this outreach plan to get the word out about the project. These include:

- presentations
- demonstrations
- social media
- websites
- community engagement
- participation in science fairs or events.

In our outreach plan, we aim to target specific audiences, deliver clear messages, and use various media to achieve our goals. We will present the CanSat project to different groups such as schools and community centers, focusing on the technology it uses and its applications. These presentations aim to increase awareness and inspire interest in STEM fields among students and the community.

We will use social media platforms like Twitter, Instagram, and Facebook to document our team's progress and share updates about the project with the public. Additionally, a dedicated website will be developed to provide detailed information, including progress updates, photos, videos, and data from the mission. This approach ensures regular communication about our challenges and successes, fostering engagement and creating a sense of community around the project.

For science fairs and events, we will target students, teachers, and the public interested in STEM education and space technology. Our message will highlight how the CanSat project can drive innovation and solve real-world problems, encouraging participants to explore STEM careers. By focusing on these activities, we aim to increase interest and involvement in the CanSat project and promote the importance of space technology and STEM education.

7 Conclusion

While we are confident in the success of the project, time constraints are currently a challenge that requires us to focus on testing each module and the system as a whole. Based on the results of our tests, we will need to adjust our design for the final version of the CanSat.

We are mindful of the significant number of work hours required to implement and test all the features we want, but we are making good progress, and if we continue at our current pace, we believe that the project will be successful, and we will achieve our goal of winning the competition.

7.1. Recommendations for next steps

Our next critical step is to construct our prototype board and conduct comprehensive testing on all modules, including RF communication, range, autonomy, telemetry data integrity, code, mechanical, g-force, and mission simulations. These recommendations are part of our testing strategy and have been carefully planned. Although there are other smaller tasks to complete, we believe these are the most critical steps to take in moving forward.

1. Improve and expand the PDR document, including defining every module and design element with formulas, sources, and references if time allows.
2. Conduct an After Action Review (AAR) to analyze what went well, what could be improved, what is missing, and why, and find solutions for the discovered issues.
3. Ensure all tests are carried out correctly and all sensors are correctly calibrated.
4. Conduct as many mechanical testing and design optimizations as possible.
5. Improve skills in LaTeX to effectively document the more complex project, ensuring clarity and thoroughness in technical reporting.
6. Allocate additional time for review and iterative improvements, considering the increased complexity of the project.
7. Schedule comprehensive team meetings to discuss progress, concerns, and plans for the future.
8. Regularly update the project plan to reflect current progress and any changes in priorities or objectives.
9. Seek expert feedback, particularly from specialists in muon detection, atmospheric sciences, and environmental monitoring, to validate design choices and methodologies.
10. Remain open-minded and be willing to adapt plans and strategies as necessary to achieve project goals and objectives.

Notes

1 https://en.wikipedia.org/wiki/Atmospheric_temperature

2 https://en.wikipedia.org/wiki/Vertical_pressure_variation

Appendices

.1. Task list

1. **Can Design and Manufacturing** - in progress
   - Can design in 3D - In progress
     - models for main IC
     - power board
     - sensor board
     - can assembly model
   - Parts (Acquisition) - in progress
2. **PCB Design and Manufacturing** - in progress
   - PCB Design
     - Power Board Design - in progress
     - Sensor Board Design - in progress
   - PCB Manufacturing
     - Power Board - scheduled
     - Sensor Board - scheduled
3. **Can Software**:
   - Mission Software
     - Sensor integration - scheduled
     - TX/RX between devices - scheduled
     - New mainboard software integration - scheduled
     - Base station software - scheduled
   - Post Mission Software
     - Data aggregation - scheduled
     - Data analysis - scheduled
     - Reporting - scheduled
4. **Testing** - scheduled
   - Recovery system
     - Parachute - in progress, partly done
     - Locator for Can - scheduled
     - Sensor reading - done
     - Can-Base transmission - scheduled
     - Base station - scheduled
   - Hardware
     - Electronics - scheduled
     - Batteries - scheduled
     - Receiver Antenna - scheduled
   - Structure
     - Crashproof - scheduled

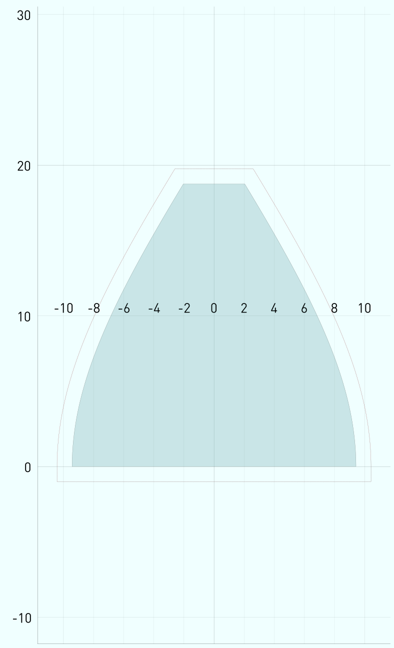
A Mission milestones

These milestones have been designed to keep us on track and ensure that we successfully meet our project goals and deadlines.

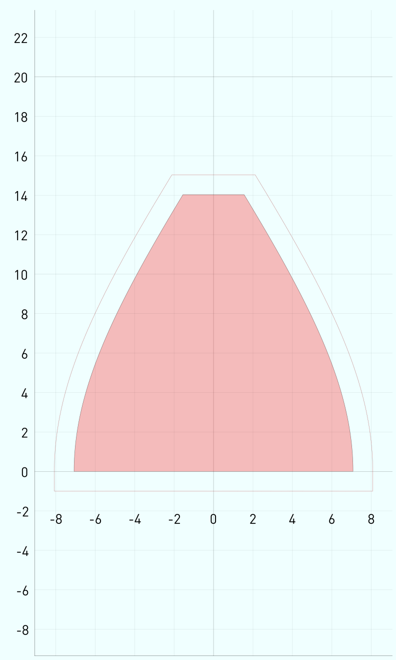
- Define Project Scope and Objectives:
  - ❏ Purpose of the project: to successfully detect muons and analyze the environment, light conditions
  - ❏ Objectives to be achieved on launch day and post-launch analysis:
    - ✓ Successful launch
    - ✓ Live RF telemetry
    - ✓ Successful parachute deployment
    - ✓ All systems nominal (good sensor and location data)
    - ✓ Descent rate between 7-10m/s
    - ✓ Landing confirmation
    - ✓ Recovery of the CanSat
    - ✓ Generating reports
- Develop a Detailed Project Plan and Timeline:
  - ❏ Assign tasks related to social media promotion and sponsor search;
  - ❏ Determine cooperation method (online/programs/meetings etc.)
- Research and Design:
  - ❏ Conduct research on required components and technologies for the mission;
  - ❏ Design the payload's structure and select materials;
  - ❏ Submit Preliminary Design Report;
  - ❏ Develop a prototype and test sensors and electronics;
  - ❏ Promote the project on social media platforms and begin searching for sponsors.
- Integration and Testing:
  - ❏ Integrate sensors and electronics into the payload's structure;
  - ❏ Conduct testing and calibration;
  - ❏ Ensure that the CanSat meets weight and size requirements;
- Launch Preparation:
  - ❏ Conduct pre-launch testing;
  - ❏ Pre-launch checklist.
- Primary and Secondary Missions:
  - ❏ Verify that the payload met the primary mission requirements;
  - ❏ Collect the missions data from the sensors;
  - ❏ Conduct data analysis and report on the results;
  - ❏ Share updates and photos of the data analysis on social media platforms.
- Submit Design Reviews
  - ❏ Preliminary Design Review;
  - ❏ Critical Design Review.
- Final Report and Presentation:
  - ❏ Prepare a final report documenting the project's objectives, methods, and results;
  - ❏ Develop a presentation to showcase the mission and its capabilities;
  - ❏ Share the presentation on social media platforms to showcase the project's achievements and thank sponsors for their support.

B Dual parachute design (Payload's Case)

The smaller parachute had a diameter of 21.7 cm and a surface area of 370 cm^2, which is designed to slow down the descent speed to 9 meters per second. The design of this parachute was based on the principles of aerodynamics and is intended to withstand strong winds and turbulent weather conditions. We believe that this parachute will be instrumental in ensuring a safe and successful landing of our Payload during windy weather conditions.



The second parachute was designed for use during calm weather conditions and had a diameter of 32.6 cm and a surface area of 834 cm^2, which is designed to slow down the descent speed to 6 meters per second. This parachute was optimized for stable and predictable conditions and is intended to provide a gentle and controlled descent of the Payload during calm weather conditions.



C Payload - software design

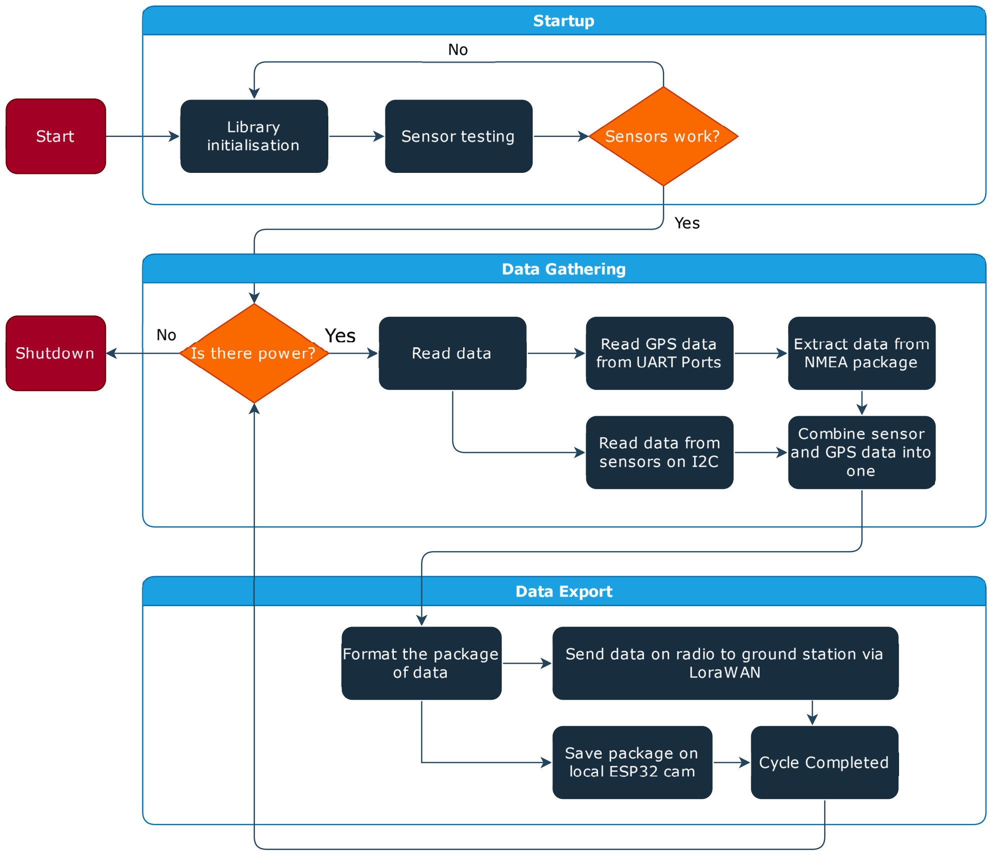


Figure 3.5: Software diagram.

D Payload - electrical design

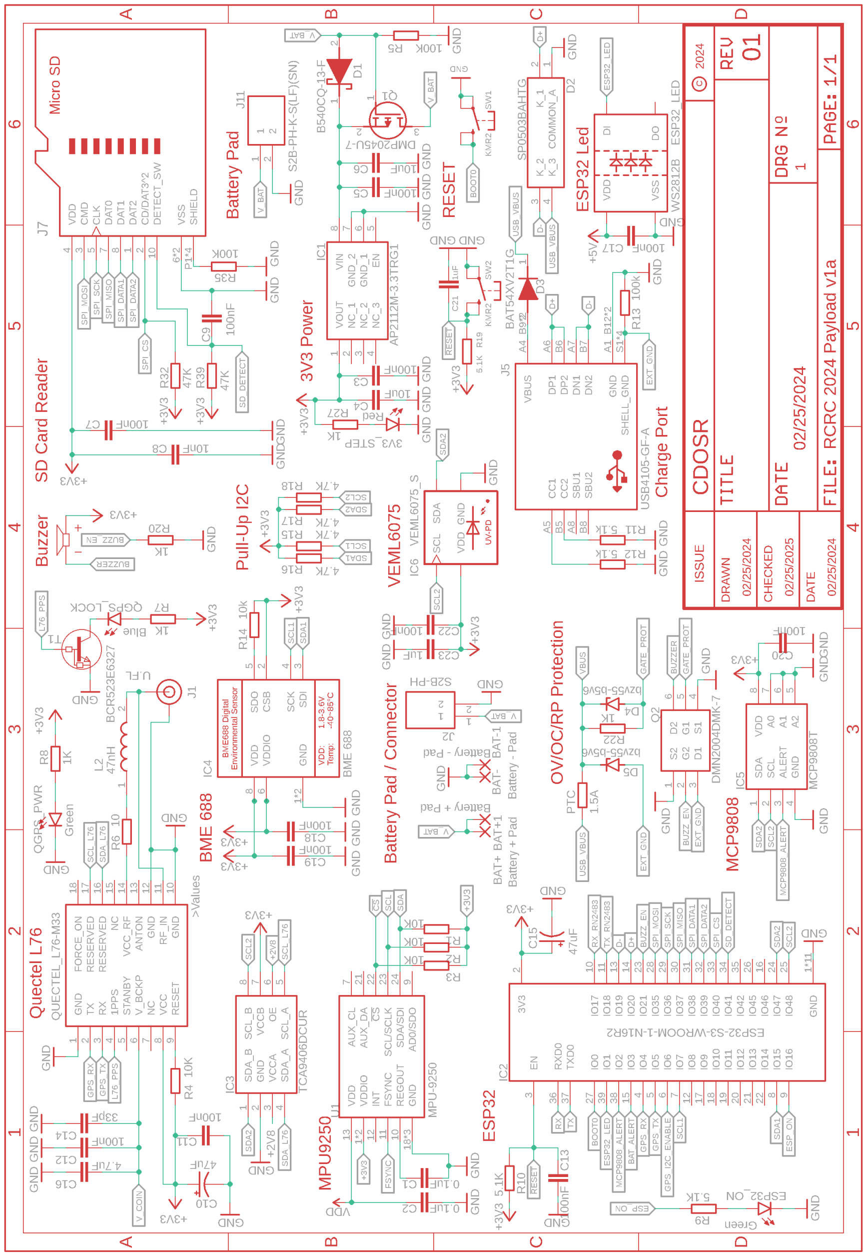


Figure 4.6: CDOSR payload electrical scheme.

E Base station - electrical design

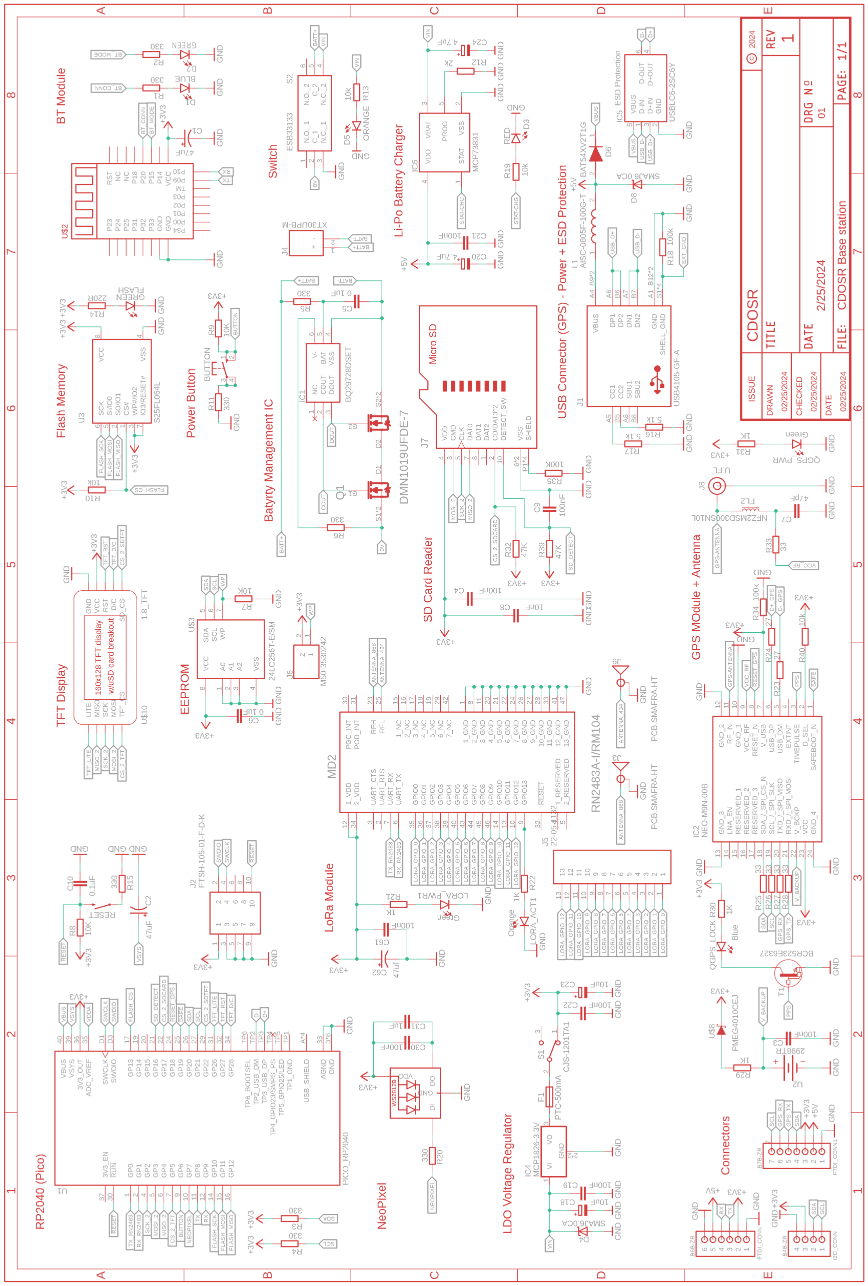


Figure 5.7: CDOSR base station electrical scheme.

F Test plan

- ✓ Mission Objective Test
  - ❏ Verify if the payload meets the competition mission requirements
  - ❏ Check that the sensors are functioning properly
- ✓ Mechanical Test
  - ❏ Make sure that the structure and enclosure are sturdy and can withstand launch and landing
  - ❏ Verify the parachute deployment and fixing are functional and reliable
- ✓ Software Test
  - ❏ Verify that the software is correctly installed and functional
  - ❏ Ensure that the software is properly processing data from the sensors and instruments
- ✓ Communication Test
  - ❏ Ensure that the payload can communicate with the ground station
  - ❏ Verify that telemetry data can be received and decoded correctly
  - ❏ Test the range and the reliability of the communication link
- ✓ Power Test
  - ❏ Verify that the power system meets the power budget and has sufficient power to operate the payload
  - ❏ Test the duration of the battery life and ensure that power consumption is minimized wherever possible
- ✓ Integration Test
  - ❏ Verify if all the components of the payload are properly integrated and functioning correctly
  - ❏ Test the overall functionality
- ✓ Ground Station Test
  - ❏ Verify that the antennas are properly installed and functional
  - ❏ Verify that the ground station software can display data from the payload
- ✓ Battery Charging Test
  - ❏ Test the battery charging system and verify that it can fully charge the batteries within a reasonable amount of time
  - ❏ Verify that the charging system is safe and reliable
- ✓ Post-Mission Test
  - ❏ Verify if the payload has returned all the required data
  - ❏ Check the data for accuracy and completeness
  - ❏ Analyze the data and compare it to the mission objectives

G Sensor testing

Pressure sensor test:

- **Task**: Expose the used sensor to a pressure change and compare the results with a reference device.
- **Method**: Place the target and reference sensors in a sealed container with a known volume of air and measure the pressure change with a manometer or a barometer. The pressure can be changed by altering the volume of the container or by using a hand

pump.

- **Estimated testing time duration**: 1-2 hours
- **Acceptance criteria**: The test will be considered positive when both sensors show the same pressure without measuring errors.

Temperature sensor test:

- **Task**: Check whether the target device and the reference device show the same temperature within 24 hours
- **Method**: Place both the target device and the reference device in the same location and monitor their temperature readings at regular intervals for 24 hours
- **Estimated testing time duration**: 24 hours
- **Acceptance criteria**: The test will be considered positive when both sensors show the same temperature without significant deviation.

Humidity sensor test:

- **Task**: Place the target sensor and the reference device in a humidity chamber where the humidity will be increased or decreased to a specific level, and the readings will be compared.
- **Method**: The target sensor and the reference device will be placed in a humidity chamber where the humidity level will be gradually increased or decreased to a specific level. The readings from both sensors will be recorded and compared.
- **Estimated testing time duration**: 6 hours
- **Acceptance criteria**: The test will be considered positive when both sensors show the same humidity level without significant deviation.

UV sensor test:

- **Task**: Expose the target sensor and the reference device to UV radiation from a UV light source and compare the readings.
- **Method**: The target sensor and the reference device will be exposed to UV radiation from a UV light source for a specific duration, and the readings will be recorded and compared.
- **Estimated testing time duration**: 1 hour
- **Acceptance criteria**: The test will be considered positive when both sensors show the same UV index without significant deviation.

GPS test:

- **Task**: Test the accuracy of the GPS module by comparing the location obtained by the CanSat with the actual location.
- **Method**: The location data collected by the GPS module during this time will be recorded and compared to the actual location using a separate reference system. The reference system may be a ground-based GPS receiver or a separate device with accurate location data.
- **Estimated testing time duration**: 1 hour
- **Acceptance criteria**: The test will be considered positive if the error margin is within an acceptable range.

H Mechanical stress testing

Drop resistance test:

- **Task**: Conduct a crash test to ensure the payload components can withstand the impact of a fall.

- **Method**: Prototypes will be dropped from a tower or drone to achieve the required descent speed. A fall test without a parachute will also be performed. Optionally, a 3-axis accelerometer will be added to record any G-force during the test.
- **Estimated testing time duration**: Estimated to be a few hours.
- **Acceptance criteria**: All components should remain intact, and the electronics should continue to work continuously.

Long-term G-force tests:

- **Task**: Simulate the G-forces that may occur during rocket transport to test the CanSat components' endurance.
- **Method**: The payload model will be placed on a carousel or string and rapidly rotated to generate the required overload due to the centrifugal force.
- **Estimated testing time duration**: The test will last for several hours.
- **Acceptance criteria**: All components should remain intact, and the electronics should continue to work continuously throughout the test period.