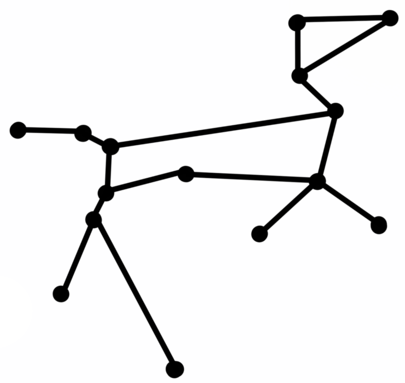


CANIS

Preliminary Design Review

Gergő Miszori

Dániel Bővíz

Patrik Bedő

Gergő Gosztolya

Boldizsár Deák

Dávid Tulkán

November 10, 2024

Contents

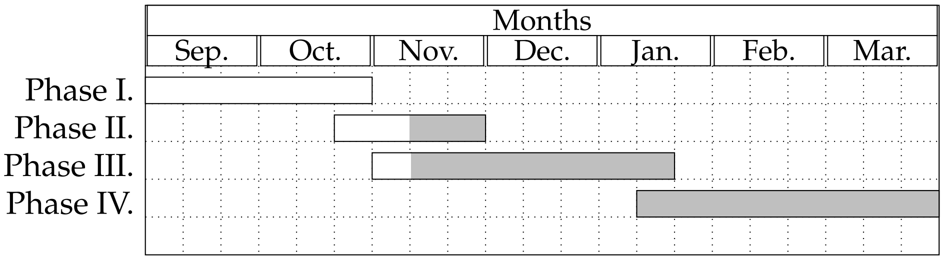
1 Introduction of the Team

Our team consists of six dedicated members from the Radnóti Miklós High School in Szeged, complemented by two esteemed mentors: **Ádám Kiss** and **Dr. András Félix Kelemen** from the University of Szeged. We take pride in representing the **11.M** class, which is focused on mathematics. Our team comprises the following individuals:

- **Gergő Miszori** - Project Manager: As the team leader, Gergő coordinates project activities and ensures effective collaboration. He is responsible for creating 3D designs and designing printed circuit boards (PCBs).
- **Dániel Bővíz** - Software Engineer: Dániel excels in programming and is tasked with developing the software for the CanSat. He also produces impressive 3D animations and renders for our publications.
- **Patrik Bedő** - Physics Engineer: Patrik focuses on the design and analysis of the parachute system. He conducts risk evaluations and structural design assessments, overseeing all tasks related to the physical principles involved in our project.
- **Gergő Gosztolya** - Software Engineer: Collaborating closely with Dániel, Gergő contributes to the development of the CanSat's software. Additionally, he is the architect of our team's website, enhancing our online presence and communication.
- **Boldizsár Deák** - Scientific Researcher: Boldizsár focuses on the scientific aspects of our project, specifically related to cosmic radiation measurements in our secondary mission. He plays a key role in ensuring that our research adheres to scientific standards and protocols.
- **Dávid Tulkán** - Scientific Researcher: Dávid is responsible for analyzing the data collected during our missions. His insights help refine our understanding of the experimental outcomes.

We communicate and organize our work via Discord, and we also hold regular in-person meetings every Friday afternoon. Our mentors support us by providing resources such as access to workshops, ordering requested components, and offering guidance with minor suggestions.

2 Timetable



Gantt Chart

Designing a CanSat is a complex process that requires careful planning and execution. Our team has divided the project into four distinct phases, each with its own set of tasks and objectives. Here is a breakdown of the phases:

- **Phase I (Sep. - Nov.):** In this phase, we focus on planning and designing the CanSat. We choose our secondary mission objectives, design the structure of the CanSat, finalize the electronic components, and develop the software architecture. This phase aims to establish a solid foundation for the subsequent stages of the project, and our Preliminary Design Review (PDR) marks the completion of this phase.

- **Phase II (Oct. - Dec.):** As we move on to the physical implementation of the CanSat, we assemble the mechanical components, integrate the electronic systems, and test the software functionalities. By the end of this phase, we aim to have a fully functional prototype ready for further testing.

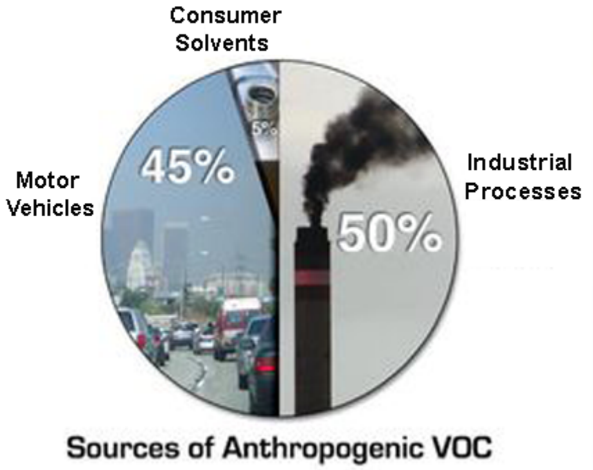
- **Phase III (Nov. - Jan.):** Along with Phase II, as the first prototypes are ready, we start testing the CanSat. If any problems arise or improvements are identified, we will implement the necessary changes to enhance our CanSat. At the end of this phase, we aim to have a fully functional CanSat ready for the competition.

- **Phase IV (Jan. - Mar.):** In this final phase, we focus on the final preparations for the competition. We conduct extensive testing, refine the software, and ensure that all systems are functioning optimally. We will write our Critical Design Review (CDR).

3 Mission Overview

Besides the mandatory primary mission objectives, we have chosen to measure Volatile Organic Compounds (VOCs) and Volatile Sulfur Compounds (VSCs) levels in the atmosphere as our secondary mission. As a technical challenge, we have also decided to measure cosmic radiation with a Geiger-Müller tube. We would also like to make calculations about the trajectory of the CanSat.

3.1 VOC and VSC levels



Sources of VOCs caused by human activities

VOCs and VSCs are chemicals that significantly impact air quality and human health. VOCs are emitted from sources like vehicles, industry, and household products, while VSCs, including sulfur-based compounds, are released by industrial processes and natural sources like vegetation. [1] [2]

Our research focuses on how human presence affects air quality in the city compared to higher altitudes above low-density areas. We will measure VOC and VSC levels with our CanSat at various locations in Szeged before the competition. In our presentation, we will compare our results with the data collected during the flight.

3.2 Cosmic radiation

In such low altitudes, we don't expect measurable difference in the radiation levels, that is why we consider this as a technological challenge rather than a scientific one.

[1] Volatile Organic Compound (VOCs) | Center for Science Education

[2] Technical Overview of Volatile Organic Compounds | US EPA

4 Risks and Expected Difficulties

Space Mission Name	**Date of Failure**	**Reason of Failure**
Soyuz 11	June 30, 1971	Cabin depressurization due to faulty valve, killing cosmonauts
Apollo 13	April 13, 1970	Oxygen tank rupture caused by a damaged fan heater
Venera 13	March 1, 1982	Failure of data transmission due to high temperatures
Challenger (STS-51-L)	January 28, 1986	Solid rocket booster O-ring failure due to cold temperatures
Mars Climate Orbiter	September 23, 1999	Mismatch between metric units and imperial units in software
Beagle 2	December 25, 2003	Communication failure caused by solar panel not deploying properly
Optical Satellites (JAXA)	2003	An unexpected failure of the gyroscopes aboard the satellite
Phobos-Grunt	November 9, 2011	Engine failure and communications failure with Earth

Murphy's Law in Space Missions

4.1 Risk analysis

Our primary goal is to conduct a successful mission; hence we value simplicity and reliability. During our work, we aim to minimize the risk of failure, but as Murphy's Law states: "Anything that can happen, will happen." We have identified the following risks that cannot be entirely mitigated or are too complex to prevent.

- Failure of non-redundant electronic components
- Midflight collision with another object

Other risks, along with method of prevention:

- Parachute failure - extensive testing
- Communication issue - on-board backup of the data

4.2 Expected difficulties

So far, we have not encountered any significant difficulties in our work. However, we expect to have difficulties with the Geiger-Müller tube, as it requires a high voltage power supply. [3] To provide that in the CanSat, we have to design and build a power supply circuit that can provide the necessary 400V for the tube. This is challenging as designing a circuit like that requires expertise in electronics, and we must handle high voltages with care during assembly.

[3] Geiger Muller Counter: Construction, Principle, Working, Plateau graph and Applications

5 Mechanical - Structural Design

First printed prototype

Our CanSat consists of three main parts: the upper body, the lower body and the electronics block. When designing our CanSat, we kept in mind, that we value simplicity and modularity. The lower and the upper body are secured together with 8 screws and they keep the electronics block in place. These designs are subject to change.

5.1 Lower body

This is the part of the CanSat that will impact the ground first. As the build material we have considered Thermoplastic Polyurethane (TPU) which is highly flexible, elastic, and durable. [4]

5.2 Upper body

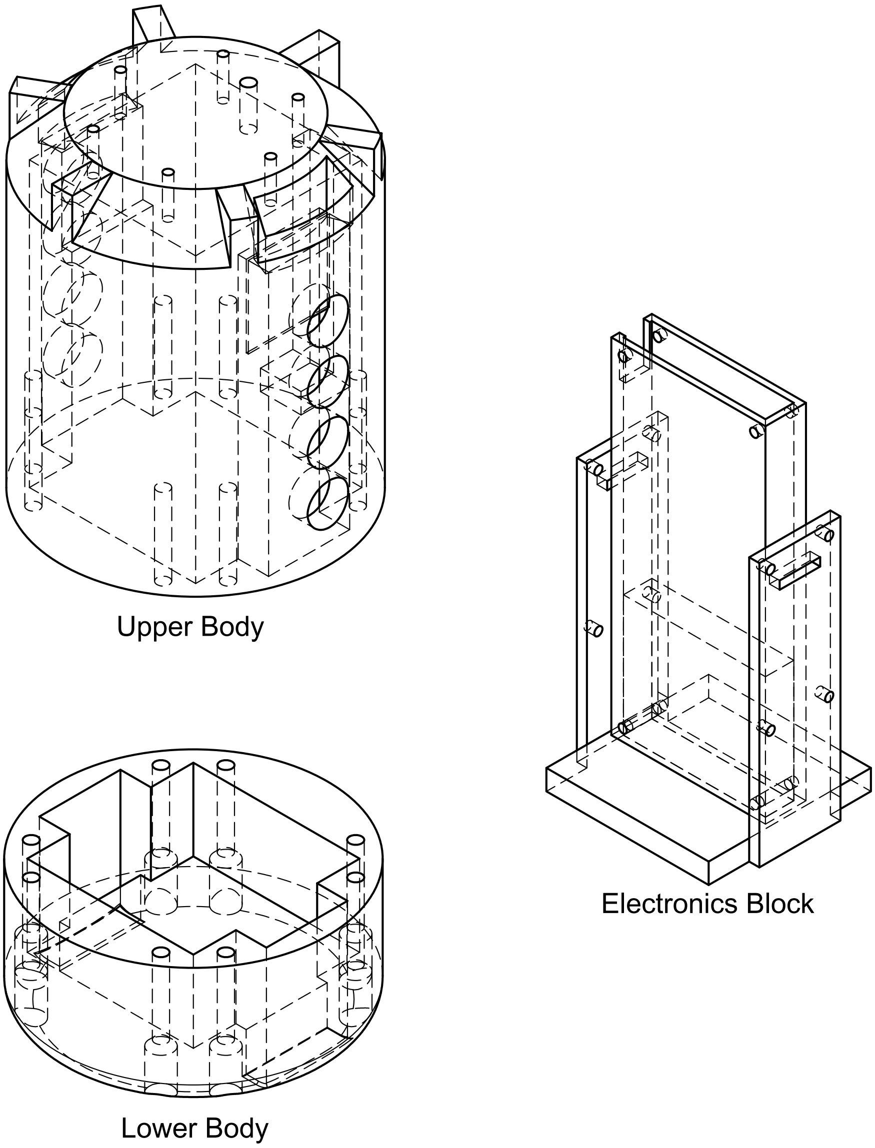
Under the upper body is the vast majority of the mission equipment. We want to expose our sensors to open air as much as possible, so supporting that, we added holes to the upper body. We would like to build it from a durable material, so we have considered Acrylonitrile Butadiene Styrene (ABS). [5]

5.3 Electronics block

Each electronic component is secured to the electronics block with screws, so they won't move during the flight. As the lower and the upper body closes together, they leave the electronics block zero degrees of freedom.

[4] Thermoplastic Polyurethane (TPU) | Formula, Properties & Application
[5] Acrylonitrile Butadiene Styrene (ABS) | Formula, Properties & Application

5.4 Blueprint

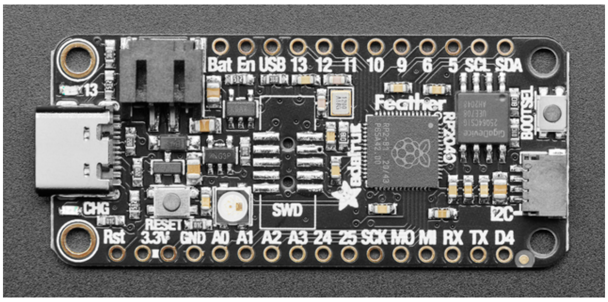


Dept.	Technical reference	Created by	Approved by		
		Document type	Document status		
		Title CANIS CanSat blueprint	DWG No.		
			Rev.	Date of issue	Sheet 1/1

6 Electronic Design

We design three different printed circuit boards (PCB) for our CanSat: the Outer Sensor Block (OSB), the Command and Data Handling (CDH) and the Inner Sensor Block (ISB).

6.1 General architecture



Adafruit Feather RP2040

The CDH is responsible for the processing of the data, the communication with the ground station and the control of the CanSat. We have decided to use components from Adafruit, as they are well documented and easy to use. Our microcontroller is the Adafruit Feather RP2040, which is based on the Raspberry Pi Pico. The GPS module is the Adafruit Mini GPS PA1010D. To detect the orientation of the CanSat, we use the Adafruit TDK InvenSense ICM-20948 9-DoF IMU.

6.2 Secondary mission equipment

The OSB is responsible for the measurement of the VOC and VSC levels in the atmosphere. We use the BME280 sensor for temperature, humidity and pressure measurements. For the VOC and VSC levels, we use the BME688 sensor. We will implement two OSBs to ensure more accurate measurements.

The ISB contains the Geiger-Müller tube and a power supply circuit in order to provide the necessary 400V for the tube.

6.3 Energy supply

The energy supply of the CanSat is provided by a 1200 mAh Lithium-Polymer battery. The microcontroller has a built-in battery charger and a regulator circuit so we will connect the battery directly to the microcontroller.

6.4 Power consumption

This section provides an estimate of the power consumption for each component, assuming all components are fully active. (We have not included the ISB in the calculations, as it is still a work in progress)

- **BME280**: 0.8 mA, **BME688**: 3.9 mA, **Feather RP2040**: 11 mA, **LoRa Radio**: 130 mA, **GPS Module**: 30 mA, **IMU**: 1.8 mA [6]

Summing all components, assuming they are active at once, the total estimated current consumption is:

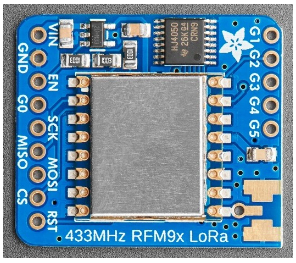
$$177.5\,\mathrm{mA}$$

For a 1200 mAh battery, the estimated runtime would be (we will calculate with 80% of the 1200 mAh to account for the potential losses):

$$\text{Runtime} = \frac{0.8 \cdot 1200\,\mathrm{mAh}}{177.5\,\mathrm{mA}} \approx 5.4\,\text{hours}$$

This represents the minimum battery life if all components operate at full power continuously.

6.5 Communication system



Adafruit RFM96W LoRa 433 MHz

For the communication, we use the Adafruit RFM96W LoRa 433 MHz module with the LoRa Automatic Packet Reporting System (APRS) protocol. This protocol is based on the LoRa technique, which is renowned for its wide range and low power consumption. [7] The APRS is designed for real-time communication and enables tracking of the CanSat over the internet. [8]

We will be using simplex communication during the flight, so we will not send any information from the ground.

[6] The power consumption values are taken from the datasheets of the components.
[7] LoRa PHY | Semtech
[8] APRS live map

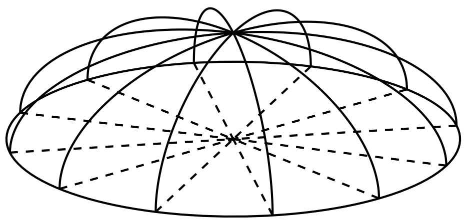
7 Software

We use the CircuitPython programming language, which is a derivative of MicroPython. It has all the advantages of Python built into the software of a microcontroller. Furthermore, it is fully supported by Adafruit, as it is the author of the software. We work in Visual Studio Code, which is a widely used integrated development environment (IDE) among programmers, for collaboration and file sharing, we use GitHub as well.

The code continuously reads the sensor values, and the collected data is stored directly on the microcontroller in JSON format. Each file consists of the elapsed time since activation and the measured values in a dictionary (key-value) format.

The data takes around 200 bytes per second, which enables it to take measurments for up to 10 hours, as the microcontroller has 8 MB of flash memory. This also means that we will be able to send it to the ground station using LoRa. [9]

8 Return System



12 gores semi-ellipsoid parachute

Our Cansat is going to use a 12 gores semi-ellipsoid parachute system which is similar to a hemispherical one, the only difference is that the distance from the top of the parachute to the center of it is 0.707 times the radius. The diameter of the parachute will be 40 cm giving the 350-gram cansat an 8 m/s landing speed. The deployment of the parachute will be assisted by the 2 airflow channels on the side of the CanSat.

The difference in the air density between the ground and 1 km is negligible, so we can use the same formula for the drag force as on the ground.

From the drag force = gravitational force equation:

$$A = \pi \left(\frac{d}{2}\right)^2 = \frac{2mg}{C_d \rho v^2} \implies d = 2\sqrt{\frac{2mg}{C_d \rho v^2 \pi}}$$

[9] LoRa bitrate calculator

With the following parameters:

$$C_d = 0.7, \quad m = 0.35\,\mathrm{kg}, \quad g = 9.81\,\mathrm{m/s^2}, \quad v = 8\,\mathrm{m/s}, \quad \rho = 1.225\,\mathrm{kg/m^3}$$

$$d = 2 \cdot \sqrt{\frac{2 \cdot 0.35\,\mathrm{kg} \cdot 9.81\,\mathrm{m/s^2}}{0.7 \cdot 1.225\,\mathrm{kg/m^3} \cdot (8\,\mathrm{m/s})^2 \cdot \pi}} = 0.3991457705\,\mathrm{m}$$

9 Ground Station

For our ground station, we plan to use an additional fully built and functional CanSat to demonstrate inter-satellite communication. Furthermore, this could serve as a spare CanSat if something were not to function properly with the primary one. This CanSat will be programmed to receive data from our flying CanSat and forward it to a laptop via Universal Serial Bus (USB). We also intend to use a computer with a dedicated Yagi antenna to minimize the risk of data loss. Beside these, the sent packets will also be available over the APRS network.

We will use the gathered information to create graphs for data analysis. Using these figures, we will be able to draw our conclusions and demonstrate our research.

10 Outreach

We plan to share our work on various platforms. By showing our work to others, we would like to motivate other like minded students to participate in such competitions and try their knowledge. We have a Facebook and an Instagram page to have a wider reach, and we plan to share the same feed on them about our progress.

On our website we shortly introduce the contest and our team. After the competition we would like to make our work open source. We also have a gallery section where we upload featured images of our team.

We will introduce the contest and our team at the VIII. Móra Kárpát-medencei Interdisciplinary Conference. We will hold a 10 minute presentation followed by a 5 minute Q&A session.

We have been offered a unique opportunity by our mentor, that after the competition we can send our CanSat up to 30 km height with a weather balloon. With that, we could broaden our research to a greater part of the atmosphere and even publish a study with our findings. Also with higher altitudes, we except that we can measure cosmic radiation with the Geiger-Müller tube implemented in the ISB.