SATE LINK

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CHANGELOG

Our project has undergone many changes since the CDR. Aside from concluding our test campaign, consisting of new vibration tests and a full mission test programme, we have managed to improve the architecture of the satellite, while enriching the project with additions to our secondary mission. Additionally, we have managed to acquire new logistical partners and sponsors, as well as having expanded our outreach campaign to further fields. All the specific changes are listed below:

- Although the electrical design of our CanSat has not changed drastically since the submission of the CDR we have decided to change the micro-SD card breakout module from the one from SB Components to a one from Adafruit which is more compatible with the Feather M0 module. Aside from that we also decided to power our feather M0 module on board the CanSat using the micro-USB port rather than the USB pin.
- We also designed and produced our custom PCB board that has all the necessary connections engraved in its surface, which makes it easier to use.
- Our rover has experienced all-rounded improvements regarding its mechanical design and role. Unlike previously, full control, including steering, is now possible when controlling the car. Additionally, it is further equipped with new gas sensors, expanding on the scientific character of the secondary mission, and increasing its number of applications in toxic environments.
- New partners, such as ICEYE, Łukasiewicz PIAP, Tamex, AppGala 24’ were acquired and sponsorship deals worth over 8000zł - completed.
- A brand-new website has been designed and put up, along with a 10-minute promotional YouTube video, including animations of the can and interviews with our team members. The outreach programme has also expanded significantly in other areas.
- Further improvements to mechanical structure, rover design, code, and recovery mechanism were also made (Section 2).

1. INTRODUCTION

In the field of advanced technological projects, the integration of satellite communication with ground station operations stands as a beacon of innovation. Our CanSat delves into the intricacies of a project that focuses on the seamless connectivity between a satellite, rover and a ground station, with a particular emphasis on the technical aspects and operational challenges involved.

Our project is aimed at the intersection of developing technology and scientific exploration, offering the potential to redefine our understanding of the cosmos. We have embarked on a mission that aims to synchronize the functionality of a satellite with a terrestrial ground station and rover, thus ensuring effective communication and data transfer. This report will offer an exhaustive examination of our plans for the project, including its objectives, methodologies, and expected outcomes.

Our overarching goal is clear: to provide an in-depth analysis of the technical design considerations for satellite and rover communication as well as the protocols governing its interaction with a ground station. Our commitment to this project extends to immense planning, thorough execution, and a rigorous adherence to the highest standards of professionalism possible. We hope this report encapsulates the results of our collaborative efforts. As we venture into this project, we underscore the importance of advancing technology, strengthening our understanding of satellite-ground station coordination, and emphasizing the pivotal role this relationship plays in the future of space exploration and scientific research.

Compliance with regulations necessitates that our CanSat incorporates a sensor to track its altitude. This sensor transmits data every second through a specialized radio module. The collected data helps us determine the rate of descent, crucial for our mission. Our CanSat maintains a communication link with the ground station through a radio module, allowing it to receive commands and store them on a memory card when not actively transmitting data. These commands are also relayed to a secondary ground station, a rover, for task execution. The rover is too distant for direct ground control, hence the need for a relay satellite for communication. This setup offers the advantage of a smaller, lighter rover with enhanced mobility and additional air sampling sensor capabilities for thorough data collection during planetary exploration. The secondary mission emulates a communication method used in ExoMars missions, optimizing our communication approach. Mission success is contingent upon the CanSat effectively transmitting commands to the rover, and the rover executing these commands.

1.1 Team Organisation and Roles

Each team member takes part in an hour-long meeting once a week provided by the school; however, we have also decided to dedicate our Saturdays to self-organized meetings to complete our CanSat. Therefore, most of the team is spending around 6-8 hours a week working towards the project.

Communication in our team is settled largely through E-mails and Microsoft Teams Groups. We also have a OneDrive folder which we update frequently to contain all the necessary files. Our team further utilises WhatsApp to share photos and urgent updates on the project.

Jan Gierszewski - System engineer, Project manager

- Jan's following a pathway of Physics and Mathematics.
- Jan is passionate in the field of mechanical engineering with special expertise on engines and aerodynamics.
- As system engineer and project manager, Jan is responsible for all the calculations, planning the work schedule and our overall primary and secondary mission targets.

Gabriela Lisowska - Report manager

- Gabriela has previous experience in the CanSat competition.
- Gabriela's A-Level choices are Physics, Mathematics and Biology.
- She is passionate in the field astrophysics and aerospace engineering.
- Gabriela will be responsible for structuring our reports and outreach such as social media activity.

Alan Tomaszewski - Electrical engineer

- Alan's A-Level choices are Physics, Mathematics and Further Mathematics.
- Alan is extremely interested in electrical engineering and is hoping to pursue a career related to said passion. He has previous experience in engineering as he attended external summer courses.
- Alan is currently responsible for the circuit design for both ground stations and CanSat.

Konstanty Augustyniak - Marketing and sales representative

- Konstanty's A-Level choices are Mathematics, Further Mathematics and Physics.
- Previous experience in external summer school programs from finance as well as engineering.
- Konstanty is responsible for setting our financial plan as well as researching and getting sponsors for the project.
- Konstanty is passionate in the field of theoretical physics, astrophysics and finance.

Aliaksandr Kuryla - Programmer

- Aliaksandr is extremely interested in programming and hopes to pursue a career related to the field.
- Although he has not begun A-Levels yet, his IGCSE pathway focuses on Mathematics, Physics and Computer Science.
- He has previous coding experience in both C++ and Python.
- Aliaksandr is responsible for managing the communication with the Ground Station and managing a temperature and pressure measuring programme.

Jakub Rudnicki - Mechanical engineer

- Jakub is passionate about mechanical engineering.
- His IGCSE pathway focuses on Mathematics, Physics and Chemistry.
- He has previous experience in electrical engineering, mechanical engineering and 3D design. He hopes to work in aeronautics or other engineering-based fields.
- Currently, Jakub is working on the preliminary mechanical design of our CanSat.

1.2 Mission Objectives:

For our primary mission, our objectives (and when we consider our mission successful) are to implement altitude monitoring during descent, using a temperature and pressure sensor connected to an onboard microprocessor. This involves activating the sensor to transmit altitude data back to the ground at least once per second through a 433MHz radio module. Additionally, back at the ground station we aim to graph the transmitted data to accurately determine the descent rate. This information, matched with the data on crosswinds on launch day, will enable us to accurately estimate the CanSat's landing position.

In terms of our secondary mission, we plan to establish a two-way, half-duplex, SPI connection between the ground station and the CanSat, utilizing two radio modules to facilitate a seamless data exchange. We also aim to enable the CanSat to store information from the ground station during periods when it is not transmitting primary mission data. Additionally, we seek to relay commands from the ground station to a rover equipped with an antenna, allowing for efficient remote task execution, such as driving or collecting air samples. Through this setup, we plan to demonstrate the rover's remote-control capabilities via relayed commands, thus simulating communication procedures like an ExoMars-style mission. Moreover, by incorporating this satellite concept, we enable the rover to carry lighter antennas and additional sensors for comprehensive data collection. Our aim is therefore to ensure smooth transmission of commands from the CanSat to the rover and successful execution of assigned tasks with the vehicle, ultimately achieving mission success.

2 CANSAT DESCRIPTION

2.1 Mission Overview

Primary mission:

As the regulations require, our CanSat will monitor its altitude while falling using a BMP 280 temperature and pressure sensor. Connected to the Feather M0 module, the sensor will activate and using the pressure – temperature correlation formula:

$$P = Po \times e^{\frac{gM(h-ho)}{RT}}$$

will transmit the readings once per second through a RFM96 radio module with an omnidirectional elastic antenna. The data will then be graphed out at Ground Station to provide us with the descent rate. Knowing the crosswind value and the rate of change of altitude, we will be able to better estimate the position of the can as it falls on the ground.

Secondary mission:

Our can establishes a two-way, half-duplex, SPI connection with the ground station, using two RFM96 LoRa modules, one on the ground as well as one in the can. When the can is not transmitting the primary mission data to Ground Station, it receives information from it and saves them on our micro-SD card. The commands uploaded to the can are then further transmitted to a second ground station (a rover) equipped with a directional receiver antenna. As a result, the rover then carries out the given task. The rover would not be able to be controlled directly through a signal on earth due to obstacles like trees, buildings, uneven terrain or even the curvature of the Earth. For such a scale (5+ km), an on-ground communication would therefore likely be interrupted by external sources that would interfere with the radio signals sent. Another obtained advantage is that the rover can carry a much more compact, lighter antenna. It will consequently become lighter and faster; therefore, like in the case of our mission, it could be fitted with more air sampling sensors to gather desired data about the explored surfaces, atmospheres or planet biomes.

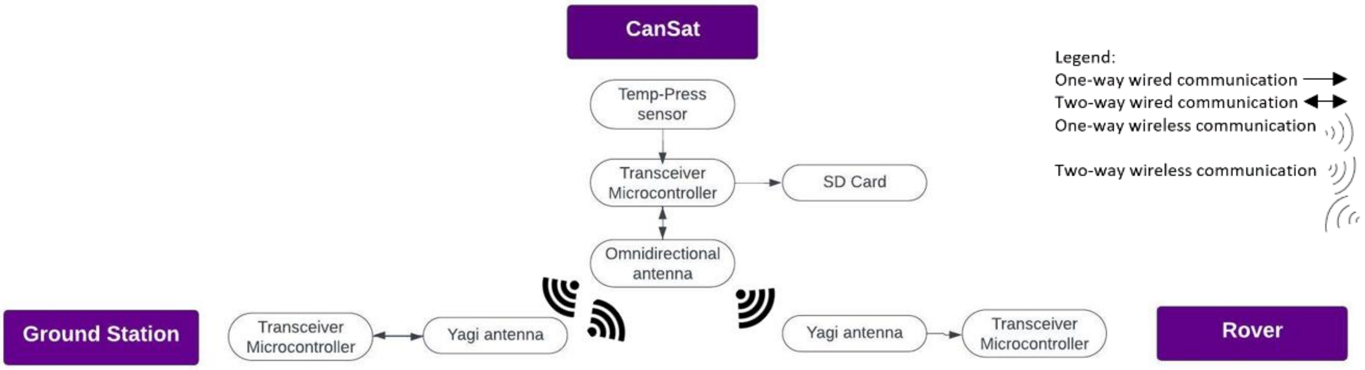

Figure 1 - Chart of the Mission Overview

2.2 Mechanical and Structural Design

The body of the Satelink CanSat was designed and engineered in Autodesk Fusion 360; allowing for a precise 3D-model of our project. As of the critical design review phase, all of the CAD components for the purpose have been 3D printed using a Bambu Labs X1 Carbon 3D printer which has been acquired using personal funds and funding from sponsors. The recently designed components and complete 3D prints of the CanSat have been printed with PC (polycarbonate) filament. After further considerations of data provided by the filament manufacturers and our testing, it has been concluded that the PC filament provides rigidity and exceptional performance during vibrational testing, high altitude drop tests and full mission tests; contrary to ColorFabb XT filament and basic PLA manufactured by Prusa. The CanSat consists of four main architectural higher components:

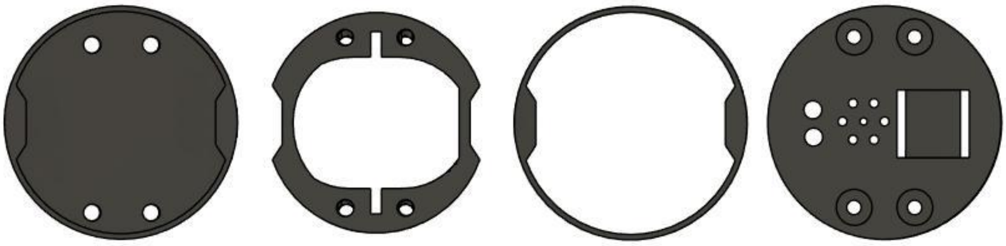

Figure 2 - Bird's Eye View of CAD Casings – Bottom Lid, Internal Casing, External Casing, Top Lid

- Top Lid: Houses the BMP 280 in a groove on its top face, exposing it to the atmosphere, allowing for the upmost accuracy of measurements while maintaining its protection. Following the high altitude drop test, changes have been made to the parachute strings attachment to the Top Lid. As of FDR, the strings are attached to the lid in a hexagonal pattern with six holes, guiding each parachute string individually; allowing for much smoother parachute deployment and less tangling. Also features two holes for led diodes and an additional hole for the wire antenna, allowing for it to extend out of the can. It is circular and has a diameter of 64mm (the CanSat's casings are wrapped in thin carbon fiber sheets from TeXtreme allowing for the final and assembled version to have a maximum diameter of 66mm) and a thickness of 3mm. The outermost edges have been made longer by 10mm, allowing for the Top Lid to be mounted to the internal casing with four M5 screws from the top and an additional 2x M5 screws from the sides, as such that it does not detach easily from the rest of the casings during parachute deployment.
- The External Casing: Primary goal is to protect internal electronics from various types of damage during flight and absorb impact during landing. It is the only component throughout the probe that is designed to potentially break during landing, assuming the unsuccessful deployment of the parachute. Provides air-tight fit with internal casing to further insure insulation from the atmosphere. The casing features four threaded holes to connect to the internal casing with M5 screws. Its updated version is lower in height, to allow for the top and bottom lids to be longer; allowing them to attach to the internal casing in the horizontal plane. It is cylindrical, with a height of 86mm, external diameter of 64mm; has an infill of 40%. Features a small hole to allow for access to the master power switch and Feather M0 reset button.
- The Internal Casing: Houses all avionics and internal components. Features a tight slide in mount for the PCB of our CanSat. As opposed to the previous iterations, the current design does not feature screws that attach the PCB to its railing (to minimize vibrations). Instead, the PCB is held more tightly by its railing and is prevented from excess movement by the top and bottom lids. The AA battery pack is positioned vertically on the casings wall and is secured strongly in a clip-in mount and strong MMA glue. The components within the casing will be positioned such that they ensure the center of gravity is on the center most part of the can to ensure stability while falling. It is based on a cylinder and has an external diameter of 60.5mm. Redesign features more obtuse angles and thicker walls to increase durability and allow for bigger screws. Certain faces have holes to optimize mass; features a 40% infill to safely house all crucial components.
- Bottom Lid: Allows for fast and easy access to batteries for replacement and management. Attaches to the internal casing with four M5 screws. It is circular and has a diameter of 66mm and thickness of 3mm with a 40% infill.
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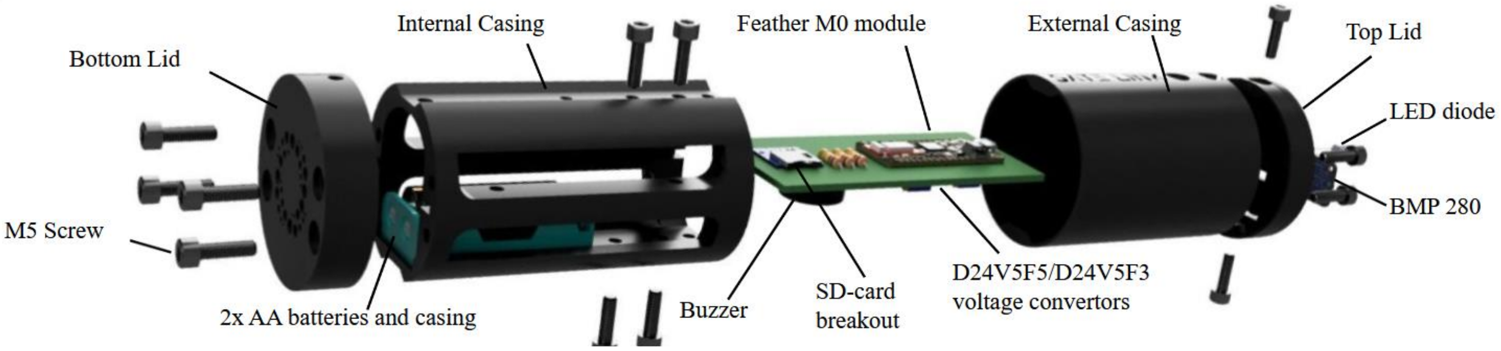


Figure 3 - Perspective View of Disassembled CanSat CAD

The casings and top/bottom lids are connected using M5 screws of 15mm lengths, with sheer and tensile strengths exceeding the necessary requirements for our missions. Threads in each of the casings have proven to be reliable during high altitude drop testing as well as vibrational testing and do not wear and fatigue as quickly with the PC filament. The internal casing is intended to be in union with the CanSat's PCB, such that the entire satellite can be secured together in a minimalistic and timely manner. The shapes of the casings prevent them from rotating and moving around once one is tightly inserted into the other, further decreasing vibrations. Furthermore, both casings are easily replicable and can easily as well as quickly be equipped with the primary and secondary mission components.
The BMP has been placed on top of the can to allow for the most accurate atmospheric measurements, secluded from any heat from within the can that could interfere with the measurements. It will be attached to the Top Lid with MMA based glue in appropriate places and will also be partially soldered to the casing, such that it does not damage any important sensors but retains its strong adhesion to the casing.

The PCB's mobility within the internal casing is inherently very limited because of the low tolerance engineering of its given railing. When pushed inside, it has proven not to move or slide out of the internal casing even without the top and bottom lids attached. Moreover, with the top and bottom lids attached, the PCB is allowed a small degree of movement +- 0.5 mm. **However, it is critical to note that during impact, the bottom and top casings are not in direct contact with the PCB and instead exert force on the internal and external casing.**

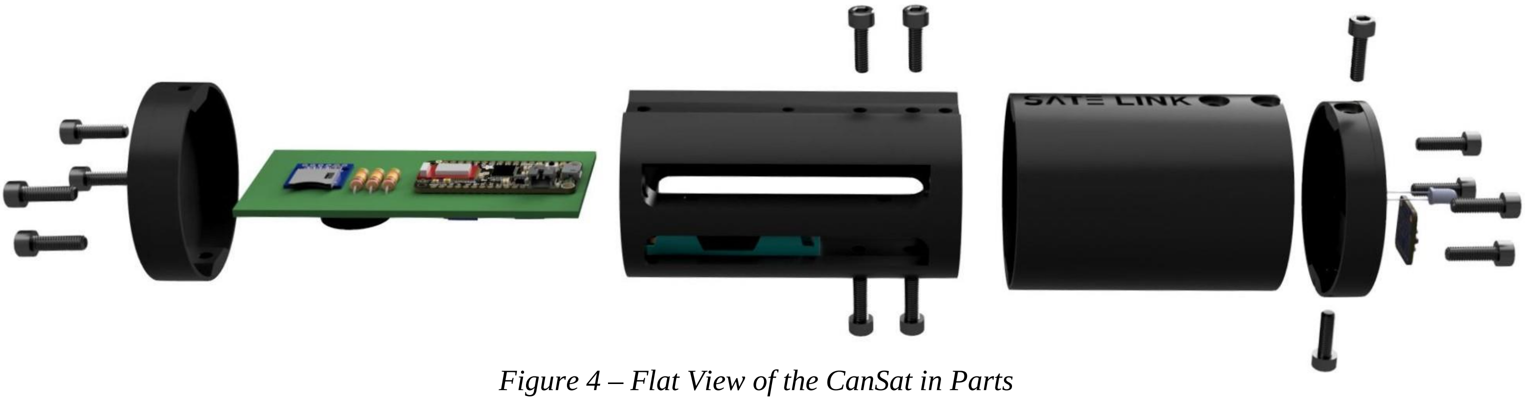


Figure 4 – Flat View of the CanSat in Parts

Electrical components are fitted on both sides of the PCB to optimize the CanSat's center of gravity and thus its stability during descent.
As of the CDR and full mission test, the parachute strings came to be mounted in the center of the Top Lid and knotted around a mount on the bottom face of the top lid; this led to the parachute opening successfully but spinning excessively and tangling, pulling unevenly on each of the parachute strings. As of the redesign, each of the parachute strings are separated and pulled through six holes arranged hexagonally and relatively close to each other (but far enough as such that the holes do not compromise the structural integrity of the lid). Each end will be knotted with an equal amount of string as such that the strings cannot be pulled out of the lid.
The CanSat's mechanical design, with longer top and bottom lids with horizontal and vertical attachment points to the internal casing, and thickened bottom lid, have also survived an accelerated fall from 20m at 7m/s with an accurate mass onto concrete with no damage to the internal casing and top and bottom lid. The external casing featured a small crack but remained intact with the internal casing.

The current structural design of the CanSat has continued to be proven reliable; surviving vibrations of up to 1000hz in horizontal x and y axis vibrations, and vertical vibrations in the z-axis of up to 20G. Collectively, accurately emulating conditions onboard the rocket. Moreover, the mechanical structure flawlessly survived a fall of 120m at 6.5m/s with no cracks or displacement of any of the casings, or PCB and electronics. Subsequently, proving the Satelink CanSat's reliability and demonstrating that it is prepared for the launch campaign.
The FEA (Finite Element Analysis) was not conducted on the CanSat's structural design due to the lack of availability of Autodesk Inventor Nastran for educational licensing in Poland.

Element name	Mass (g)	Mass Growth Allowance
Parachute	**10**	**0%**
PLA Casings	**180**	**0%**
M5 screws	**38.1**	**0%**
PCB + soldered components	**45.7**	**0%**
2xAA batteries + casing	**39.8**	**0%**
BMP 280	**1.3**	**0%**
Micro SD card	**2.0**	**0%**
RGB LED	**1.2**	**0%**
TOTAL	**318.1g**	**318.1g**

Above is the current measured estimate for the mass of the entire can. Masses of each individual component have been assessed using weighing scales with an accuracy of up to 0.05g, borrowed from the chemistry laboratory in AHS. Furthermore, to account for changes in design, the Mass Growth Allowance (aligning with suggested values from the AIAA Mass Properties Control for Space Systems) has been included. Provided that the potential changes to the mass will meet expectations, the CanSat's maximum mass should not surpass 350 grams. On the other hand, if the can is below the minimal weight limit before the launch campaign, it will be weighed down by increasing component infill to reach an appropriate mass.

2.3 **Electrical Design**

2.3.1 General Architecture

The CanSat consists of many electrical components, each carrying out a specific task. The decision to use the Feather M0 module was made because it is perfectly capable of carrying out tasks for both the Primary and Secondary Mission. The module contains a 32-bit microcontroller ARM Cortex M0 ATSAMD21G18, as well as an integrated radio module, RFM96 LoRa. Previously, the plan was to use an Arduino Nano ESP32 and a LoRa SX1278; however, as the secondary mission heavily relies on good radio communication between the Ground Station and the CanSat, the decision was made to use a module with an integrated transceiver as it allowed the communication systems to be tested straight away without the need for soldering the transceiver to the microcontroller. The core of the Primary Mission is the BMP280 pressure and temperature sensor. It will record the pressure and temperature during the launch of the CanSat and send it back at one-second intervals to the ground station via the radio module. This will allow for an accurate measurement of the altitude of the CanSat, which will be calculated using the hypsometric formula. The data from the BMP280 will be stored onto the micro-SD card that will be attached to the Feather M0 via a micro-SD card breakout. As the Arduino Nano ESP32 with an integrated SD card was decided against, the search for other options to store the data for the primary and secondary missions was necessary, hence the decision to use an SD-card breakout. The micro-SD card that will be used has a storage of 16GB, which is much more than will be needed.

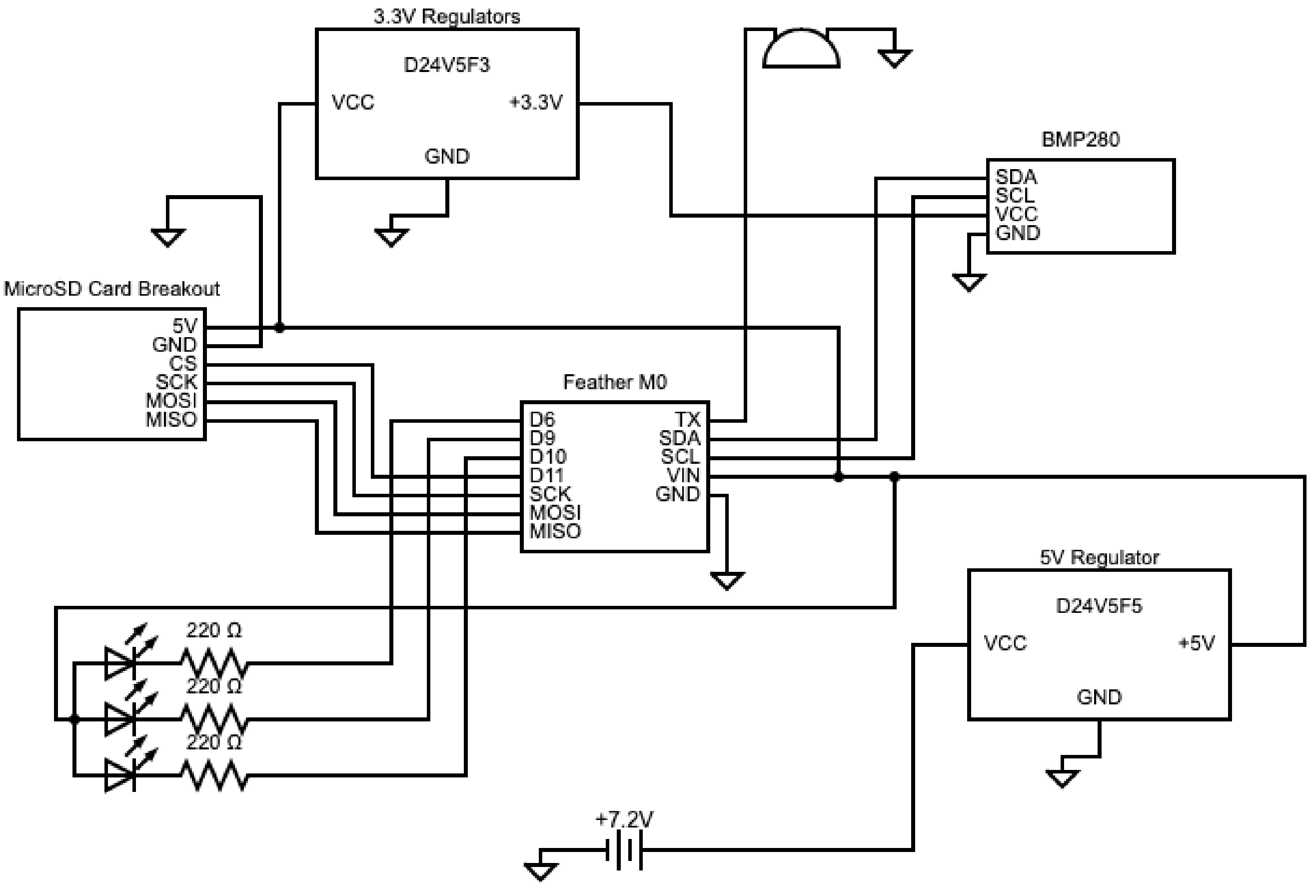


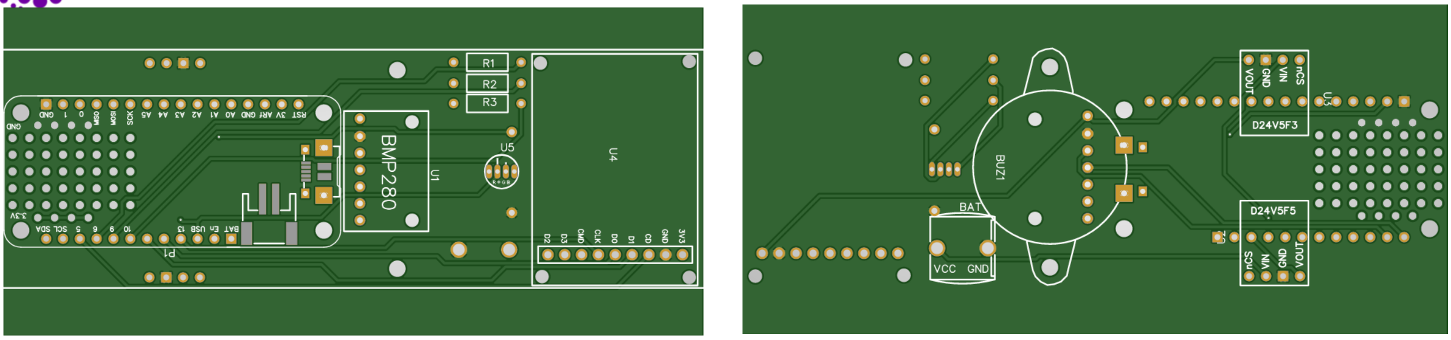
Figure 5 - Electric Circuit Diagram

To power the CanSat, 2 x 3.6V batteries with a capacity of 1800 mAh will be used. This will give a total voltage of 7.2V which will be perfectly enough to power all the components. The large capacity of the batteries also eliminates the risk of the CanSat running out of battery during the actual launch. Previously, the use of 3 x 3.7V batteries with a capacity of 650mAh was considered, but this idea was abandoned as most components operate on 5V and 3.3V, therefore there is no need for a total voltage of 11.1V that would eventually have to be stepped down. As most components operate on 5V and 3.3V, two voltage regulators will be used in the can. One (D24V5F5) will step down the voltage from 7.2V to 5V for powering the Feather M0, Adafruit microSD card breakout and RGB LED. The other voltage regulator (D24V5F3) will step down the voltage from 5V to 3.3V for the BMP280. The Can will also be equipped with a wire antenna for communication with the Ground Station and the rover. To aid in the recovery of the CanSat after a successful launch, an 82dB buzzer will be used so that the CanSat can be traced using sound and therefore recovered for potential future use. Another crucial component in the CanSat will be the RGB LED diode that will be connected to the Feather M0 and programmed to shine different colours, indicating whether the CanSat is on, receiving or transmitting data and if there are any problems with the communication between CanSat and Ground Station.

2.3.2 PCB Design

After carrying out all the necessary tests, the decision was made to create a custom PCB board using the EasyEDA design software. Firstly, the design was conceptualized, and the requirements for the PCB, such as layers, size, and functionality, were determined. After that, the schematic of the circuit was drawn and converted into a PCB layout within EasyEDA. This process auto-placed all the components onto the PCB, with all the connections that were made in the schematic. The next step was to adjust the placement of the components and routing of the traces to optimize the design for manufacturing and functionality. As there is not a lot of space inside of the can, the placement of all the components had to be carefully adjusted so that they do not interfere with the mechanical design of the can.

Following this, the design was exported as Gerber files from EasyEDA. The order for the custom PCB was placed with PCBWay, as the website is very user-friendly and easy to operate. Also, the delivery time of the PCBs was taken into account as there was a desire to have them as soon as possible, to carry out tests and have enough time to make potential changes.



Figures 6,7 – Top and Bottom of our PCB

The PCB consisted of two layers. The decision was made to put the components on both sides as it allowed for a lot of space to be saved and worked perfectly with the mechanical design of the CanSat, making the PCB easy to slide in. This was a crucial part of the design as it allows for easy access to all of the components on the printed circuit board. For further optimization, the BMP280 was not soldered directly onto the PCB as there was a need to place it as far as possible from the other components to prevent it from detecting inaccurate temperature and pressure values, which would decrease the reliability of the altitude readings. Instead, the BMP280 was connected using extra cables and placed at the top lid of the CanSat. Similarly, the RGB LED was placed at the top lid, connected to the PCB via cables so that it is easily visible as it is used to detect whether all the components inside of the CanSat are operating as expected. Also, to comply with the CanSat regulations, the switch was placed on the side of the can, so that it is easily accessible for turning on and off the power supply of the can.

2.3.3 Primary Mission Devices

For the primary mission, there is an obligation to measure the temperature and pressure during the launch of the CanSat. For this purpose, the BMP280 sensor has been chosen due to its high reading accuracy for both temperature and pressure. For temperature, it has a measurement range from -40 to 85 °C and an accuracy of (+/- 1 °C). Furthermore, for pressure, it has a measurement range from 300 to 1100 hPa and an accuracy of (+/- 0.12 hPa). According to the manufacturer, this will allow for an uncertainty of +/- 1m. To remove any errors in the readings of temperature and pressure and to be as reliable as possible, the BMP280 sensor will be isolated from all other electrical components as they may heat up, which would influence the measurements of the temperature. The BMP280 will be programmed to measure the temperature and pressure at 1Hz. The readings will then be processed by the Feather M0 microprocessor and transmitted through the radio link established between the CanSat and the Ground Station. The data recorded will then be saved on the micro-SD card, which will be connected to the Feather M0 via the micro-SD card breakout. After that, the readings will be sent to the ground station by the RFM96 LoRa integrated in the Feather M0. On the ground, the data will be displayed using a data visualization code in Python, displaying a live graph of the CanSat's altitude throughout the mission. This will then be stored on the on-ground PC.

2.3.4 Secondary Mission Devices

The main goal of the secondary mission is to establish a two-way, half-duplex, SPI connection between the CanSat and the main ground station. Therefore, the secondary mission heavily relies on a good radio connection between the CanSat and the ground station. For this purpose, the decision was made to use the Feather M0 module with an integrated RFM96 LoRa transceiver, a long-range radio communication module. Two different transceivers, Semtech LoRa SX1278 and NRF905, have been previously experimented with. The main reasons for not using the NRF905 were that it was not included in the radio modules permitted by the organisers, and it had a weaker receiver sensitivity and maximum power output than the LoRa SX1278. Moreover, after the PDR was submitted, the decision was made to use the Feather M0 with integrated RFM96 instead of the Arduino Nano ESP32 and LoRa SX1278 as it occupied less volume and did not require any soldering to be done. On the can, the RFM96 will be connected to a wire antenna, while the RFM96 on the ground station and the rover will be connected to an external Yagi antenna. Due to the high possibility of crosswinds that might cause the CanSat to fly in unexpected directions, it is necessary to ensure that the radio communication with the ground station and the rover is sufficient, even in the worst scenarios. Consequently, in the radio link budget, communication range of up to 7km has been accounted for. To avoid interference between the primary and secondary missions, the Feather M0 will be programmed so that the radio module on board the CanSat will be able to both receive and transmit data simultaneously. This will allow for not only transmitting the readings of temperature and pressure to the ground station at one-second intervals but also receiving the necessary commands that will later be relayed to the rover.

2.3.5 Power Supply

For the power supply of the CanSat, the decision was made to use 2 x 3.6V batteries connected in series to step up the voltage for the components. Each battery has a capacity of 1800mAh and therefore the total battery capacity is 1800mAh because they are connected in series. Previously the consideration was using 3 x 3.7V batteries with a capacity of 650mAh, however, since all components operate on a voltage of either 3.3V or 5V, there is no need for the input voltage to be as high as 11.1V if it still must be stepped down to 3.3V and 5V using voltage regulators. The decision was also made to use batteries with a much greater capacity in order to further eliminate the risk of the power supply not being sufficient for the whole mission. To calculate the total energy stored in the battery, the following formula is used:

$$\mathbf{E = Q \times V \div 1000}$$

where *E = Energy stored in battery (Wh), Q = Battery Capacity (Ah) and V = Voltage of the battery (V).*
This eventually gave us an answer of 12.96Wh since: E = 1800mAh x 7.2V / 1000 = 12.96Wh.

To estimate the total power consumption of the electrical components, the working current of most components is multiplied by its working voltage. For the voltage regulators, instead of just multiplying the voltage by the working current, the formula is used:

$$\mathbf{P = (V_{IN} - V_{OUT}) \times I_{OUT}}$$

to obtain the power dissipated in the regulators. Finally, the total energy supplied from the batteries (Wh) is divided by the total power consumption, and it is found that the estimated battery life for the CanSat would be around 7.03h. These results show that even in the worst-case scenario, when there would have to be a wait of up to 4h for the launch, there would still be around 3h to carry out the missions and recover the CanSat after it has reached the ground. Note that the highest current consumption rate for the Feather M0 has been used, which assumes that the RFM96 LoRa is constantly transmitting data; the current consumption is significantly lower during full sleep mode (300µA) and during active radio listening (40mA).

Component	Working Voltage (V):	Current Consumption (A):	Power (W):
Feather M0 + RFM96 LoRa	5V	0.12A	0.6W
BMP280	3.3V	0.00112A	0.003696W
Buzzer	3.3V	0.03A	0.099W
RGB LED	3.3V	0.025A	0.0825W
MicroSD Card Breakout	3.3V	0.08A	0.264W
Regulator (3.3V)	1.7V	0.13612A	0.231404W
Regulator (5V)	2.2V	0.25612A	0.563464W
Total Power:	-	-	1.844064W
Energy in Battery (Wh):	-	-	12.96Wh
Battery Life (h):	-	-	7.03h

2.3.6 Communication System

In the communication process, the CanSat will receive commands from the ground station, transmitting its telemetry – which includes pressure, temperature, and command information. This telemetry will be received at both ground and rover stations, with each base extracting different values from it. The cycle will repeat at least once per second to comply with primary mission regulations.

As mentioned earlier, communication between the CanSat and ground stations will be established using a RFM 96 transceiver module and an omnidirectional wire antenna. The transmitting power will be increased to the regulatory maximum of 20dBm, with an expected gain of approximately 2.5dBi from the wire antenna. Although this is less than the initially expected 10dBi gain, the 22.5dBm output at the antenna will suffice for communication.

Furthermore, the use of stock receiving sensitivity settings of -148 dB, along with the regulatory 125kHz bandwidth, will facilitate communication at up to 293 bits per second, exceeding the maximum requirement of 200 bits per second (25 bytes). This has led to the abandonment of the initial plan to reduce sensitivity for enhanced communication speed.

Additionally, a flexible wire antenna, soldered directly to the Feather M0, will be positioned through the upper lid to avoid signal interference from internal metallic components. The system will operate in SPI mode as a half-duplex module, allowing for smooth transitions between transmitting and receiving.

For the ground and rover stations, the setups will include a microcontroller and the RFM96 with 20dBi output, along with a 5 element DK7ZB Yagi antenna for a directed connection with the satellite. Connections to the Feather module will be made through a 1.13mm U.FL – N type cable.

The antenna will provide an 11.3 dBi gain and -16.5dB backwards radiation, with a beam width of 58 degrees vertically and 48 degrees horizontally, reducing the risk of losing the CanSat from the beam's view and minimizing packet loss. The rover station will use the same setup, but the Feather module will be configured for continuous reception of information, as opposed to half-duplex, two-way communication.

In the communication between ground station and CanSat, a bidirectional link will ensure that both modules either transmit or receive, avoiding signal interference and maximizing communication duration. Proper synchronization will maintain a constant connection, while the rover will remain in receiving mode to ensure efficient transfer of commands.

Radio Link Budget:

Variable	Value
Frequency	433MHz
Tx Power	20dBm
Tx Cable Loss	<1dB
Tx Antenna Gain	2.5dBi
Distance	<7km
Rx Antenna Gain	11.3dB
Rx Cable Loss	1.4dB
Rx Sensitivity	-148dBm

Variable	Value
Fade Margin	76.8 dB
Free Space Loss	88.1dB
Rx Signal Strength	-71.2dBm

Above is also the current, updated Radio Link Budget. As we can see in our case, the Rx signal strength is at –71.2dBm, so significantly bigger than the sensitivity threshold of –130dBm for our antenna. Consequently, as long as the Fade Margin remains above 10dB (now at 76.8 dB), we do not assume that any difficulties in communication should occur. This was further confirmed by our communication range test.

2.4 **Software Design**

The code for CanSat, Ground Station (GS) and the rover is written in Arduino IDE, utilizing C++, and extended libraries tailored for communication, sensors, SD card readers and the rover motion. The code for the life graph plotting and commands sending was written in Python. Each Feather M0 unit has distinct software customized to its specific functions. CanSat and the rover are equipped with SD card, while the Ground Station (GS) is outfitted with a computer for data storage. Below you can also find the link for the GitHub page of our project: https://github.com/Pe1mehk0/Satelink_cansat_competition

2.4.1 Radio Communication (Data receiving and transmitting process)

2.4.1.1 Ground Station

Ground Station (GS) is set to receive mode, focusing solely on acquiring messages from the CanSat without performing any other tasks until the message is successfully received. Once received, the message's arrival time is recorded for graph plotting, and its data is stored for subsequent analysis.

GS then checks the Serial Buffer, a crucial holding area for rover commands awaiting transmission. If a command is found, GS promptly reads it and transmits it to the CanSat. Following transmission, GS separates the collected data into pressure and temperature readings. Using the hypsometric equation, GS calculates the CanSat's altitude; then, converts temperature to Celsius and pressure to hectopascals for display.

This communication method is more secure and quicker than our previous approach, as it eliminates the need for a separate synchronization step and does not depend on fixed time intervals. It ensures continuous synchronization throughout the flight, even if one of the Feathers is reset.

The final step involves outputting the pressure, temperature, altitude, and time data to the Serial Monitor of the Arduino IDE which plots the necessary pressure-time, temperature-time, altitude-time graphs

2.4.1.2 CanSat

CanSat starts its main loop from measuring temperature and pressure. The next step is the creation of the telemetry. The telemetry is an array with pressure, temperature, rover command (numbered 1 - 9), and command status – flag (0 for old, 1 for new).

Example: (102400.25,273.15,91) means we receive: *Pressure = 102400.25Pa = 1024hPa; Temperature = 0*^{o} *C / 273.15 K; New Rover Command = 9.*

Then, this telemetry is saved to the SD card and transmitted to both to the rover and to GS to check the reception of the command by CanSat. Following both transmissions, CanSat turns on the receiving mode and waits for the message with the command from GS. The maximum waiting time is 300 milliseconds. If the command was successfully received, the can saves it to a designated variable and toggles a flag from 0 to 1. In the absence of a command, it retains the previous command and updates the flag from 1 to 0. The flag variable serves to indicate whether the rover is receiving a previous or a new command, helping reduce packet loss and eliminate unnecessary repetitions of the same rover controls.

2.4.1.3 Rover

The rover is always set to receiving mode, awaiting telemetry. Upon receiving it, the rover initially checks the last digit. If it is 0, rover looks to the digit on the left and compares it to the last received command. If they are different, it adds it to the list of commands. If they are the same, it ignores it. This allows to reduce the packet loss of commands. If the last digit is 1, it means that there is a new command, so it adds it up to the list of commands.

The rover will also check time passed since receiving its last command. Once the rover received 9 or no commands are received for over 3 minutes, it starts performing the whole list of tasks it was given. When it is done with the list, it turns on the receiving mode, cleans the list and repeats the procedure. The last step is to ensure that if 9 is not sent before the end of the flight of the can, the rover will still perform all of its tasks.

2.4.2 Gathering of Primary and Secondary Missions Data:

When the main loop starts, CanSat measures temperature and pressure. The next step is to convert temperature to Kelvins. Then, on GS, these measurements are used to calculate altitude of the Can. If those are the first measurements that arrived from CanSat, GS treats them as the initial values.

When it comes to Secondary mission, if the rover receives 8 as a command, it starts to analyse the air for alcohol, benzene, hexane, methane, carbon dioxide, toluene, ammonium, acetone, carbon oxide, hydrogen gas and flammable gas. After the rover got the samples, it prints the percentage in the air of each element on the LCD and saves them on the SD card. It is done to plot these values on the graph after the mission.

2.4.3 Graph plotting and interface on the Ground Station

The program initiates by setting up a connection to the Feather M0's Serial Monitor at the Ground Station. In operation, it divides its focus across three concurrent processes, enabling simultaneous data reception and command handling. The first of these processes acts as a console, standing by for user-inputted rover commands. Upon command entry, the program captures this input and stores it in the Serial Buffer, making it accessible for Feather M0's subsequent retrieval. The second process involves reading data from Feather M0's Serial Monitor. After computing the altitude, Ground Station (GS) displays the gathered data—pressure, temperature, altitude, and the timestamp of data reception—on the Serial Monitor. This data is then collected, stored, and transferred to the program's main, third process. This third process is dedicated to the live plotting of data and the storage of these plots on the computer's disk, providing a real-time visual representation of the mission's metrics. Through this structured approach, the program ensures efficient data management and command execution, enhancing the overall mission control experience.

2.4.4 Control of the Rover (PWM code):

The rover will be controlled, using the onboard Electronic Speed Controller and a Servo steering motor, by sending Pulse Width Modulation signals from the Feather M0. The signals differ with their lengths ($1000\ \mu s$ - $2000\ \mu s$) and accordingly control the speed of the rover. In our case, numbers 1-9 that will be transmitted to the Feather module will be assigned to different values from this pulse length range, consequently enabling control of the vehicle at different speeds, moving forwards and backwards, as well as left and right.

2.4.5 Debagging process:

In the debugging process for the CanSat, we employ a LED indicator for immediate status feedback. This LED displays green when the radio module, BMP280 sensor, and SD card are all functioning correctly. However, should any of these components malfunction, the LED switches to red as an alert.

Specifically for the BMP280 sensor, should it encounter operational issues or generate invalid data during the flight, we omit the erroneous pressure, temperature, and altitude readings from the plotted graphs. Nevertheless, this data continues to be received, ensuring no loss of information.

For error reporting, different strategies are applied based on the component. The Ground Station utilizes the Serial Monitor to log any encountered errors. Conversely, for the rover, we opt for an LCD display to showcase any issues, where, for example, an "ERROR 1" message indicates a malfunction in the radio module. This error data, along with any anomalies detected by gas sensors, especially if the LCD display fails, is recorded on the SD card. This redundancy ensures that critical data remains accessible for analysis, maintaining a comprehensive overview of system health.

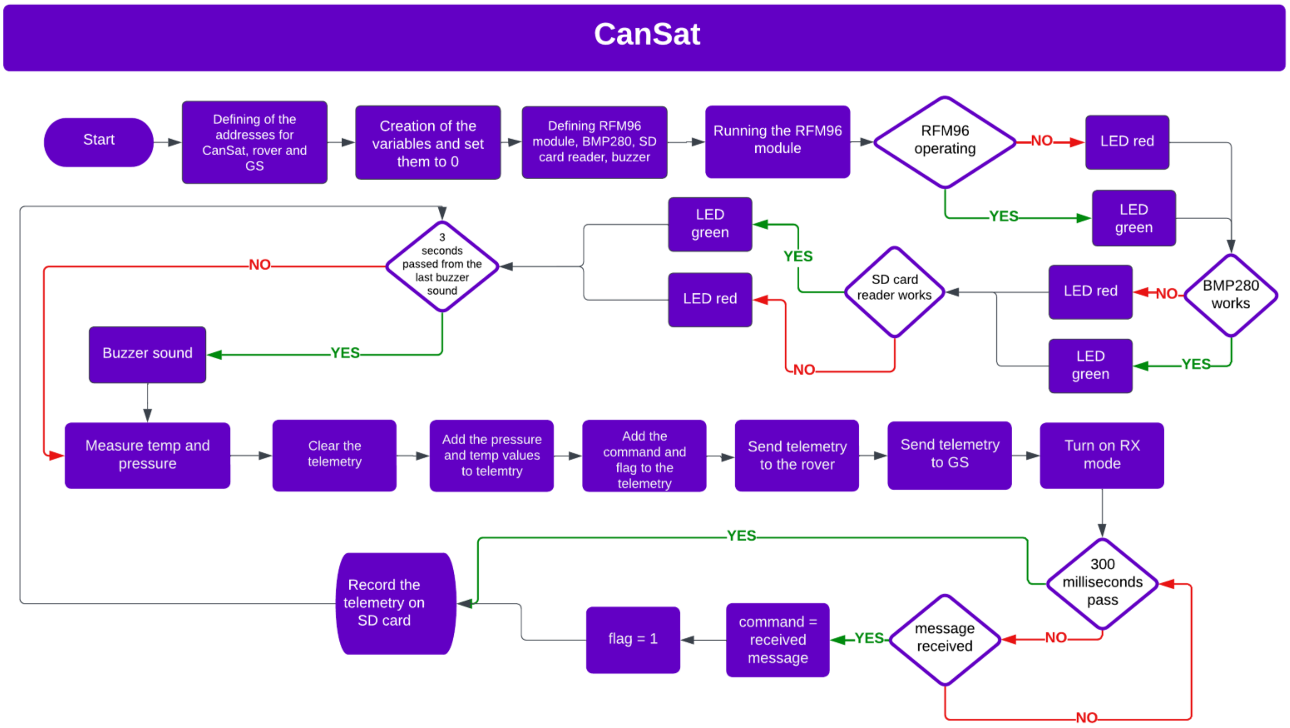
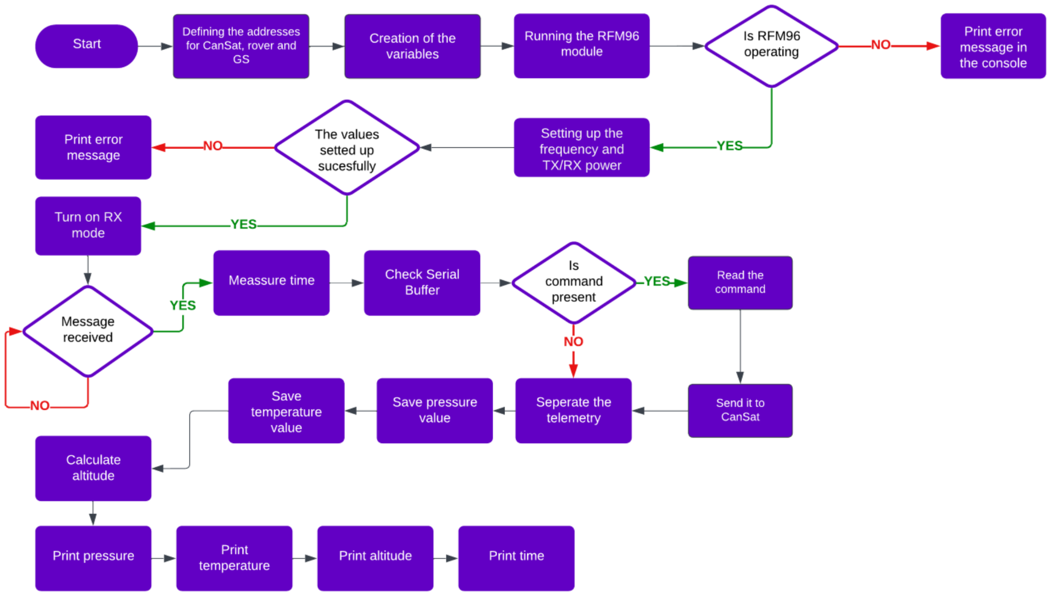
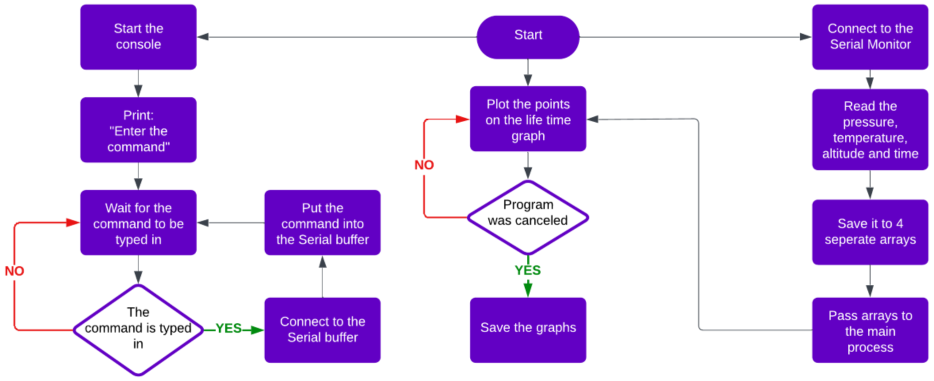


Figure 8 – Code Flowchart – CanSat

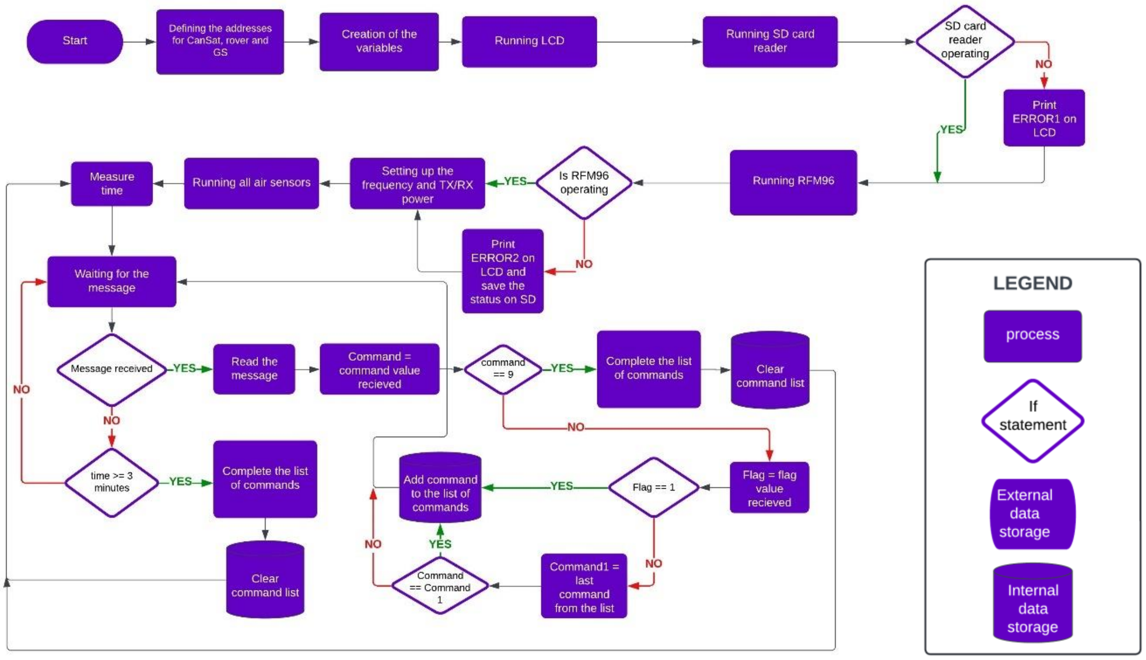
GS (Feather M0)



GS (Computer)



Rover



Figures 9, 10, 11 – Code Flowcharts for GS and Rover

2.5 Recovery System

Our specific mission does not require us to find the can to consider it successful, therefore we decided to limit the recovery system to just a parachute with a carefully calculated descent speed and buzzer. The parachute is bright red and the buzzer makes loud, higher frequency sounds, ensuring that the CanSat can be seen and heard from large distances. Furthermore, upon landing the can will constantly transmit a command from its Feather module as such that it could be found using a Yagi antenna. We will therefore be able to establish the direction that the can is transmitting the signal from, helping locate it after the fall. Although it was not tested yet, we assume that the method will work efficiently at the range of up to 200m, depending on the obstacles between the searchers and the CanSat.

On the other hand, the buzzer installed within the can operates at 85dB and it has been tested to emit sounds distinctly audible from over 100m, even in windy conditions. Additionally, because of the previously calculated descent speed and measured crosswinds on launch day, we would be able to rather accurately predict the Can Sat's landing location.

During tests, we found that the simple hexagonal (circular when flattened but hexagonal when attached using its three strings) parachute design helped minimize the effects of crosswinds and enhance stabilization. For our mission, it is critical that the CanSat does not fall too quickly and doesn’t have time to establish radio communication with the rover on the ground. However, it must also move fast enough to avoid being pushed out of range by any heavy crosswinds.

Suspension lines of the parachute must also be sufficiently long to allow the parachute to catch the greatest amount of air during descent. We are aiming to descend our CanSat at a speed of 8 m/s to meet the provided regulations while also ensuring the completion of our secondary mission.

To obtain the appropriate parachute size was calculated assuming the weight and a falling speed of 8 m/s (+/- 0.1m/s) using the formula:

$$s = (2 \times m \times g) \div (v^2 \times c \times d)$$

Where S – Parachute surface area, m – mass = $0.35kg$, g – gravitational acceleration = $9.81ms^{-2}$,
v – velocity = $8ms^{-1}$, c – aerodynamic resistance coefficient ≈ 0.78, d – air density = $1.2\ kgm^{-3}$

Consequently, the surface area of the parachute should measure approximately $1510cm^2$ ($1146cm^2$).

Currently we are using the Rocket-model Klima GmbH 55 cm, as it is light, and its strings are easily manageable and were tested to collectively withstand forces of up to 1000N. The parachute measured $2380cm^2$, far exceeding the requirements for our mission and providing a descent speed of 5.6m/s, as calculated with the equation above, and 6.25m/s average terminal velocity during the tests.

Figure 12 – Deployed Parachute

Therefore, we noticed that the equations offer only approximate values and do not account for many factors. Using them for establishing the appropriate size of the parachute hole would likely be unreliable. To counter this, we decided to cut out a circular hole in the centre of the parachute during real-life tests – the process described in section 3.3. Consequently, we arrived at the appropriate value of a cut-out with a 3.5cm radius.

We have also run early CFD simulations in Ansys Spaceclaim, which showed the terminal velocity to be at 7.6 m/s. However, again, we do not consider them to be very reliable as they do not account for any flexibility of the parachute or crosswind effects.

Nevertheless, we have successfully adjusted the parachute to the 8m/s. The advantage that we therefore obtain, is that our CanSat is less likely to drift away due to side winds. Consequently, we are more likely to stay within our horizontal antenna beam range, preventing potential problems in communication. Similarly, it will become easier to predict the final position of the CanSat upon falling to the ground, as it will become more resistant to horizontal motion.

On the other hand, the velocity is not significant enough to drastically reduce our time of radio link. As we expect for now, around 100 seconds of relay communication should be enough for a viable demonstration of our secondary mission being successful (the demonstration length can always be shortened, for example if on launch day the drone is used to raise the can to only 500m).

Consequently, the 8m/s seems to be the optimal terminal velocity for our mission.

2.6 **Ground Support Equipment**

2.6.1 Ground Station (PC)

The main ground station will play a crucial role in our primary and secondary mission. After the temperature and pressure is recorded by the BMP280 sensor on the CanSat, the data will be saved on the micro-SD card and sent to the ground station using the RFM96 LoRa module integrated in the Feather M0. On the ground station there will also be a Feather M0 module with an integrated RFM96 transceiver that will be connected using a 1.13mm, U.FL – N type cable to the 5 element, 28/50 Yagi antenna, that will receive the data for the primary mission. The ground station will also be responsible for sending the stored commands to the CanSat for our secondary mission.

Figure 13 – Ground Station Picture

2.6.2 Rover Station

The Rover, equipped with a 5800mAh battery, executes commands sent by CanSat. Based on the RC Traxxas Slash 4x4, it was adjusted to perform the required tasks for our mission. Firstly, it is equipped with a non-stock spring suspension, set to the stiffest possible setting to support the weight of all components. On top of it, sits a flat mount for the wooden Yagi antenna pole, mounted diagonally to allow for more stability. We further plan to improve the mounting system's stability by adding a 3D printed base, set to screw into the wooden base, holding it in place with a series of M5 screws. The angle of the antenna can also be modified thanks to the adjustable mount at the end of the pole (as shown in pictures), allowing us to find the optimal antenna setting, independently of where the organisers will provide the agreed space for the "rover station".
Aside from the 5800mAh battery for the rover's electric motor, another power source (1650mAh 5V battery) will be powering the Feather M0 with the 5 element Yagi set constantly to receiving mode, as we do not plan for it to transmit back to ground station. The module is also connected to the Electronic Speed Controller of the car in order to allow for PWM control of the throttle input, and possibly – steering input (more in section 2.4). As we plan to do it for now, the Feather will first receive all the commands and only then execute them – consequently the system will also be equipped with a micro-SD card connected to the Feather.

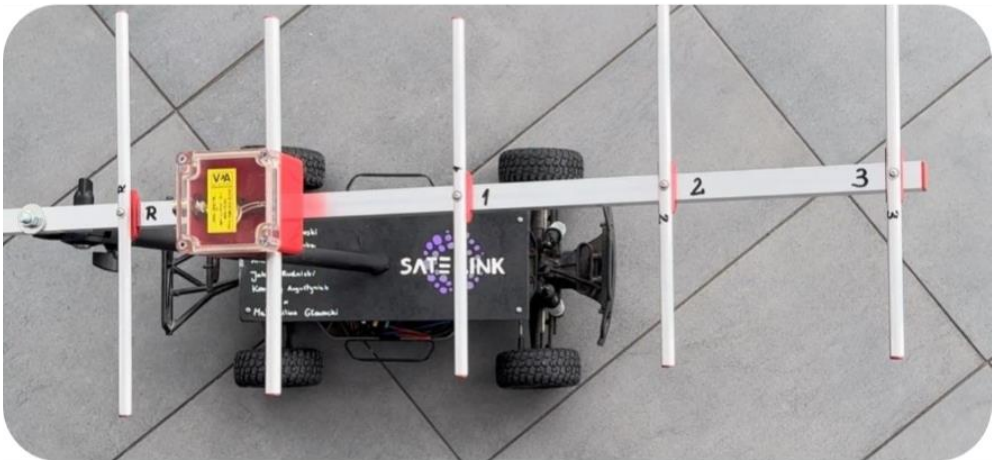


Figure 14 – Top View of our Rover

To enhance our secondary mission, we've decided to outfit our rover with a variety of gas sensors for air analysis. The collected data from these sensors will be stored on a micro-SD card within the rover and analysed after our mission concludes. The sensors are located below the black SATELINK platform and include:

- MQ135: Detects benzene and alcohol.
- MQ3: Sensitive to alcohol and ethanol.
- MQ4: Measures methane levels.
- MQ7: Identifies carbon monoxide presence.
- MQ8: Assesses hydrogen concentration.
- MQ9: Detects carbon monoxide and combustible gases.

The sensors are connected according to the schematic:

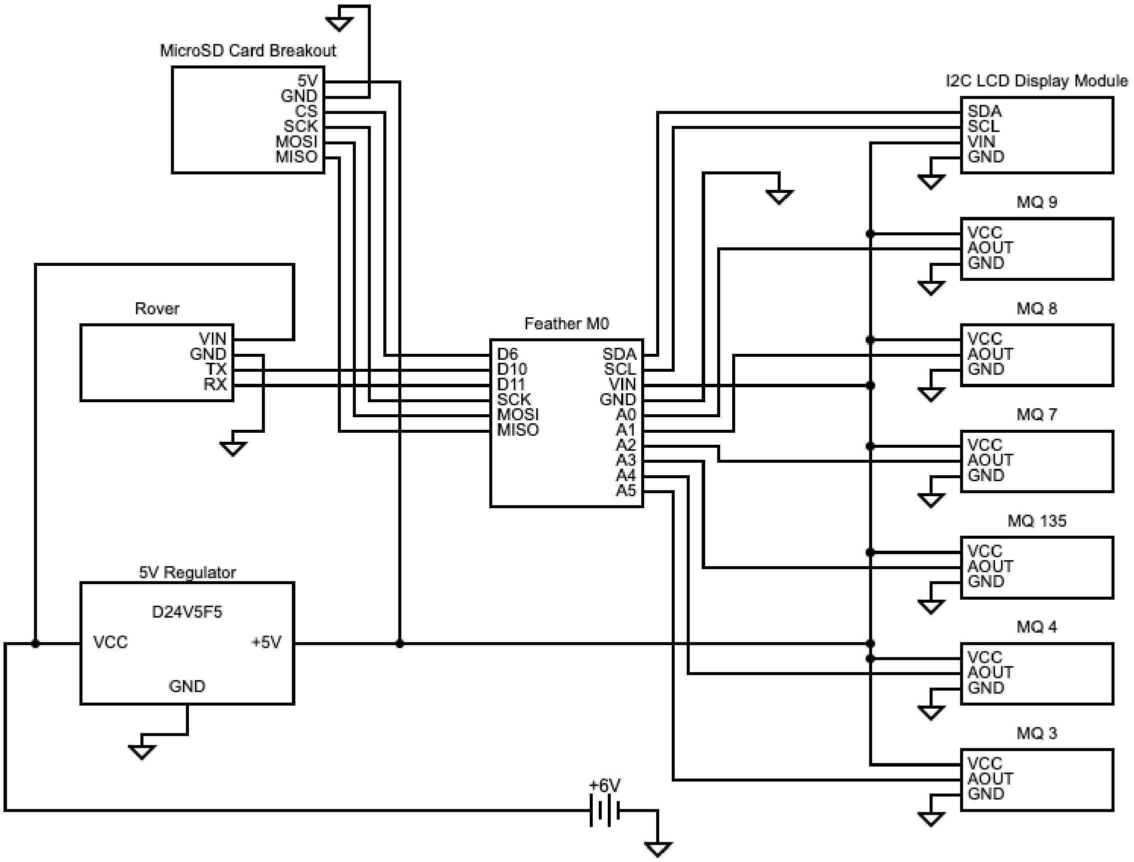
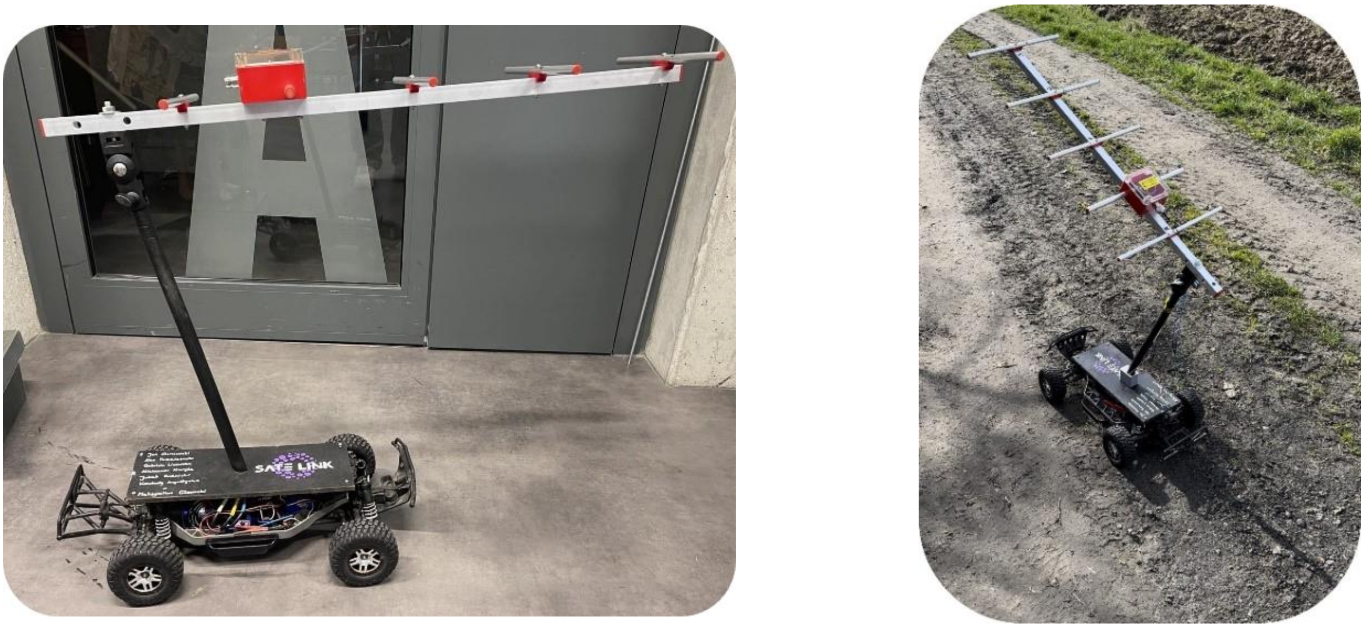


Figure 15 – Electric Circuit Diagram for Rover

In addition to storing data for later analysis, we're also incorporating an I2C LCD1602 display module on the rover. This module will show the live data readings during the mission, providing real-time insight into the environmental conditions. Each gas sensor will be connected to an analog input on the Adafruit Feather M0 module and powered by a 5V supply. This setup aims to blend thorough environmental analysis with straightforward, real-time data reporting, enhancing the mission's capability to gather and utilize environmental data effectively.



Figures 16, 17 – Rover Station in Building and on Launch Day

2.7 User Interface and Satellite Master Switch

As the regulations require, we are obliged to present to the organizers the access to the main power switch of the CanSat. In our case, the switch is located directly above the battery casing. It can easily be accessed and toggled through the hole in the external casing, using a thin metal rod, or toothpick (Figure 18).

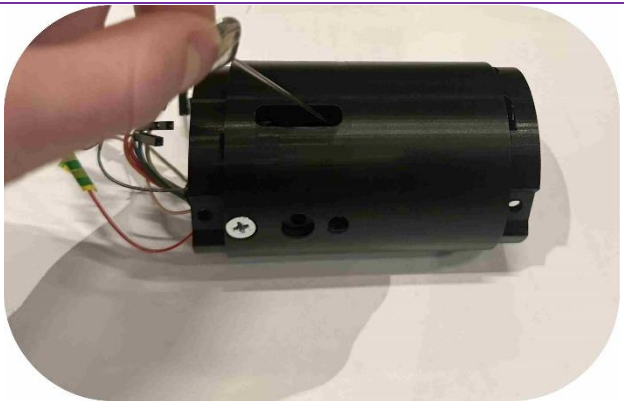


Figure 18 – master switch access photo

Simultaneously, we also want to showcase our current primary mission user interface, providing us with a live view on the auto-scale adjusted graphs of temperature-time, pressure-time, and altitude time-relationships. Using the data we are also able to calculate the Can's average velocity in the last 10 seconds:

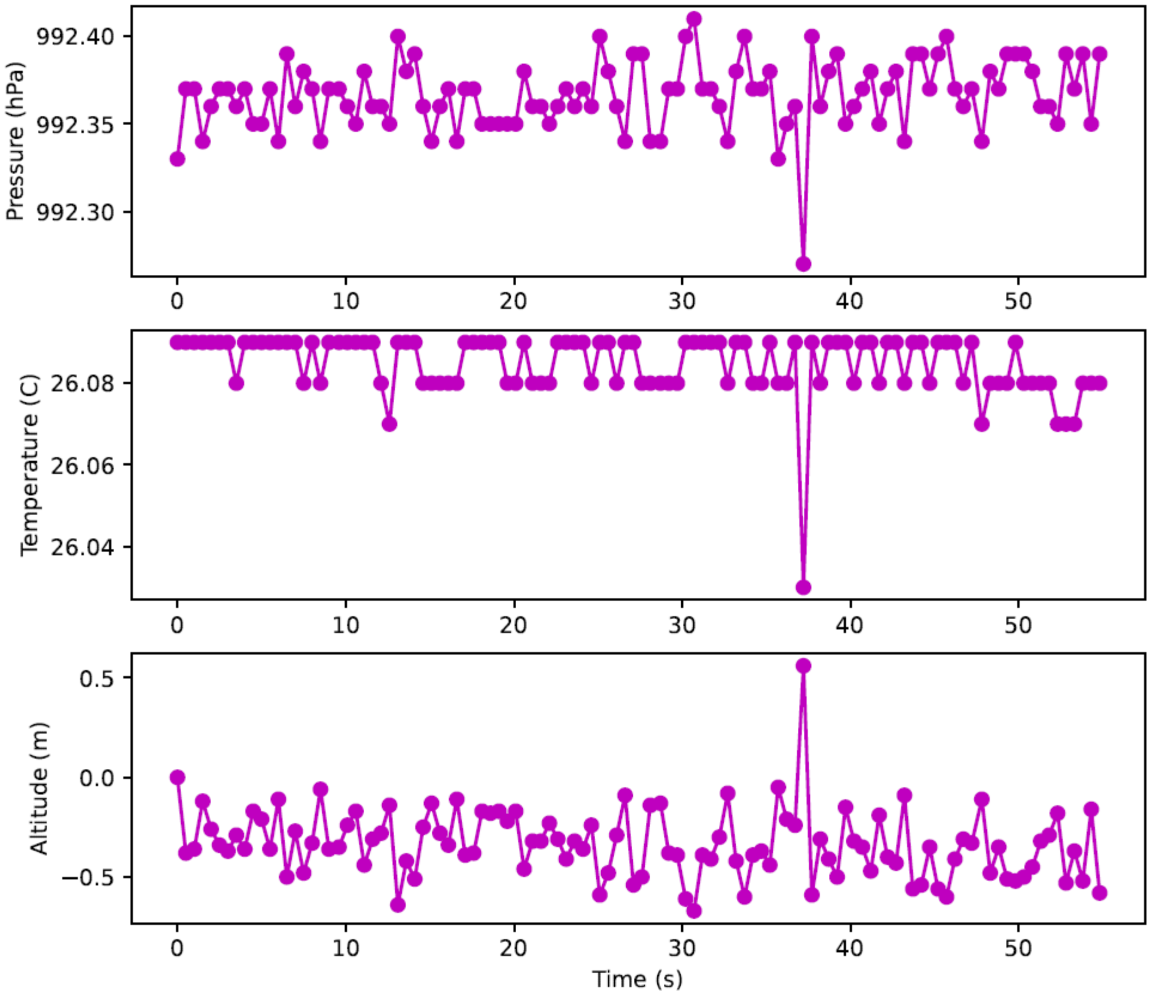


Figure 19 – Ground Station User Interface

3 TEST CAMPAIGN

Test no.	Requirement	Verification	Result
1	Use of hypsometric formula to find and plot altitude graphs	Connect a BMP 280 sensor to the Feather M0 and convert the temperature-pressure readings to altitude graph on a laptop.	Success
2	Descent from altitude at the regulatory terminal velocity of 8m/s	Conduct a drop test of the can from height to allow it to reach maximum velocity and measure it using the onboard BMP 280	Success
3	Use of radio frequency band that is permitted by CanSat regulations	Record the frequency band of the signal emitted from the antenna and ensure it is at 433MHz and no wider than 125kHz.	Success
4	Transmission of primary mission data back to ground station at least once per second	Check if Feather connected to a BMP280 can transmit the temperature and pressure data at least at 1Hz.	Success
5	Two-way communication with the ground station	Connect two Feather M0 modules and check whether they can send data one to another.	Success
6	Three-way, relay communication	Ensure that the connection of two Feather M0 modules, communicating through a relay is possible	Success
7	Communication at up to 7km distance	Use two Feather M0 modules – one with omnidirectional, one with Yagi antenna and test communication speed at 7km distance	Success
8	Batteries withstand at least 4 hours with the circuit running at maximum power usage	Conduct a power budget test where time on batteries is measured as all the components are connected and operating at expected power.	Success
9	None of the components overheat inside the CanSat	During the power budget test, record the maximum temperatures of the components to ensure that they will not overheat during the mission	Success
10	Ground impacts at up to 10m/s cause no permanent damage	Drop the CanSat from an altitude to allow it to reach terminal velocity. Then, record any damage when it lands on the ground.	Success
11	Vibrations at up to 20g and 1000 Hz cause no permanent damage	Giving the CanSat to a testing facility where it will undergo durability tests at different frequencies on a vibrating platform.	Success
12	Recovery of CanSat using antenna	Place the transmitting CanSat at a distance of a few hundred meters and check if a receiver antenna can pick up the direction of signal.	Success
13	Recovery of CanSat using the buzzer	Test the loudness of the buzzer at 10, 20, 50 and 100 meters away from the CanSat.	Success
14	Rover carries out the commands from microcontroller (including air sensor functioning)	Connect a Feather M0 module to the rover and transmit any command numbers 1-9 to it; then observe the behavior of the rover controlled by PWM signals.	Success
15	CanSat is able to complete both primary and secondary missions when operating on the ground	Prepare all of the components for the launch – GS, Can, Rover station on the ground. Then, start communication and record mission results.	Success
16	CanSat falling from altitude is able to meet all the primary and secondary mission goals we have set.	Bring the CanSat to the maximum legal altitude of 120m using a drone and drop it. Then record the result of primary and secondary missions.	Success

3.1 Primary Mission Tests

Test 1

This test works by checking if the altitude received from the hypsometric formula with the BMP 280 is reliable. We have conducted this test even before the Preliminary Design Review with the Arduino Uno R3, which operates in the same exact way as our new onboard microprocessor – the Feather M0. Consequently, we checked briefly if the code works with our new components and it turned out to be a success. This was later confirmed in the results of the recovery mechanism test (Test 2), where our BMP readings had a gradient of the altitude–time graph (so velocity) within the expected range compared to the real life, distance-time measurements. In the first round, with the stock parachute, we have achieved 0.3 m/s difference (6.1 m/s with the BMP and 6.4 m/s with our method). On the other hand, after the adjustments, the readings were even closer, differing only by 0.1m/s (BMP at 8.0 m/s and our method at 8.1 m/s)
As a result, we opted not to repeat the tests in the building and include below the results obtained with the previous attempt.

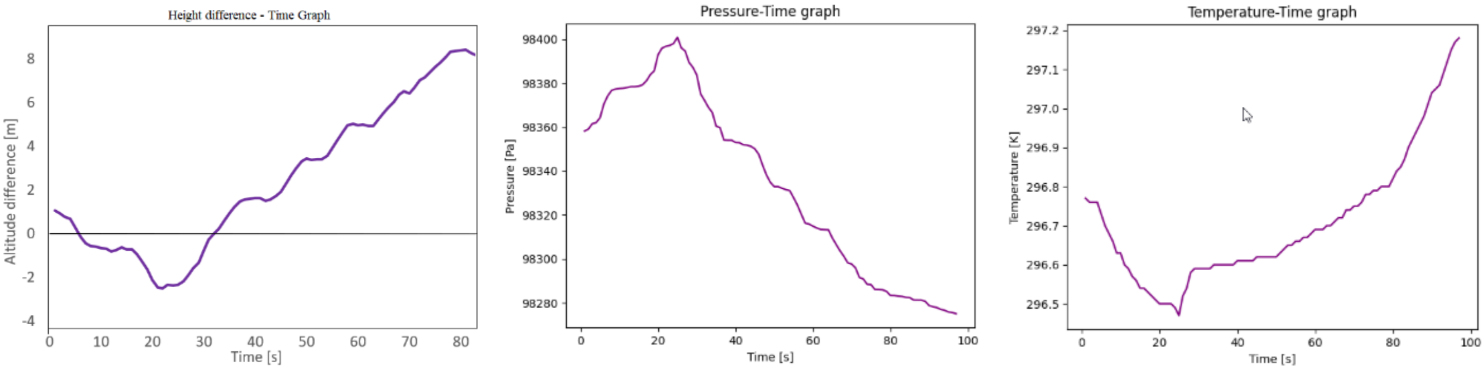


Figure 20 – BMP graphs (from left): Height-time, Pressure-time, Temperature-time

As a reminder, it is worth noting that the measurements were taken when walking down, then up a staircase of a 4-story building, beginning on the ground floor and stopping midway through each stint – hence the shape of the curves. Accordingly, we concluded the tests successful and expect no problems on the launch day.

Test 4

As mentioned above, we have conducted a test of the BMP 280 data transmission simultaneously with Test 2. Inside the can, there was a Feather M0 module, connected to the sensor like in Figure 15. Throughout the test, the temperature-pressure readings were transmitted from the Can at 4Hz, which exceeds the regulatory minimum of 1Hz. This was to ensure that the terminal velocity of the can is a more precise reading.

The data table below also represents the relative altitude readings from the BMP, every 0.25s for the whole duration of the flight.

Time	Relative Altitude Received
0.00s	13.50m
0.25s	13.22m
0.50s	12.31m
0.75s	10.87m
1.00s	9.34m
1.25s	7.83m
1.5s	6.30m
1.75s	4.77m
2.00s	3.26m
2.25s	1.73m
2.50s	0.21m

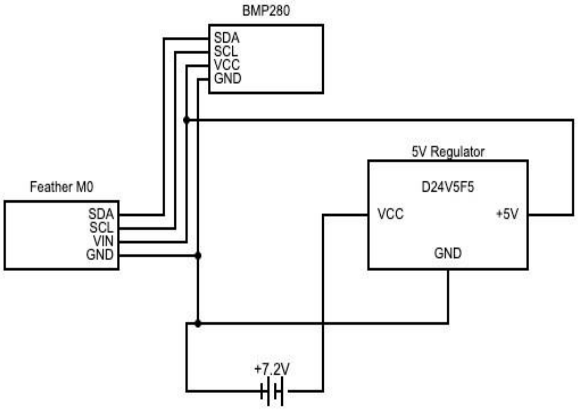


Figure 21 – Test 4 Circuit Diagram

3.2 Secondary Mission Tests

Test 14

As explained earlier in the document, our rover is controlled using the Pulse Width Modulation (PWM) signal. Consequently, in order to assess the reliability of our secondary mission, we decided to run the components in the same configuration as in section 2.6.2 (Figure 15) As expected, commands 1-7 caused the movement of the vehicle forwards and backwards, while steering left, right and straight accordingly. On the other hand, command 8 caused the sensors to collect a new data sample, saving results to the micro-SD and displaying them on the LED screen. Command 9 caused execution of all of the previously saved commands.

As expected the test was a success – the data samples collected by the gas sensors met our expectations (Figure 22). In turn, the rover also completed all of the driving commands with no issues – showcasing its ability to be controlled and drive in any given direction, while gathering the data samples.

Gas:	Alcohol	Benzene	Hexane	Methane	Toluene	NH_4	Acetone	CO	H_2	Flammable Gasses	CO_2
Concentration (Parts Per Million)	0	0	0	1.64	0.01	0.02	0.01	0.02	0.72	2.54	374

3.3 Recovery System Tests

Test 2

The CanSat, equipped with a parachute, was dropped from an altitude of 13.5m with the BMP 280 and Feather M0, transmitting onboard temperature-pressure data in order to predict the right adjustments for the recovery mechanism (parachute).

Initially, without any adjustments, the BMP indicated the terminal velocity of the can during the fall was 6.1 m/s. Using a high-quality video recorded from a distance leveraged against measured elements of the building, we established that the can descended at 6.4 m/s.

Since we observed that the calculations we made in Section 2.5 are only approximates and should not be considered reliable, we decided to establish the appropriate size of the central, circular hole with an experimental method.

Consequently, we have cut out bigger and bigger holes in the parachute, testing the terminal velocity along the way. We have tried out holes with radii of 1.5, 2, and 3cm before arriving at the final, 3.5cm radius cut-out.

The table below presents the average of the BMP velocity and our velocity readings for each of the attempted holes.

Hole diameter	BMP reading	Our reading	Average
0cm	6.1m/s	6.4m/s	6.25m/s
3cm	6.8m/s	7.0m/s	6.9m/s
4cm	7.3m/s	7.2m/s	7.25m/s
6cm	7.7m/s	7.7m/s	7.7m/s
7cm	8.0m/s	8.1m/s	8.05m/s

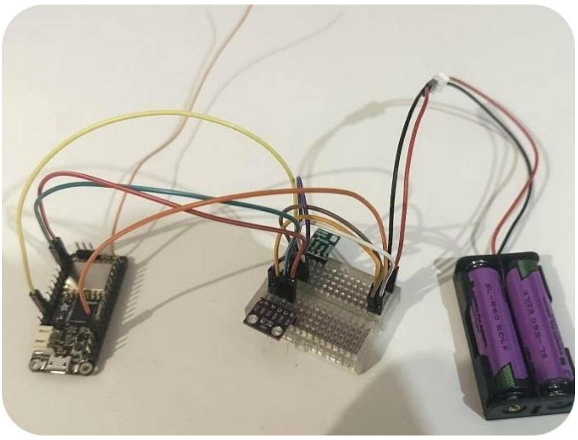


Figure 22 – BMP-Feather Test Circuit

Test 10

When thrown downwards onto grass from an altitude of 13.5m the can did not sustain any damage to its structural or mechanical components. We plan on recording what happens in a scenario where the components are also fitted inside.

Then, we would also be able to notice better how our CanSat will really be able to withstand the force of impact with the ground.

However, when dropped on concrete from the same height, the Bottom lid of the can cracked but remained intact with its four screws. Consequently, it proved that this section of the can should be strengthened either by making it thicker or by wrapping it in the carbon fibre we will soon receive from our sponsors.

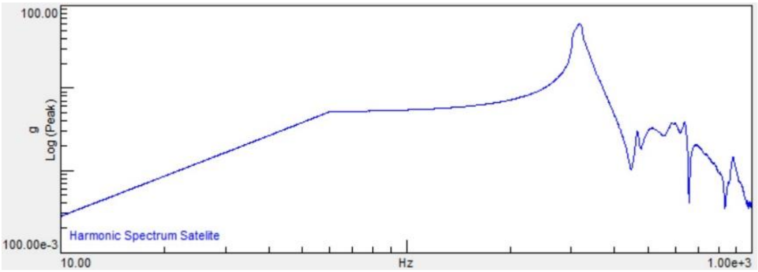
Figure 23 – CanSat with Parachute

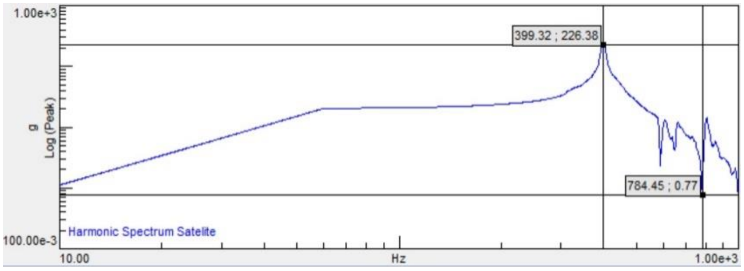
Test 11

On the 19th of March representatives of the Satelink team visited the Łukasiewicz institute of PIAP laboratory in Warsaw to conduct vibrational testing of the assembled CanSat to emulate conditions of rocket launch.

Prior to the testing, the institute provided the team with comprehensive diagrams and schematics of the “vibrations tables” which the probe will be attached to, based on which we were suggested to build an appropriate mounting mechanism. The system included metal brackets with appropriate holes that would screw into the CanSat and table, providing accurate measurements and minimizing the impact of the mounting system on the results of the testing. The specific CanSat featured throughout the testing was designed with two additional holes for screws and flatter walls to be more adjusted to the use of screws. However, according to the institute's suggestion, the mounting was accordingly tight, and the probe was additionally fastened with bolts, vibrating the structure as a whole and mitigating any additional vibrations from the mounting system. The procedure of the test included the fully assembled CanSat with operating electronics relaying telemetry data and radio signal, identical to the one that took part in the full mission test (also close to identical to the one that might participate in the launch campaign) to comprehensively simulate the potential launch of the satellite abroad the rocket provided by the organizers of the CanSat competition in Poland.

Figure 24 – CanSat on the vibration table





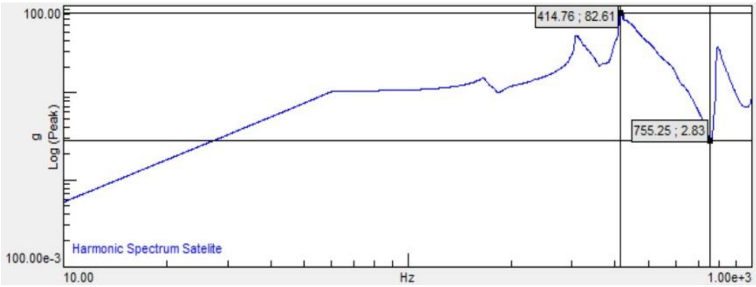


Figure 25 (top right) – X axis vibration results

Figure 26 (top left) – Y axis vibration results

Figure 27 (bottom left) – Z axis vibration results

The CanSat was fitted with provided accelerometers to find the CanSat's resonant frequency in each axis throughout which it was vibrations tested. The installed sensors indicated when the probe was overloaded, and beyond which point it became unclear whether the probe was able to safely withstand the given frequencies. More specifically, this occurs when the voltage of incoming signals from accelerometers onboard is higher than the voltage ranges of the data acquisition device can handle. Throughout the first sinusoidal testing in the x plane, the probe reached a peak frequency of 303.6hz and accelerated at 20g. However, it continued to tolerate up to 1000hz, before an overload was indicated by the accelerometers and the test was terminated. Moreover, throughout the same species of testing in the y plane, the probe reached resonance at 400hz and further withstood frequencies up to 1000hz with 20g acceleration, beyond which the test was also terminated. In the z plane where the CanSat was vibrated vertically, the maximum frequency reached during resonance was 755.25hz at 20g after which the probe further reached frequencies surpassing 1000hz; beyond this, the test was terminated.

Following the series of testing, the CanSat's mechanical structure was examined to determine any physical damage to any of the casings, which indicated no damage to any of the 3D printed components and negligible loosening of screws. Furthermore, the PCB and electronics continuously managed to relay telemetry and radio, deeming all of the electrical systems onboard to be fully operational throughout the entirety of the testing. Collectively, further indicating that the Satelink CanSat is beyond capable of withstanding flight level vibrations and impacts, allowing for it to be safely transported abroad the rocket provided by the organizers; given that it has been able to previously survive emulated conditions beyond the specifications provided.

Test 12

As said in the test section, even upon falling to the ground, the loop of the code inside the can will continue. Consequently, if a Yagi antenna is pointed in the direction of the can, lying on the ground, we should still be able to receive Telemetry 2 data, described in Section 2.4. In order to test that, we went to a field outside our school and placed the can laying flat on the ground, with the Feather M0 inside it transmitting at full power. Then, using the same setup as for the ground station, we pointed the Yagi towards the can and received signal for lengths of 10, 20, 50, 100 and 200 meters. Therefore, provided that our can falls on the ground in a flat area, we should have the possibility of finding it using the antenna. However, the likelihood of that remains low, and obstructions will probably stand in the way of the signal. Consequently, we are additionally preparing other recovery mechanism methods.

Figure 28 – Yagi Landing Direction Test Picture

Test 13

In order to help us recover our CanSat after it has been launched, we are obliged to use a buzzer. We are currently using an 82dB piezoelectric buzzer. We will most likely replace that buzzer with a different one, before submitting the FDR, so that it can be programmable and is not buzzing throughout the whole launch, and only after the CanSat is already on the ground. To test the effectiveness of the buzzer in recovering the CanSat we decided to power the flat-sat, with the buzzer and record the loudness from different distances. We used a phone application - decibelX that measures the loudness at different, audible frequencies in decibels and recorded it at distance intervals of 1, 10, 20, 50 and 100 meters from the can.

Figure 29 – Buzzer Loudness Values (from left) at 1m, 10m, 20m, 50m, and 100m from the Source, Frequency

As seen above, the buzzer can be heard even from farther distances, provided that there is no significant wind / background noise. The emitted waves were also measured to be roughly 4000Hz, which is an easy to hear, high pitch noise.

3.4 Communication System Tests

Test 3

As we know, precise spectrum analysers are outside of our budget range and cannot be used for our test. However, this experiment can be successfully conducted thanks to our software. The RFM 96 radio library contains a function for setting the bandwidth of our signal. In our case, CanSat allows for 125kHz of width. Simultaneously, in order to meet the general frequency requirement, the library also contains a frequency set function, with possible values ranging from 433 to 470 MHz. In our case, we have left it at an equal 433MHz, but the value can be modified at any instant. Therefore, we are sure that on launch day, we will pass the test of a spectrum analyser.

Test 5

In this test, we have successfully reached the goal of obtaining a two-way communication between two Feather M0 modules. Upon connecting them to two separate laptops, we were able to efficiently transfer exactly 17 bytes in the form of numerical values from Feather 1 to Feather 2, and back, within a 1 second interval (34 bytes per second). Therefore, we showed the capability of sending at least 272 bites per second between the modules. Consequently, we have managed to prove that establishing the connection is a seamless process, provided that the two modules can synchronise easily. In our case, the required synchronisation was very basic and it is understandable, that in long-range communication it may not be as trivial.

Test 6

In order to conduct the test, we have connected three Feather modules to two laptops and a PC (Figure 30). The communication relied on module one transmitting “1” values and receiving “2” values back in a communication with another Feather. The “2” values were simultaneously received by a third, independent module. Consequently, the secondary mission communication type, based on the satellite relaying commands by sending universal, telemetry values to both on-ground stations was successful.

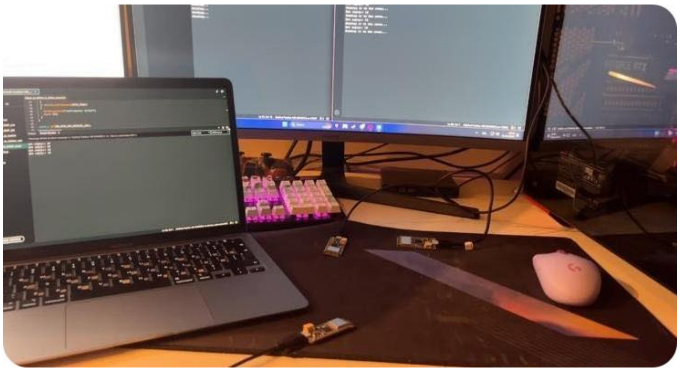


Figure 30 – Relay, Three-way Communication Picture

Test 7

To conduct the communication range test, three of the team members – Alan, Aleks, and Jan travelled outside of Warsaw. It was of crucial importance for us to simulate exactly what may happen throughout the launch day, meaning that at least 4km of flat land with no obstructions was required. Consequently, we stood in the positions as according to Figure 31. One side of the communication consisted of our CanSat’s Feather M0 with the wire antenna, while the other was equipped with a laptop, a Feather M0 and a hand-held Yagi – just like in the can – ground station communication. The test was successful. Over this large distance (4.05km), we have successfully managed to receive the telemetry from the CanSat at the GS. The can also received commands back from the Yagi – which proved for the link to work in both directions, as predicted on launch day.

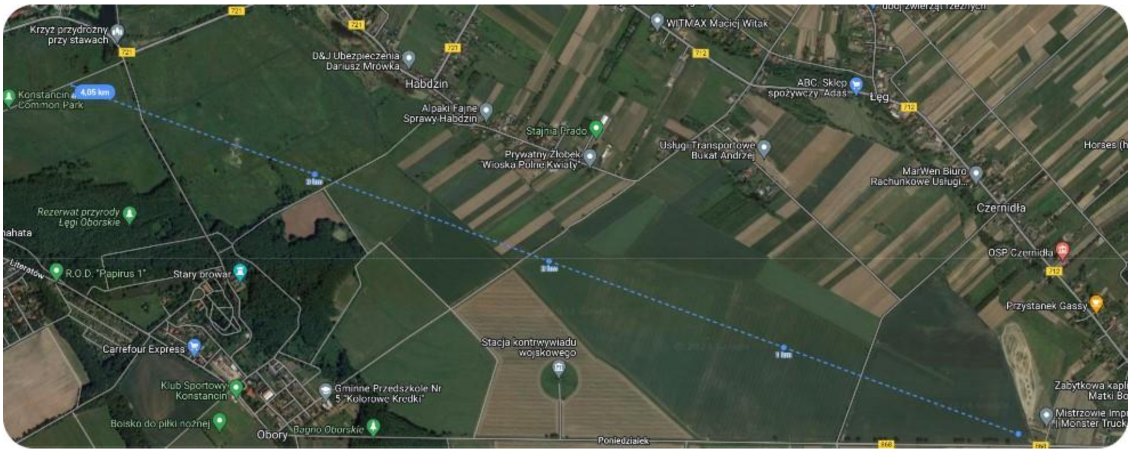


Figure 31 – Communication Range test – Satellite View of Terrain + Distance (4.05km)

3.5 Electric Circuit Tests

Test 8

As described in the power supply section, to power our CanSat we use 2 x 3.6V batteries, with a capacity of 1800mAh, connected in series to step up the voltage for our components. From our calculations we estimated the battery life to be approximately 7.03h, with the components operating at their maximum power usage. To not only rely on estimated calculations of the power budget we decided to carry out an energy budget test and verify whether the circuit will still work after 4h as required by the CanSat regulations. Firstly, we soldered all the components and assembled the flat-sat. We then programmed the Feather M0 and made sure that it constantly transmitting the pressure and temperature readings from the BMP280 to another Feather M0 module that would represent the ground station. We left the flat-sat operating at maximum power usage for exactly 4.5 hours and it was able to constantly transmit the readings to another Feather, without any disturbance. We can therefore be sure that the fully charged batteries will be able to power our electrical components for at least the duration of the competition.

Moreover, we used the same (uncharged) batteries to later carry out our long-range communications test and they were able to power all the CanSat components for another 2h approx. Due to the constant signal transmission, it is appropriate to assume that the power usage was close to the maximum we will obtain in our mission.

All in all, we can therefore safely assume that the power consumption will not be a significant issue on launch day.

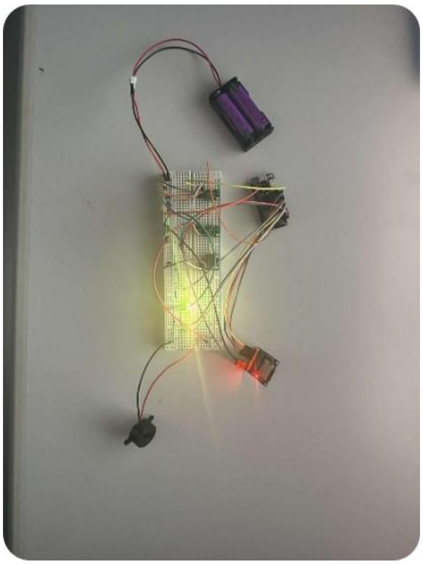


Figure 32 – Power Budget test Picture

Test 9

During the energy budget test, we also decided to carry out a heating test, as we were worried that using two voltage regulators in our circuit could result in having significant heating. After measuring the temperature of both the regulators and the Feather M0 at 15min intervals throughout the 4h of our energy budget test, we have not recorded any significant heating. Initially the temperature recorded was 21.9ºC, and the highest temperature recorded throughout the test was 28.9ºC. When we physically checked if there is any heating by simply touching the operating components, we also did not feel any warmth whatsoever. Therefore we predict that the heating effect is not significant

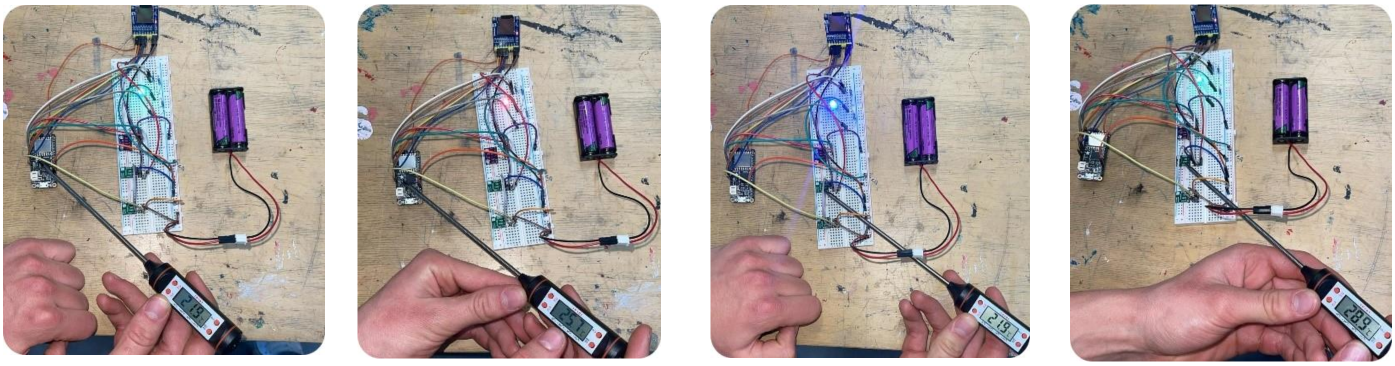


Figure 33 – Temperature Values (from left) of Feather M0 and Voltage Converters Before and During Test

3.6 Full Mission Tests

Test 15

The goal of the test was to ensure that the key features of our CanSat were working before the aerial launch. However, the documentation for this test is much less precise than the full mission test.

At first, we have assembled the Ground Station and Rover Station, pointing both of the antennas towards the chair, where the can was located. Then, we assembled the CanSat along with all the components and checked if we are able to receive BMP data and relay rover commands.

Figure 34 – Test Ground Station Picture

Figure 35 – Rover Station and CanSat Test Stations

We were able to successfully receive commands from the BMP. Additionally, we have managed to send and execute 1-7 commands on the rover, showcasing the vehicle's ability to drive in any given direction. This was a positive sign for us to continue with the drone test.

Test 16

Overview:

The full mission test was conducted in Habdzin, by the Konstancin Airport. There, with the help of Michał Surma from Filmforce, we have managed to attach the parachute our can to the Inspire 3 drone, flying it to the maximum legal limit of 120 meters above ground, followed by a drop of the satellite.

Test plan:

In order to have a clear idea of how to conduct the test, while determining if the mission is successful, we followed a flowchart:

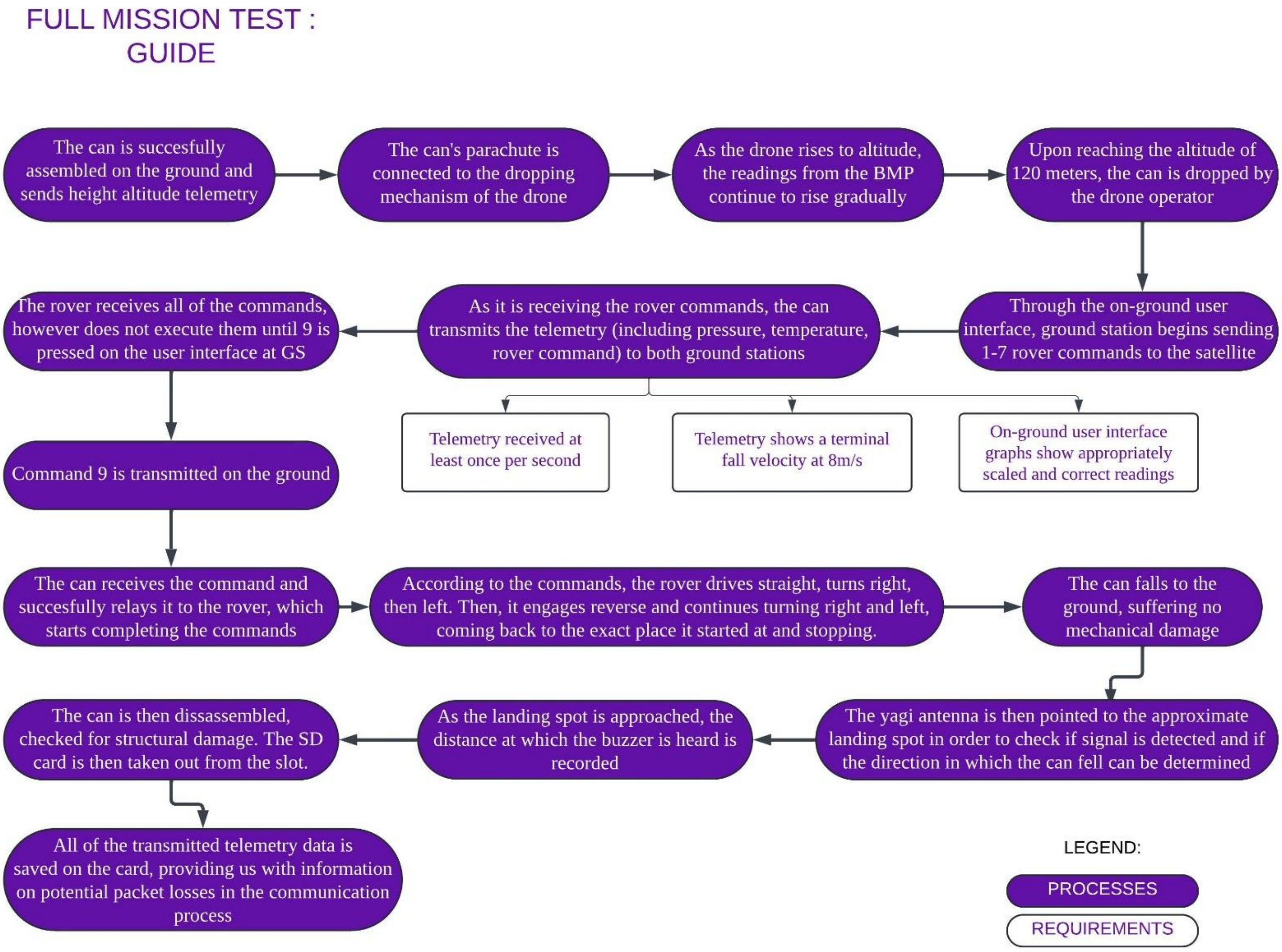


Figure 36 – Full Mission Test – Guide Flowchart

Primary mission requirements – SUCCESS

Throughout the missions, the BMP 280 temperature-pressure readings were successfully gathered by the Feather, and transmitted as part of telemetry back to the ground, where it was de-coded and graphed in the user interface.

The precision of the readings was also confirmed by the altitude readings collected on the drone. When the drone was hovering 120 meters above the ground, the BMP readings showed approximately 119.7 meters of relative altitude.

What's more, the falling terminal velocity of the can calculated after the test (7.98m/s) was concordant with the previous expectations (8m/s) and the terminal velocity calculated from the videos of the launch (7.92m/s).

The communication speed allowed for intervals of approximately 780ms between each of received signals, fulfilling the requirement of communication at least once per second. We have also not suffered any packet loss, with the telemetry being received at equal intervals, with no points missing on the graphs throughout the test.

Figure 37 – Full Mission Test – Drone with Can

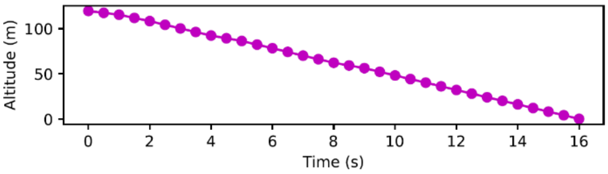


Figure 38 – Full Mission Test – Altitude Data

Additionally, upon disassembling the CanSat and removing the SD card from the reader, we have observed that all of the primary mission data was saved successfully.

Secondary mission requirements - SUCCESS

The key in determining the mission a success was seeing the rover move according to the relayed commands. Following the pre-determined procedure, we expected the rover station to receive all the commands 1-7 and execute them only after command 9 is relayed. This would cause an according motion forward and backwards, while turning left, right and straight. This was a success, as the rover moved accordingly.

An additional advantage confirmed throughout the test was the ability to fully control the motion of the rover. In the previous stages we were unsure if predicting the rover's exact position after a certain number of commands is possible. However, as proved, the mobility of the vehicle and the character of its motion are repeatable, allowing for more precise manoeuvres with the vehicle.

Figure 39 – Full Mission Test – Rover Station

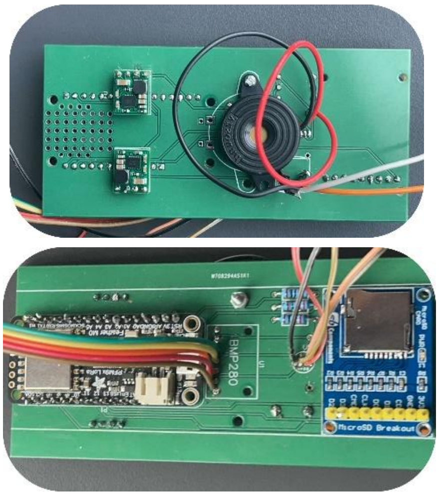


Figure 40 – Full Mission Test – PCB

Mechanical requirements – SUCCESS

First of all, the can's external casing crucially survived impact with the ground, as expected following the vibration testing. However, due to a incorrect attachment of parachute to the drone in the initial part of the test, the can required to disassembly and reconstruction, as the LED diode inside became loose. The top lid allowed for little to no movement of the diode, however it lacked a proper mounting mechanism holding the diode in place. However, after applying a layer of glue around the diode, we were able to survive another drop from the drone with no mechanical faults.

Crucially, none of the components / solders were damaged, as the PCB remained intact upon impact. Although it is not required by the regulations, we remain sure that upon better preparations on launch day, our satellite will not experience any mechanical defects.

Other requirements - SUCCESS

While conducting the full mission tests, further inspections of the recovery mechanisms and solutions were conducted.

First of all, anticipation of the direction that the can fell towards using the Yagi antenna has proved successful. The solution turned out to be helpful at longer distances, where the buzzer could not be heard (50+ meters). One minor flaw regarding this method is that due to the specification of our mission, and a wide area covered by the beam of the antenna (45+ degrees), the estimated location is not very precise. Instead, it offers a more general information in which area the satellite is located. On the other hand, due to heavier winds on test day, the buzzer turned out to be less efficient than expected – providing sound coverage only about 20 meters upwind from the can.

Secondly, an important conclusion was made regarding the necessary commodities for the rover – before the launch we should ensure that the rover is situated near a relatively flat ground surface. That is because of the high risks of the rover tipping over / becoming damaged when driving over uneven surfaces.

4 PROJECT PLANNING

4.1 Task list / Time Schedule

Task	Due Date / Status
Gathering the team and assigning roles	11.09.2023 (Done)
Establishing the Secondary Mission	11.09.2023 (Done)
Creating an Instagram Page	13.09.2023 (Done)
Preliminary list of components	13.09.2023 (Done)
Researching appropriate sponsors	13.09.2023 (Done)
Write the code for the BMP280	14.09.2023 (Done)
Write the code for the NRF905 radio module	16.09.2023 (Done)
Testing the code for BMP280	20.09.2023 (Done)
Testing the code for NRF905 communication	23.09.2023 (Done)
Changing from NRF905 to LoRa SX1278 (To not violate the regulations of the competition)	25.09.2023 (Done)
Write the code for LoRa-LoRa communication	30.09.2023 (Done)
First Draft of 3D-design on Fusion 360	30.09.2023 (Done)
Prusa MK4 print settings and material assessment	30.09.2023 (Done)
Write code for LoRa-LoRa-LoRa communication	02.10.2023 (Done)
Print of casings on MK4	03.10.2023 (Done)
Final list of components (For primary and secondary mission)	07.10.2023 (Done)
Parachute calculations and testing with internal casing	07.10.2023 (Done)
Beginning to create the website	07.10.2023 (Done)
Contacting potential sponsors	07.10.2023 (Done)
Beginning to edit the PDR	08.10.2023 (Done)
Finish the electric circuit schematic drawing	10.10.2023 (Done)
Meeting with Mr. Czapski regarding Antennas and radio communication	13.10.2023 (Done)
Deciding on the Antennas for our mission	13.10.2023 (Done)
Soldering the BMP280 and LoRa SX1278 for tests	14.10.2023 (Done)
Secondary Mission test (Successful)	14.10.2023 (Done)
Preliminary design with PCB mount and battery casings	20.10.2023 (Done)
Mass growth allowance calculations	20.10.2023 (Done)
Importing electronics into design on Fusion 360	20.10.2023 (Done)
Primary Mission Test (Obtaining the altitude graph from the BMP280)	21.10.2023 (Done)
Submit the PDR	**23.10.2023** (Done)

Switch to Feather M0	30.10.2023 (Done)
Ordering all the new components (including Yagi antenna)	06.11.2023 (Done)
Sponsorship contract with TeXtreme	25.11.2023 (Done)
Remodelling of internal and external casings	01.12.2023 (Done)
Beginning to edit the CDR file	05.12.2023 (Done)
Testing the code for two-way communication of the RFM96 modules	10.12.2023 (Done)
Testing the code for the BMP280 with the Feather M0	12.12.2023 (Done)
Creating an updated circuit diagram with new components	14.12.2023 (Done)
Designing the rover antenna mount	14.12.2023 (Done)
Finalising and securing the sponsorship contract with TeXtreme	15.12.2023 (Done)
PCB rail and Bottom/Top lid modelling	17.12.2023 (Done)
Bottom lid adjustments for power switch holes	18.12.2023 (Done)
Reaching out to Royal Subway for sponsorship	22.12.2023 (Done)
Testing the code for three-way communication of the Feather M0 modules	27.12.2023 (Done)
Finalising and securing sponsorship from Royal Subway	27.12.2023 (Done)
Soldering components (without PCB)	27.12.2023 (Done)
Reaching out to WeNet for sponsorship	28.12.2023 (Done)
Visiting school in Puławy to arrange a presentation of our project for the students	28.12.2023 (Done)
Extrusion of PCB rails and component casings	30.12.2023 (Done)
Writing and testing the rover code	30.12.2023 (Done)
Planning a podcast with Innovation Hub representatives	02.01.2024 (Done)
Reaching out to Booksy for sponsorship	03.01.2024 (Done)
Adjusting the rover for mission characteristics	04.01.2024 (Done)
Building the Flat sat	05.01.2024 (Done)
Energy budget and heating tests	05.01.2024 (Done)
Reaching out to science influencers for partnership	10.01.2024 (Done)
Modelling of main casing and screw threads	13.01.2024 (Done)
Reaching out to WebWave for sponsorship	15.01.2024 (Done)
Updating the power budget with new components	21.01.2024 (Done)
Slicing and print of all components	25.01.2024 (Done)
Recording the podcast with Innovation Hub	26.01.2024 (Done)
Print finish / sanding and removal of support components (Final CanSat casing ready)	27.01.2024 (Done)
Testing the parachute and durability of the CanSat casing with appropriate weight	27.01.2024 (Done)
Communication range test	27.01.2024 (Done)
Recovery system test (Buzzer)	27.01.2024 (Done)
Final Rover testing	31.01.2024 (Done)
Publishing the podcast and article	05.02.2024 (Done)
Submit the CDR	**06.02.2024** (Done)
PCB railing durability test	09.02.2024 (Done)
Finalizing the design of the Custom PCB and ordering it on PCBWay	12.02.2024 (Done)
Finalizing the sponsorship from Booksy	13.02.2024 (Done)
Creating the new code for 2-way communication and telemetry formula	13.02.2024 (Done)
Reaching out to Michael/Ström for sponsorship	15.02.2024 (Done)

Internal casing CAD design changes to optimise durability	18.02.2024 (Done)
Finalizing the sponsorship from WeNet	20.02.2024 (Done)
Writing the code for ground station live graph plotting interface	25.02.2024 (Done)
Slicing and 3D Print of first FDR draft	27.02.2024 (Done)
Presenting about CanSat in our School	27.02.2024 (Done)
Finalizing Michael/Ström sponsorship	28.02.2024 (Done)
CAD design of Yagi antenna rover mount	01.03.2024 (Done)
Writing the code for gas sensors with LCD on the rover	04.03.2024 (Done)
Soldering the Gas Sensors	06.03.2024 (Done)
Testing the code for gas sensors on the rover	06.03.2024 (Done)
Meeting with Tomasz Zajkowski	06.03.2024 (Done)
Receiving the ordered PCB and soldering all the components onto it	06.03.2024 (Done)
CAD Top lid design changes to adjust changes of BMP module and alternative parachute mounting method	07.03.2024 (Done)
Slicing and 3D print of the second FDR draft	08.03.2024 (Done)
Writing and testing a new code for the SD card reader	07.03.2024 (Done)
Finalizing the sponsorship from WebWave	09.03.2024 (Done)
CAD design modifications to Internal/External casing for PIAP vibrations testing mounting	10.03.2024 (Done)
Recording Satelink CanSat Promotional Video	10.03.2024 (Done)
Completion of the final code for CanSat, Rover and Ground Station	11.03.2024 (Done)
Presenting about CanSat on the school Science Fair	12.03.2024 (Done)
Full Mission Test on ground	13.03.2024 (Done)
Full Mission Test using a drone	15.03.2024 (Done)
Meeting with Iceye	18.03.2024 (Done)
Vibration tests	19.03.2024 (Done)
Ordering custom Satelink Hoodies	20.03.2024 (Done)
Posting our promotional video on our YouTube page	21.03.2024 (Done)
Interpretation and analysis of data from PIAP vibrations testing	22.03.2024 (Done)
Finalizing Iceye Partnership	23.03.2024 (Done)
Submit FDR	**25.03.2024** (Done)
Launching the Satellite	**April 2024** (To do)

4.2 Resource estimation

4.2.1 Budget

The price budget includes the prices of all the components that are used to create the can and carry out all the missions. According to the regulations of the competition the price budget of the can (only), cannot exceed €500 (2171,58 PLN; Euro to PLN as of 24.03), which means that we do not really need to worry about exceeding the cost regulation since the total cost of building our CanSat is 1030,52 PLN (€ 237,27 as of 24.03).

It is also worth noting that the price budget table (on the left) includes only the price of the components onboard the can, which must not exceed €500. The other price budget table (on the right) includes other costs, such as the price of the Yagi antennas used at both the ground station and the rover station for communication with the CanSat. As the organisers agreed, the vehicle will serve as a second ground station, and despite serving a crucial role in our secondary mission, will not contribute officially to the budget for the can.

Components:	*Price (PLN):*
Feather M0 + RFM96 LoRa	209,00 PLN
BMP280 Adafruit	59,90 PLN
AA Batteries 1800mAh 3.6V	258,00 PLN
Battery Case (2 x AA)	3,50 PLN
MicroSD Card Breakout Adafruit	64,30 PLN
16GB MicroSD Card	16,75 PLN
3.3V Regulator D24V5F3	29,90 PLN
5V Regulator D24V5F5	29,50 PLN
82dB Piezoelectric Buzzer	4,30 PLN
RGB LED Anode	0,88 PLN
Resistors (220 Ω)	3,49 PLN
Cables	15,00 PLN
Custom PCB Board	130,00 PLN
Screws	15,00 PLN
Printing Filament	25,00 PLN
Parachute	100,00 PLN
Carbon Wrapping	100,00 PLN
TOTAL:	***1030,52 PLN***
TOTAL (EURO):	***€ 237,27***

Components:	*Price (PLN):*
Yagi Antenna (x2)	506, 37 PLN
Purchasing Domain	220,20 PLN
Feather M0 modules (x4)	836,00 PLN
Rover	430,00 PLN
Batteries for Rover	405,00 PLN
Sensors for Rover	350,00 PLN
I2C LCD Display Module	60,00 PLN
Drone renting	2214,00 PLN
TOTAL:	***5021,57***
TOTAL (EURO):	***1156,18***

4.2.2 External Support

We have deeply researched every single one of our sponsors, to make sure that they will be both willing to help, and helpful in the work itself. From the very beginning of the project, we knew that for our goals to be fulfilled, we will need external funds to cover our expenses. Our goal was to secure approximately 10,000 PLN to comprehensively cover all our up-to-date and potential future expenses. As of now, we have already outperformed the initial expectations, raising over 11,000 PLN in total.

SPONSORS:

Galeria Wypieków Lubaszka is a local business, which has 55 locations across all of Poland. It is owned by an enthusiast of aerospace engineering. This allowed us to create an agreement, where the company kindly agreed to collaborate and sponsor our project.

- Our first contact was on the 14th of October 2023. We initially asked for covering our first order, however, they kindly agreed to cover an amount of 1000 PLN. We reached the agreement relatively quickly, as it only took 10 days to finalise.
- In return, we added the logo of the company to the 'sponsor' section on our website, as they were the first official sponsor that we managed to secure.
- The CEO was keen to cooperate as he is driven by a profound, he also agreed to represent us throughout the entirety of the competition.

TeXtreme is an international firm, based in Sweden, that produces carbon fibre material for aviation, industrial and sport's needs.

- We initially contacted the company on the 25th of November 2023, asking for financial support or professional assistance in building our can. In return, they came back with a counteroffer to send us 10 square metres of raw carbon fibre, if we agreed to present their logo on our website as well as on our products
- The contract was signed by our team leader and finalised on the 2nd of December. The website was then updated with the company logo.
- We received a roll of 10 square meters of industrial grade carbon fiber on the 6th of February.

Royal Subway is a branch of subway franchises that is owned by a Polish entrepreneur. They own a few locations in Warsaw, including the first subway opened on the Chopin airport.

- Our first contact with the company was by email on the 22nd of December. Due to the nature of the company, we asked whether it would be possible for them to support us by catering our meetings, and in turn we'd add their logo to our website.
- The owner was keen to work with us, as he has never worked with such a project. He also helped us to pick which logo we should use to represent them on our website.
- The amazing work of the Royal Subway staff severely improves the comfort and quality of our work during our long meeting during the weekends, which tend to last over 4 hours.

WeNet is a Polish company that works in the field of e-commerce. They have built over 30,000 websites, across over 900 fields of expertise. They have over 50,000 clients across Poland.

- We contacted the company through email, after researching the structure and the expertise of the company.
- The CEO offered to finance around 3000 PLN of our project needs, and received the funds on the 20th of February.

Booksy is a cloud-based appointment booking solution for both small and large companies. It offers appointment schedules, calendar management, online payments and marketing management through their website.

- We contacted the marketing department of the company by email, and finalised the deal on the 13th of February.
- Booksy has covered 3000 PLN of costs for our project, as our contract was signed and finalised.
- The money went primarily into financing the full mission drone test and aiding the team's budget for future expenses.

WebWave is a Polish e-commerce company that specialises in development of web pages by using AI based technologies.

- After a brief conversation with the marketing department of the company, we came to an agreement that WebWave was willing to support us financially, as well as reviewing and giving us advice on how to improve our website.
- As a part of the sponsorship deal, our CanSat team received 3000 PLN.

Michael/Ström is a Polish brokerage firm which specialises in bond trading and bond emissions. They have conducted more than 4,7 billion PLN in bond trades, and have over 3600 open accounts.

- We contacted the company on the 15th of February, asking for financial support.
- The contract was finalised on the 28th of February, and we received 1000 PLN from the company.

PARTNERS:

Iceye is an international microsatellite company, it is based in Southern California. The company specializes in SAR (Synthetic Aperture Data).

- As a part of our partnership, we have met with the companies' engineers as well as the sales director, on the 18th of March.
- We got support on our FDR, as well as the team answered questions about some technical issues we had.
- We got to see how the sector of aerospace engineering works both in Poland and Worldwide.
- During our meeting with Iceye, we learned a lot about how the aerospace engineering sector works. This allowed us to expand our knowledge in the field, and gave us new perspectives on our project as we realized every large company began form a similar position to us. Even though it might not seem like significant knowledge to be learned, it really can help when it comes to motivation on working on the project.
- We believe that this could help in the success of our project as we delve deeper into how the aerospace engineering sector works. We would also like to thank the team for showing us how their own lab works, and on what specifications and components they work as a multimillion-dollar company. We have also signed contracts with the company that allow us to use the company logo as our partner.

Łukasiewicz PIAP Institute is a branch of technological facilities made for research purposes.

- We contacted the institute by email asking whether we could conduct our vibration tests in the facility.
- They were very eager to partner up with us, and they were willing to conduct all the test our can for free, as a part of a sponsorship deal.
- We conducted the tests on the 22nd of March, and got a full analysis of vibrations data in the X, Y, and Z axes.

Appgala 24’ conference which is a Mobile Marketing Conference with more than 200 IT professionals and speakers.

- After brief conversations with the organizers we have been invited to the segment on the 18th of April.
- The conference is held in “Space Club” in Warsaw, and we are hoping to learn many new skills, as well as some insightful information from the speakers and professionals attending.

Tamex is a Polish construction company specializing in sports facilities. They have been on the Polish market for over 15 years.

- We initially contacted them by email on the 3rd of March, asking whether they would be able to assist us in parts of 3D design.
- We have conducted a meeting with Tamex, and some of their engineers. They helped us with the external design of our can.
- We have acquired them as a partner quite late, on the 20th of march, which is 5 days before the submission of the FDR.

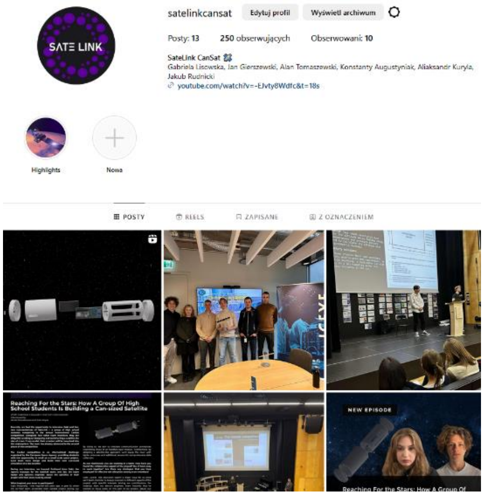
Creotech is a leading Polish space company, that works in the sector of satellites.

- Due to the complicated radio communication incorporated within our mission, we began an early search for external support. We have managed to reach an agreement, leading to a meeting with one of their specialists - Mr. Paweł Czapski, an expert in the field of radio communication and antennas. The online meeting we had organised was instrumental in our further progression at the beginning from the project.
- During the meeting, our focus was primarily on the communication aspects, particularly antennas. Mr. Czapski recommended using three-element or cross Yagi antennas, explaining their radiation patterns and respective advantages. For the can, he suggested a wire antenna that could be suspended from the top, mitigating potential issues with radio wave reflections from the metal screws in the can's structure.
- We also encountered challenges with the code and communication sensitivity. Mr. Czapski advised us to consult Semtech's application notes for the module and explore the code samples available in the online Lora library. Implementing his recommendations, we made significant strides and achieved successful three-way communication the very next day.

5 OUTREACH PROGRAMME

Over the last 6 months, we've been actively working on the exposure our project through sources such as Instagram, sponsorships, our website and interviews/presentations about CanSat in smaller towns in Poland.

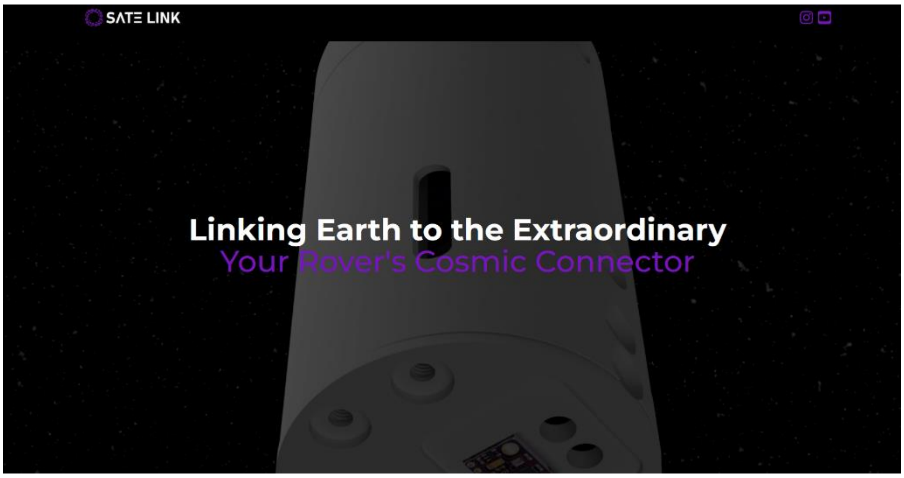
Our first step in maximising the outreach of our project, was creating an Instagram profile where we could post our progress and create a group of followers to follow us on our journey. As of the FDR our Instagram has 250 followers and receives an average of 110 likes per post. In addition, we have created “Story Highlights” where we post insights into what we're currently working on. According to our analytics, our account has reached over 1500 accounts since its launch. We are trying to actively post updates and will hopefully reach a larger audience throughout the rest of our project. We also use our profile to share our progress in the competition with our followers as well as anyone who might be curious about which stages of the competition we have progressed to. The link to our Instagram account is as follows: https://instagram.com/satelinkCanSat

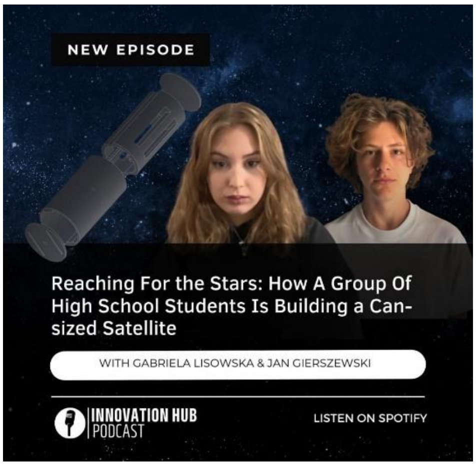

satelinkcansat

Posty: 13 250 obserwujących Obserwowani: 10

SateLink CanSat
Gabriela Lisowska, Jan Gierszewski, Alan Tomaszewski, Konstanty Augustyniak, Aliaksandr Kuryla, Jakub Rudnicki
youtube.com/watch?v=-EJvty8Wdfc&t=18s

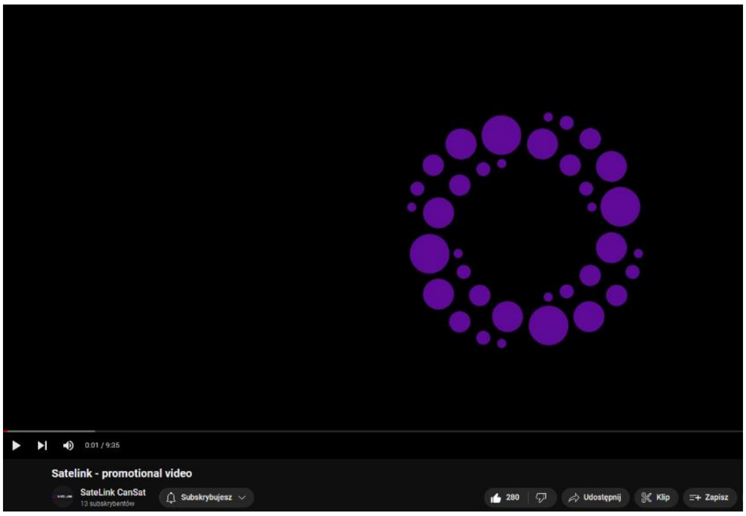
Our team has meticulously crafted a dynamic website centered around Satelink, designed to captivate visitors with comprehensive insights into our primary and secondary missions. It delves into our team's composition, mission objectives, and project milestones showcased alongside a captivating gallery of project-related imagery. As you explore, an engaging Blender animation unfolds, welcoming viewers into our innovative journey. Embracing openness, our website advocates for accessibility by offering open-source resources, such as our reports and CAD models, and fostering community engagement. Integrated shortcuts provide effortless access to our Instagram page and direct channels for connecting with our dedicated team. The link to the website is as follows: https://satelinkcansat.pl/





What's more, Jan and Gabriela were interviewed by the creators of innovation hub (a NPO as well as science magazine) about our project. The interview is now available in the form of both a podcast as well as article. Jan and Gabriela dove into multiple details of the competition from teamwork to engineering, truly describing the competition for what it is and what people who want to participate should realistically expect from taking part. Jan and Gabriela also shared some advice for future students taking part and hopefully helped anyone with better understanding the regulations and realities of CanSat. It was an amazing opportunity and will hopefully inspire as many young students as possible to take part in CanSat. The podcast is now available under the following link: (https://open.spotify.com/episode/3YbZDDV9ezdRxs2QMwnQ86). The article can be found in our story Highlights on Instagram as well as on our website and has been published in the paper back copy of the magazine.

Moreover, underscoring our dedication to transparency and fostering engagement, we've launched a dedicated YouTube channel, representing an important avenue for showcasing the strides made by our team. This channel stands as a testament to our commitment to providing a comprehensive glimpse into our project's ongoing activities. Our promotional video has already garnered significant traction, amassing an impressive 2100 views and 280 likes over a 10-minute video. Crafted with meticulous attention to detail, this video features interviews with team members and captivating snippets from our meetings, offering both entertainment and profound insights into the realm of CanSat for enthusiasts and prospective participants alike. The painstaking effort invested in its creation renders it a cornerstone of Satelink's progress post-CDR. Accessible directly through our website, this video serves as a beacon for those eager to delve deeper into our team's journey and the intricacies of the CanSat competition. Link: https://www.youtube.com/watch?v=-EJvty8Wdfc&t=1s



Janek visited his old primary school to conduct presentations about CanSat for students soon going to High School. He visited the school upon previous conversations with one of the Physics teachers, Andrzej Dubas. In total, Jan delivered 3 presentations for over 70 students in grades 7-8. He presented key information about CanSat, our progress in the competition and how they can potentially participate in the future. His presentation included a description of how to use the BMP280 sensor with a Feather M0 module to carry out the primary mission for the CanSat competition. He concluded this presentation with a 5-minute Q&A session where he further explained as well as answered any questions about how the project works and what are the benefits of taking part in such a competition.

In addition to that, Gabriela is finalizing a visit to a High school in Pulawy, Lubelszczyzna, to present about our CanSat and spread word about the competition in cities other than Warsaw to motivate other teens to participate. This is a long process as finding a date suitable for both Gabriela and the High School is quite tricky. However, her visit is planned for the end March as the school had trial final examinations and could not host her before the FDR deadline. We will be sharing further insights on our Instagram linked above. Moreover, Gabriela and Jan are planning to visit Jan's primary school to carry out a short presentation about CanSat and Satelink to younger audiences soon embarking on higher level education. We think this would be a great idea to set an example for others and hope to inspire as many potential CanSat participants as possible; as well as further publicizing our project.

We have also finalized our project's exposure on our school's social media platforms, as well as in the monthly newsletter distributed to all parents, teachers, and students. This strategic dissemination aims to raise awareness among our peers about the CanSat competition and inspire potential participants within our school community. Our project has yet to be posted on our highly curated school social media accounts due to scheduled timing, we are anticipating its appearance. Any posts of our project made by our high school will be mentioned on our Instagram.

Moreover, our team has crafted merchandise featuring our team logo alongside those of our sponsors. We believe this innovative approach will not only captivate attention but also serve as a powerful tool for promoting the competition. Our hoodie now finalized will be worn within our school premises and beyond. As depicted in the image (IMAGE), our hoodie design shows our team members' names, the team logo, and the logos of our sponsors. Featuring our team's colours, it exudes a sense of unity further reflecting our unwavering commitment to our project.

In addition to our efforts, Gabriela took the initiative to address an audience of approximately 150 students and staff members during a school assembly. With a captivating PowerPoint presentation titled "The CanSat Competition and Why You Should Participate"; aimed to inspire even more of our high school student body to consider participation once they meet the age requirements for the competition. Gabriela's presentation was crafted to be interactive, ensuring maximum engagement and retention of key information. By incorporating interactive elements, she not only captured the attention of her audience but also maintained a lively and entertaining atmosphere throughout her presentation. Following the assembly, numerous students approached Gabriela to inquire further about the competition, indicating a heightened interest and potential for increased participation in the future.

Furthermore, we are exploring the concept of hosting a webinar; a platform through which we can address questions and concerns, addressing individuals interested in participating. The interactive session would be facilitated by our entire team, drawing upon our collective expertise as each member holds responsibility for their own domain; spanning from outreach strategies to electrical engineering. Our primary aim with this webinar is to provide a supportive space where aspiring participants, especially younger individuals, can freely inquire about any aspects of the competition they find daunting or uncertain. We are committed to ensuring that participants feel well-equipped to navigate the challenges of the competition. We believe that offering this platform for interaction will play a huge role in achieving this goal.

We have also explored further opportunities to engage with the scientific community, such as the European Rover Competition and workshops hosted by Polskie Towarzystwo Miłośników Astronomii (Polish Society of Astronomy Enthusiasts), among others. These events offer a platform for us to expand our network of supporters and garner broader support across all age groups, spanning from primary school children to elders. Attending such events not only allows us to showcase our project and its potential impact but also provides an avenue for us to connect with like-minded individuals who share our passion for science and technology; engaging with audiences of varying age groups enables us to inspire and empower individuals at different stages of their lives.

Recognizing the importance of sharing knowledge and facilitating the journey for future CanSat enthusiasts, we have made the decision to publish our reports on our website. This initiative stems from our desire to provide inspiration and guidance to students planning on embarking on their own CanSat projects in the future. Understanding the overwhelming task of transforming a blank document into a comprehensive 50 page report; particularly for those new to the competition. By offering our reports as a reference point, we hope to aid students in the process of report writing. Our intention is to reach as many aspiring CanSat participants as possible, fostering a supportive community where knowledge sharing is key.

In addition, Gabriela's proactive efforts have established a valuable connection with Dr. Tomasz Zajkowski, a renowned astrobiologist and co-founder/president of the Polish Astrobiology Society. Leveraging Dr. Zajkowski's insights, we are crafting a compelling presentation for an upcoming meeting with PTAstroBio and PSPA. This presentation aims to introduce our project and inviting feedback from any aerospace professionals present. We see this as an opportunity not only to showcase our work but also to forge partnerships within the aerospace industry. With Dr. Zajkowski's guidance and the platform provided by PTAstroBio and PSPA, we are poised to embark on a journey of collaboration that promises to advance space exploration and technology.

Amidst our school's annual science fair, Aleks and Jakub presented about our project. During a one-day science festival dedicated to celebrating STEM topics deserving of more recognition, they took the stage to advocate for CanSat. Over the course of a very well-crafted 20-minute discourse, they discussed the potential of CanSat to ignite a passion for science, technology and engineering among participants. Through anecdotes and real-world examples Jakub and Aleks painted a vivid picture of CanSat's capacity to inspire creativity, nurture critical thinking skills, and foster collaboration. Their presentation left a lasting impression on the audience, igniting a spark of curiosity and inspiring others to take part.

6 CANSAT CHARACTERISTICS

6.1 CanSat Characteristics Table

Characteristics	Figure
Height of the CanSat	114mm + 10mm elastic space
Diameter of the CanSat	66mm
Mass of the CanSat	318.1g
Estimated descent rate	8 m/s
Radio transmitter model and frequency band	RFM96 LoRa (433MHz)
Estimated time on battery	7.03h
Cost of the CanSat	1030,52 PLN

6.2 CanSat Competition Regulations Checklist

Requirement no.	*Description*	*Result*
1	Dimensions of CanSat within 115mm x 66mm	YES
2	Mass of CanSat within the range 300-350g	YES
3	The power supply is sufficient to power CanSat for min 4h at maximum power usage	YES
4	The batteries are easily accessible	YES
5	Easily accessible main switch	YES
6	RGB LED to signalise the state of the CanSat (ON or OFF)	YES
7	CanSat is operating at a frequency of 433MHz in the range of 125KHz	YES
8	The maximum signal strength at exit of radio module below 20dBm	YES
9	The communication module is accepted by the moderators	YES
10	CanSat is equipped with a recovery system	YES
11	Terminal velocity of CanSat is within the range 8 – 11 m/s	YES
12	CanSat is able to withstand an overload of up to 20g	YES
13	The price of CanSat components does not exceed 500 EUR	YES
14	The CanSat does not use Li-Pol accumulators	YES

„Exploring space, Expanding Horizons”

THE END