cansats in europe

CanSat 2023

Preliminary Design Review (PDR)

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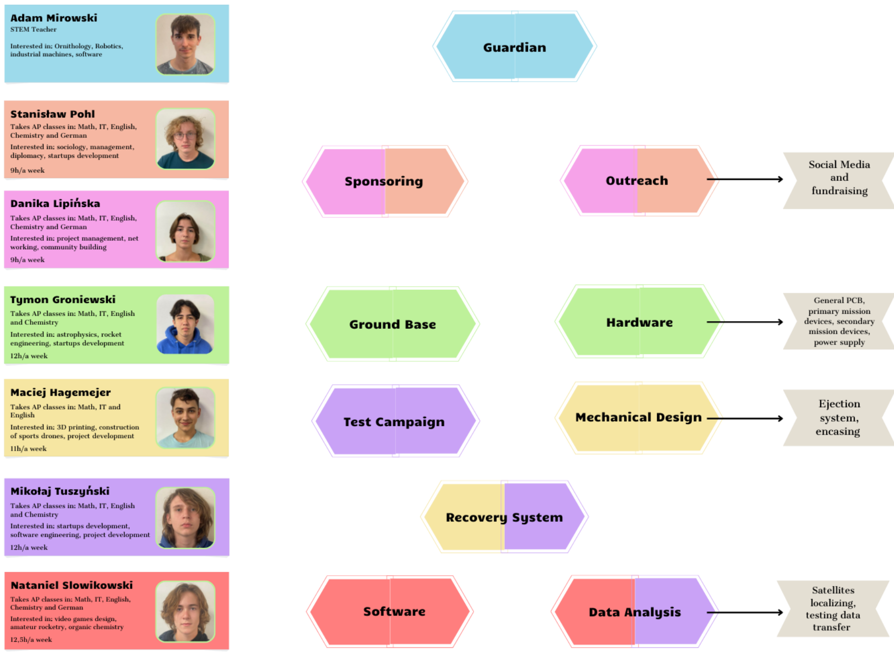
1 INTRODUCTION

1.1 Team organisation and roles



1.2 Mission Objectives.

The primary mission of every CanSat is to measure air temperature and atmospheric pressure during its descent and to send those measurements to the ground station every second. The same data will be collected and stored in CanSat's memory on a microSD card, for further analysis. We plan to use the data from the primary mission to tell when our micro-sat's landed, so we can start our secondary mission. Also based on this data we can calculate the height of every micro-sat during their descents. This data put together with data from our secondary mission can also be used to simulate the trajectory of each micro-sat in post-analysis.

The goal of our secondary mission is to build a CanSat that will split into three micro-sat's, which will restart after landing, create a radio network, and then the closest one will connect to the ground base. After establishing two-way communication between the network and the ground base, we will commission it to perform various tasks, e.g., uploading and modifying a file to each micro-sat, and then returning it to the base, or sending temperature and pressure data from each micro-sat using a radio connection only with one of them.

The second mission was inspired by our (humanity's) attempts to colonize other celestial bodies and by our problems with cosmic garbage. Using a communication system on the surface of the planet will assure communication over long distances without sending multiple satellites, requiring only one rocket launch, to place them in the correct places

The mission's purpose is to conduct an experiment that could show the way of building a simple communication web, which could provide communication in a large area, or over big distances without satellites. Such a solution would be cheaper to maintain than a satellite and replacing it after it expires would be less expensive and more ecological. You could easily connect two distant locations even if there were mountains between them. Additionally, this could be an additional way of communicating with earth if one of the hubs had lost its ability to do so.

To ensure the success of the missions, we must achieve what follows:

- The ejection system must work properly and dismantle the microsatellites into self-dependent machines.
- All three of the parachutes must open, and they cannot interrupt each other. All of the microsatellites must survive the descent and the landing and be able to work after landing.
- The microsatellites must be able to implement the web system after landing, connecting to each other and via one of them to the ground base. Executing all of the commands afterward.
- The communication system must be stable, as it is a key part of our experiment, it has to be able to communicate on six channels (3 between the ground base and 3 between the microsatellites) and then on four (1 between the web and the ground base and three inside the web) – firstly to take the measurements from each microsatellite and then to execute the experiment.
- The software must work and execute all assumed algorithms which are: save and transfer the measurements, during the flight, disconnect the ground station from the microsatellites, connect the microsatellites and start the web, connect the station to the web via one of the microsatellites, and execute all of the experiments, to prove the connection between them.
- The power supply must be small and lightweight because there must be the same power supply in each of the micro-satellites. Moreover, it has to have a high energy reserve so it will be sufficient for the system for the expected 6 or more hours and it must be proven to be safe to use.

2 CANSAT DESCRIPTION

2.1 Mission Overview

Our CanSat will be prepared to fall from an attitude between about 500-3000 metres from a drone or a rocket. As soon as the CanSat starts descending 3 parachutes will deploy. This will allow our CanSat to split into 3 microsatellites. Each capable of collecting, sending, and receiving data. The parachute system will ensure that the falling speed doesn't exceed 12m/s.

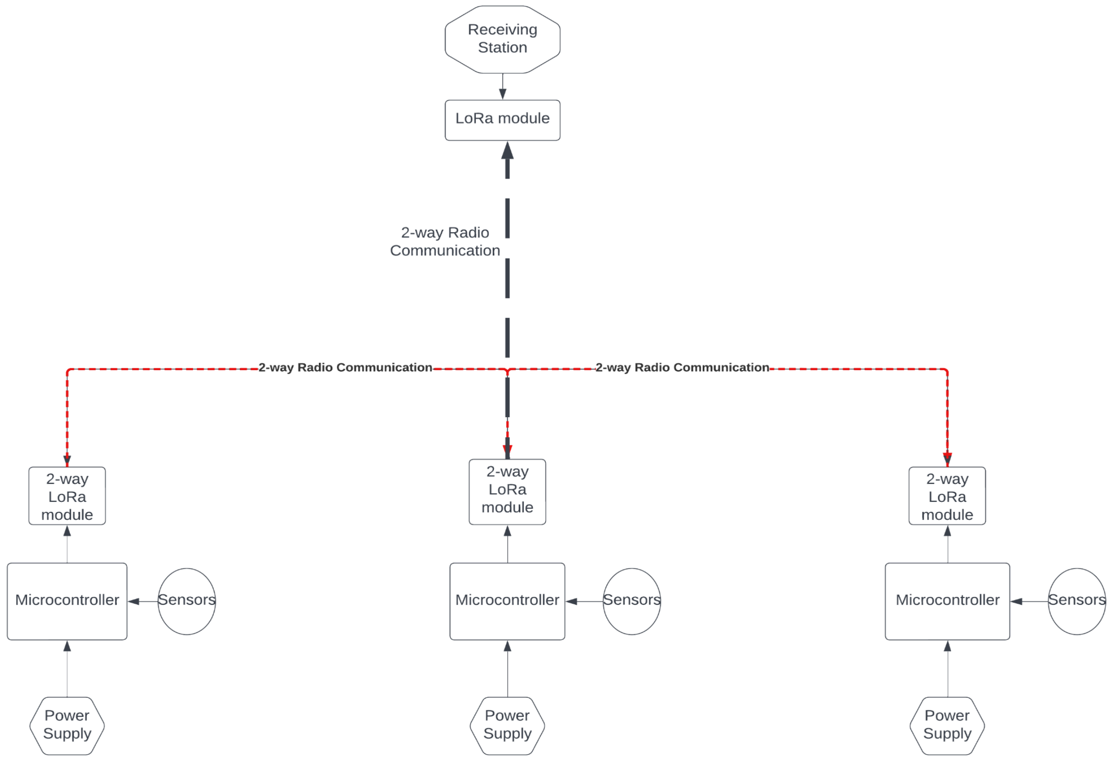
Every Part of the satellite will have an onboard data collection system which consists of a pressure and temperature sensor. Our microcontroller will be responsible for collecting data from the sensors, recording them on an SD card, and sending via the radio module.

Every CanSat needs to land slowly to assure the safety of the mission. After landing, communication between the microsatellites will start. This will allow us to create a small data network capable of collecting data from many places and then sending them to the one that's connected to the base. The system is optimised to collect and transfer data every second.

The base transmitter will stop the connection with the transmitters and switch to network mode. This will be achieved by sending a ping signal and the first part to receive it (the closest one) will start a 2-way communication with the part that's closest to the base. This will be possible thanks to the directional antenna at the station and onboard LoRa modules.

Using the collected data we will be able to draw conclusions about the environment we are testing.

Additionally to what was said above, we plan to calculate the signal delay of the satellite that is closest to the base. It will allow us to know the approximate distance from the microsatellite without using GPS. We know that it is physically possible but don't know if we have the resources to achieve it.



2.2 **Mechanical/structural design**

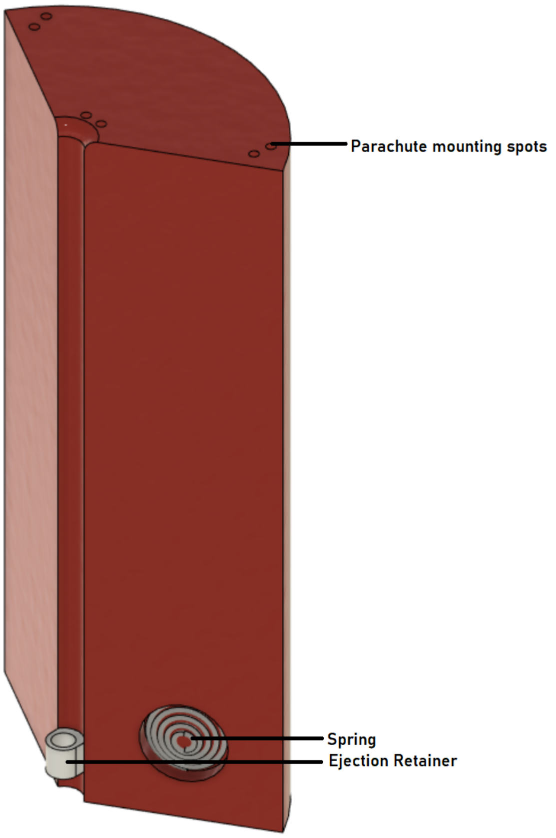


Figure 1

Figure 1 presents one of the three microsatellites that our CanSat will turn into. The can will separate into three parts fully mechanically without any electronic components. To accomplish that we settled on using three springs which will separate the can and help to get some distance between them.

2.2.1 **Electronics Slide**

The Electronic Slide will slide in, through an opening in the bottom of the can and will be used to mount all of the components. That way we will be able to quickly access our microcontroller and be able to swap batteries.

2.2.2 **Ejection mechanism**

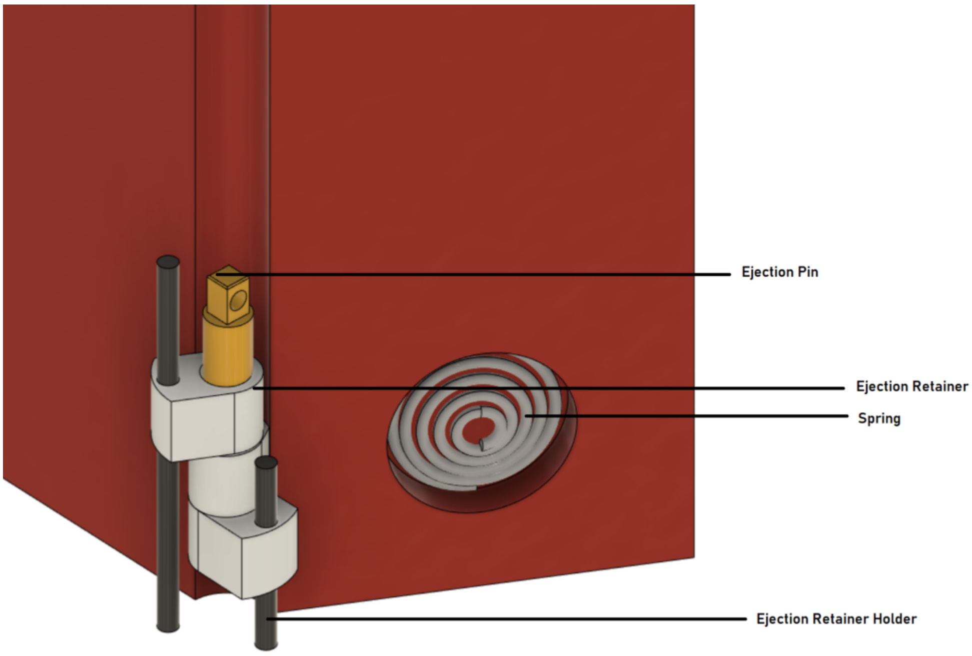
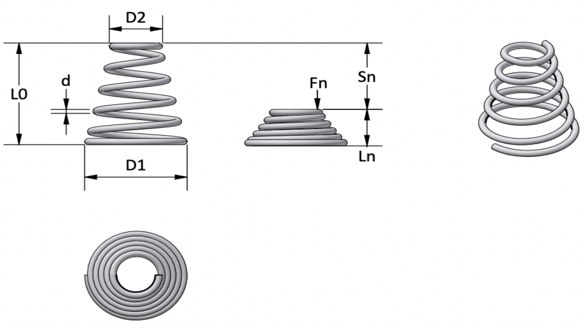


Figure2

Figure 2 presents our ejection retention mechanism. One of our three parachutes will have one extra shorter string which will get pulled on the moment that the parachute deploys, when that happens the ejection pin will come out and release the springs. We were worried that the pin might get tangled in the parachute lines, so we decided it would stop on the last Ejection Retainer. Because of the way that we designed the Ejection mechanism we needed a low-friction material to make the Ejection retainer. We settled on a material called iglidur (https://www.igus.pl/product/12404?artNr=I150-PF-0175-0750). It is a material made by IGUS, it is used to make bearings. Igludur is easy to process while being strong and most importantly low friction. The Ejection Retainer Holders' purpose is to hold the Ejection retainer inside of our cansat. It will most likely be made out of metal.

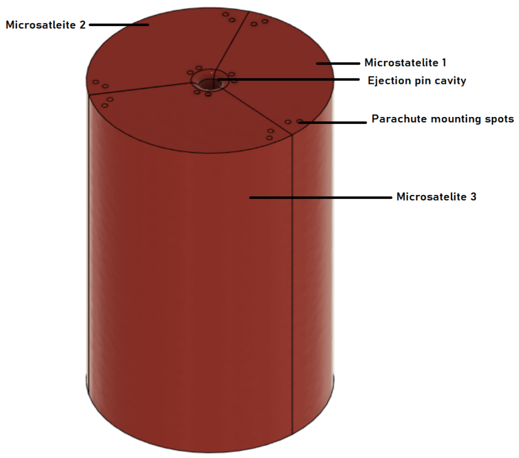
2.2.3 **Spring**



D1-12.19 mm
D2-3.96mm
d-0.81mm
L0-15.88mm
Fn-max load in LN- 27.27 N
SN spring travel-14.26mm
Ln-length under max load-1.62mm

The spring will be used to separate our CanSat into three parts. The recoil will help us to get a satisfying distance between the microsatellites.

Source(https://www.sodemann-sprezyny.pl/a480-032-062)



2.2.4 **Outer Shell**

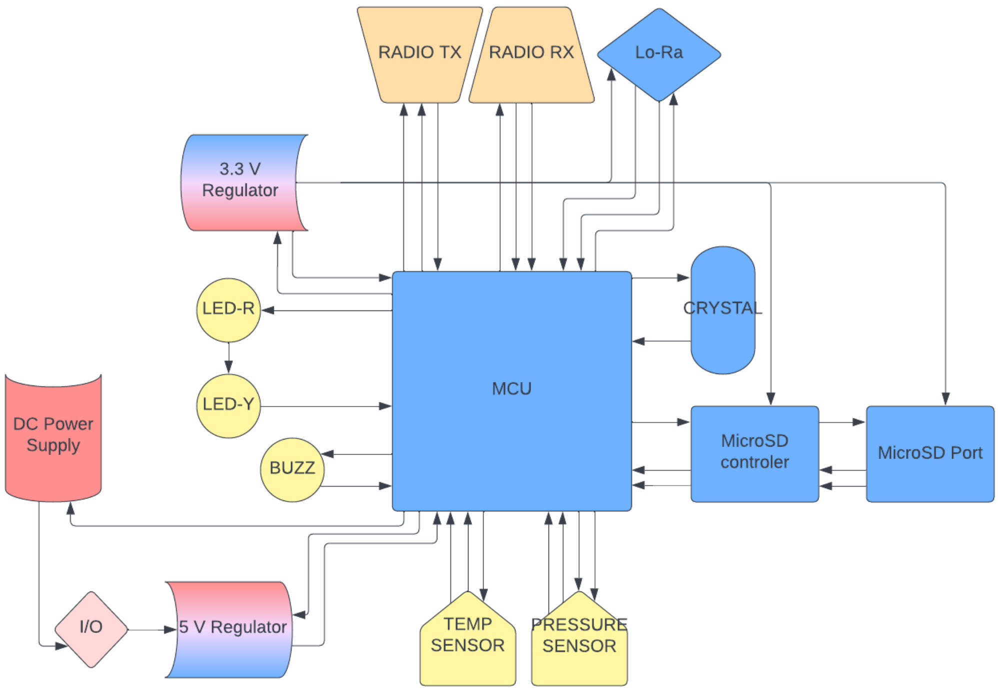
Figure 3 presents the outer shell. Its purpose is to contain our ejection system and electronic systems.

2.3 Electrical design

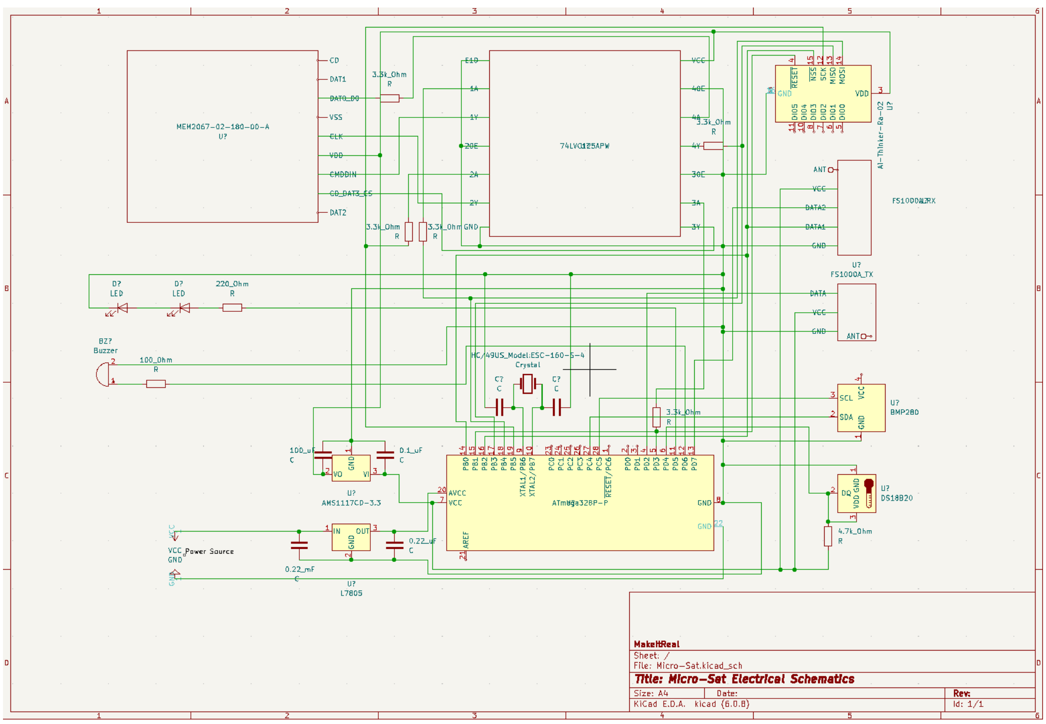
2.3.1 General architecture

Since our can-sat will be divided into three smaller ones, we need to develop our own PCB which will fit in a microsatellite and will contain all the systems that need to be inside a full-sized Can-Sat. Therefore the PCB will include our MCU, crystal, memory saving system (microSD), power supply control system, and main communication system.

Here you can see the simplified diagram of our system. The colors represent their purpose and location: Blue parts - main PCB. Red parts - power circuit. Yellow parts outside of the main PCB due to the sensors and sygnalizers requirement to contact the atmosphere. The Orange parts - locating the micro-sats - outside of the main PCB.



The next diagram is a complete schematic of the electrical circuit:



2.3.2 Main system PCB

Because we decided to place our main system on a custom PCB, we need to implement several systems to ensure the proper work of all Micro-Sats. That includes an MCU, Crystal clock, microSD data saving system, voltage control systems, diodes for testing and locating the micro sats after landing, and a buzzer for the same purpose.

System MCU: **Atmega328P-PU**

SPECIFICATION

Architecture: AVR, Operating Voltage: 5 V, DC Current PER I/O PINS: 40 mA, Input Voltage: 5V, Digital I/O Pins: 32 (6 PWM Pins), Power Consumption: 19 mA, Size: 3.28 x 37.4 x 6.76 mm
We plan to implement this microcontroller in our PCB. Because it can be used for this purpose, and it enables us to use all of our modules simultaneously which makes it the best choice for our needs.
Link: Atmega328P-PU Price: €12,58

Crystal clock: **HC/49US ESC-160-S-4**

SPECIFICATION

Frequency: 16MHz This crystal module will be used as our CPU clock to enable the use of the modules which require higher speed.
Link: HC/49US ESC-160-S-4 Price: €0,36

Saving data:

Logic level shifter chip: 74LVC125APW,118

This module will allow safe communication between our MCU and the microSD card without the risk of damaging it. We will implement it on our PCB as well as the microSD port. It supports SPI and works on 3.3V.

We decided to use it because it's a proven quality module used also in commercial products
Link: 74LVC125APW Price: €1,24

MicroSD reader chip: MEM2067-02-180-00-A

This particular model is compatible with the chosen logic level shifter chip and is a reliable product.
Type: 8 contact, temperature operating rate: -40 °C ~ +85 °C

Link: MEM2067-02-180-00-A Price: €1,24

Additional peripherals:

Voltage Regulators:

AMS1117: V_{in}: <15 V V_{Out}: 3.3 V, Current: 1 A, Operating: -50°C ~ 125°C Link: AMS1117 Price: €0,52
L7805CD2T-TR: V_{in}: 7-30 V V_{Out}: 5 V, Current: 1.5 A, Operating: 0°C ~ 125°C Link: L7805CD2T-TR Price: €0,36

Other components:

Antennas: We decided to choose our antennas basing on our test's in the next stage of the competition
Capacitors: 0.1 mF x 2, 100 mF, 100 nF, 22 pF x 2
Resistors: 3.3 kOhm x 4, 100 Ohm, 220 Ohm, 4.7 kOhm
Main power switch: ESP1010
Diodes: LED yellow and LED red, cover: DIP 10 mm, luminosity: 50 mcd, Current: 20 mA V_f: 2.1 V
Buzzer: V_{in}: 5 V, volume: 85 dB, Current: 30mA, Frequency: 2,3 kHz ± 500 Hz

What is notable, because our main PCB doesn't have a USB port we plan to use an AVR programmer. You can find more information: Ground Support Equipment

2.3.3 Primary mission devices

To complete the primary mission we plan to use:

Gravity: DS18B20 Temperature Sensor - as our temperature sensor

SPECIFICATION

Supply Voltage: 3.3V, current consumption 1.5 mA, temperature range: -55 °C ~ +125 °C, accuracy up to ±0.5 degrees Celsius, size: 22x32mm, Interface: Digital with digital temperature conversion and output

The sensor will be used to measure the temperature, firstly for further analysis and after landing, it will be part of our experiment of building a communication web

We chose this particular sensor, because of its high accuracy and high reliability in low price

Link: DS18B20 Price: €0,99

Fermion: BMP280 Digital Pressure Sensor - as our pressure sensor

SPECIFICATION

Operating Voltage: 5V, Current consumption: 2.7 mA, Pressure Measuring Range: 300~1100hPa, Absolute Accuracy: ±1hPa, Size: 18x11.5mm, Communication Interface: I2C

We will use this sensor to measure the pressure, firstly for further analysis and after landing, it will be part of our experiment of building a communication web

We chose this sensor because of its high accuracy, long term stability, small size, and low power consumption

Link: BMP280 Price: €7,12

2.3.4 Secondary mission devices

Because the goal of our project is to execute experiments on our web and locate our Micro-Sats, the devices for the secondary mission are also used for our communication system.

Ai-Thinker Ra-02

SPECIFICATION

Supply voltage and work: 3.3 v, Work temperature: -40 to + 80 C, Range: up to 15km, Transmission speed: up to 300kbps, Transmitter power: +20dBm - 100mW, Working frequency: -148 dBm, High sensitivity: -148dBm, Communication method: LoRA, Communication protocol: SPI The Ra-02 module guarantees that every one of our micro-satellites will be in the range of the signal, which is necessary to complete our secondary mission, in addition, it meets the requirements of frequency for cansat's and it's a low-cost product. Link: Ra-02 Price: €8,19

FS1000A

SPECIFICATION

Supply voltage: 5 V, Current consumption: 4 mA for 5 V, working frequency: 433MHz, range up to 100 m (the range can be easily increased), transmission speed: up to 9.6 KB, dimensions: transmitter: 20 x 19 mm, receiver: 30 x 14 mm, has a connector for soldering an external antenna
This module will be used for locating our can-sat after landing. We will use the delay of the signal to determine the distance between the micro-sats and our ground base. Link: FS1000A Price: €0,78

2.3.5 Power supply

The power supply will be chosen in the next phase of the competition to fit our demands.

2.3.6 Communication system

Radio waves from the base will be only directed to one of three Micro-Sats. The satellite which receives the signal first (It will be the closest one) will be marked as “Main Satellite” in the software. The main satellite will send signals to other parts of the satellite and create a full radio communication net.

- Maximum power will not exceed 20dbm to fulfill the requirements in the rules.
- We will use a LoRa module for radio communication.
- Communication will be working on the 433MHz public channel/frequency.

All 3 Micro-Sats will be equipped with an elastic antenna which will be directly connected to the parachute. The antenna will straighten up when the parachute opens.

Most of the time our already separated Micro-Sat’s will solely reflect the signal and exchange signals with each other. Unlike our base, they will not broadcast new signals.

The first signal which will initiate the radio net process will be directed from the base.

Required software:

- Directional antenna and well-working software in the ground station. We will also need a receiver to receive signals returning from the “Main Satellite”.
- 3 LoRa modules and 3 antennas inside of satellites.

The products shown here are only examples and may change depending on availability. Especially the LoRa device gateway which has many substitutes may change depending on the needs and availability.

These are some examples of our possible choices for Lo–Ra communication devices:

LoStik – USB LoRa device

LoStik is an open-source LoRa device that is compatible with all available devices. It has great

documentation and easily accessible information about specifications.

Chip - R2483

Connectivity: USB 2.0

Receiver Sensitivity: down to -146 dBm

TX Power: adjustable up to +18.5 dBm

Range: up to 15 km coverage in suburban and up to 5 km coverage in urban areas

Price - 59.82€

Connector SMA male/ SMA female

Length – 10.0m

Price - 6.16€

USB delock cable 5.0m

Flexible USB extension allowing to connect our LoRa device to a computer

USB 2.0 on both endings, socket type (A)

Length – 5.0m

Price = 11.57€

2.4 **Software design**

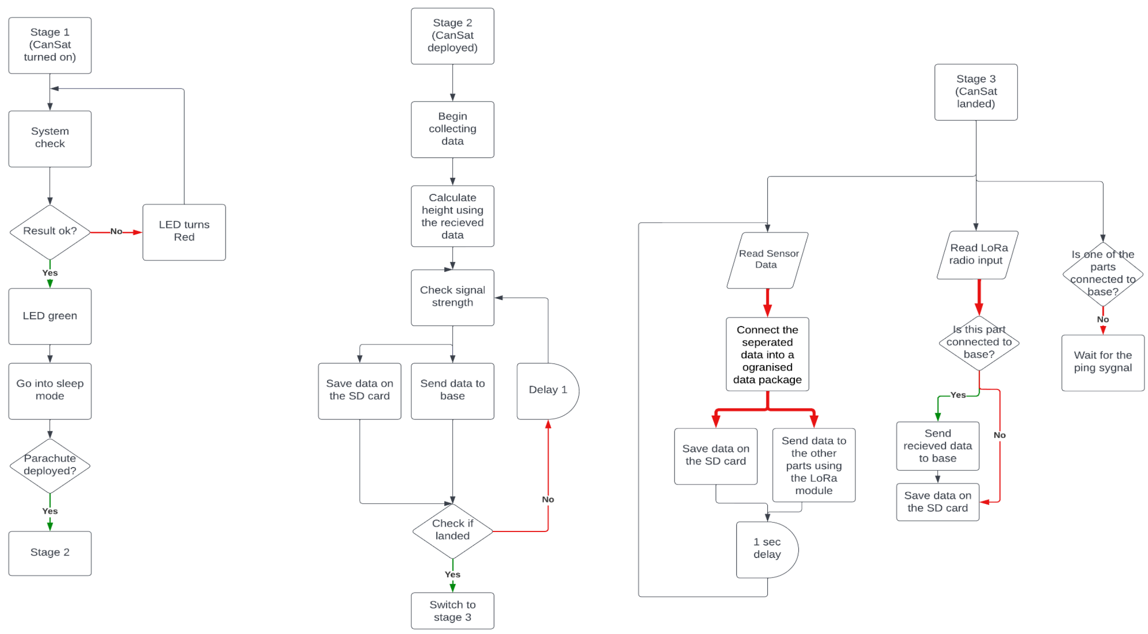
The software designed for the onboard computer and base station will be designed in the Arduino IDE environment, using C++. A program written in Java will be used to visualize the data.

Stage 1: CanSat is waiting for deployment and a basic test starts.
Stage 2: The satellite starts collecting primary mission data and sending them to the base. After landing Stage 3 starts
Stage 3: The most important part of our mission. As soon as every part has landed they start searching for each other to create a network. After receiving confirmation that the microsatellites are connected. We send a ping signal from the base to locate the closest part and the first one to receive it begins a 2-way communication with the base. A more detailed description of the ground support transmitter code can be found in the *Ground Support Equipment* section

After landing we are planning to calculate the distance using signal delay. We know it is possible but as of today, we don't have an exact plan for it.

The amount of data gathered is too small to have an impact on the mission so we decided not to calculate it before the test campaign.

The diagram presents a simplified way of how the program works.



2.5 Recovery system

To maintain the maximum speed of 12 m/s for our recovery system we decided to use a round-hole parachute. We chose a round hole parachute because it's the easiest type of parachute to calculate drag force and that means that we can easily control the maximum speed of descending. We still consider ram-air parachutes for drifting away purposes. We are also strongly thinking about using a swivel to deal with possible entanglements. We decided on a terminal velocity equivalent to 8m/s in order not to exceed maximum speed safely. With known terminal velocity we can easily calculate the area and the radius of the parachute. We will also implement the spill hole on the top of the parachute to ensure that the parachute will not tilt sideways. The spill hole will cover 5% of the parachute surface as usual in a round hole parachute. As our satellite will split into three parts we will create three same-looking parachutes to handle maximum speed for all of them. We were inspired by NASA's (Orion parachute system) research and we will try to create a similar system.

The parachute will be made out of Nylon

(Equation for the area of non-round parachutes)

$S = 0.024$ area of the parachute

$Rh = 0.019m$ Radius of the spill hole

$Rp = 0.089m$ Radius of the parachute (without spill hole)

$V = 8m/s$ Terminal velocity of cansat (assumption)

$m = 0.116$ - Cansat mass(Only for on part not 3), (approximation)

1.2 - Drag coefficient (assumption)

π = 3.1415 – Pi constant (approximation)

g = 9.81m/- Gravity acceleration (approximation)

ρ = 1.225kg/- Air density (approximation)

2.6 **Ground Support Equipment**

Our ground base will consist of these parts:

- Laptop
- AVR Programmer
- Software to analyse data
- Spare parts and batteries
- Receiving and transmitting station:
    - YaGi directional antenna
    - LoRa module
    - Software to capture and send data using the radio module

1. Laptop

Any laptop compatible with our software and the LoRa module

2. AVR Programmer

Since our PCB won't have a USB port we need to implement our program using such a device. For example, this one fits our demands perfectly: AVR Programmer

3. Software

- Data analysis:

This software collects all the telemetry data and then sends them to a visualization program. This will allow us to analyse later the height at which the satellite was, how fast it was descending, and the weather influence on the flight.

- Data receiving and transmitting:

During the microsatellites descent, there will be a one-way communication used just to transfer telemetric data. After landing the connection will switch into a network mode where the base station will have a 2-way communication to the closest micro-sat (that is already connected to the other two). Then using the LoRa module we will also have the ability to send data into the network not only collect it, which will allow us to execute experiments to prove the proper work of our web.

4. Receiving station
    - Described in Communication System

Test Campaign

2.7 Primary mission tests

Measurement and data download tests

Pressure and temperature sensor test: We will use a reference device to measure the pressure in different environments and then compare the result with our sensors. This will let us check the work of sensors and SD card modules to find every possible problem in both the sensor system and data saving system.

Sending/receiving tests

The test will contain multiple trials to check if the connection is stable and reliable enough to send data every second. It will also allow us to check the delay and the speed of data compliance.

2.8 Secondary mission tests

Satellite splitting test

1. We plan to drop the cansat from a special drone module to test if CanSat is splitting into 3 parts properly. For that, we will have multiple tests on the splitting mechanism. This test is going to help us predict the spring recoil and distance between each part after landing.
2. In the same test we will also test the connection between parachutes and splitting mechanism which will be highly associated with each other. To test this we are going to drop down the CanSat multiple times to find the best and worst variants of the system to avoid the possible consequences of entanglement of the parachute ropes.

Data network test

We will connect all 3 transmitters and a computer to simulate the network. Then we will input information and analyse the way data is managed. If everything turns out to be working right, transmitters should send the signal right away, without any errors.

TOF Sensor test

Our research shows that counting distance based on signal delay is possible. But we don't know if we will be able to make this a feature of our cansat. To check if it will be possible the testing will consist of using the system to measure distance and then checking it using GPS. It will also help us to define an error margin if one exists.

"t1 + t2 – delay = t" "t1 = time of flight from base to the cansat" "t2= time of flight from the cansat to the base" "(t1 = t2)" "Delay = time between receiving and transmitting the pulse in the satellite"

*"d = c*0.5(t0 – delay)" "d = distance" " c= speed of light" "t0 =time between transmitting and receiving the pulse in the base unit"*

Satellite direction test

In this test, we will try to find the direction of the satellite. For this test we will use a directional YAGI antenna with significant directional gain. When we will detect maximum radio waves power we will know approximately where the satellite is.

Endurance tests

During landing, any electronic part of the cansat can't be damaged as it can disrupt the whole mission. We are planning to do crash tests by using a dummy can to measure the impact and check if the materials and electronics won't get damaged if something during the landing goes wrong.

1. Drop-down test: Using a drone or by going to the top of a high building we will drop our satellite from various heights to ensure:
    a. Can a cansat shell withstand dropping down on the ground with a terminal velocity of 8m/s?
    b. Can the cansat components withstand dropping down on the ground with a terminal velocity of 8m/s?

Recovery system test

1. Parachute deployment test: using a drone or by going on top of a high building we will drop our satellite from a big height in various weather conditions, to check if these important elements of our mission will be completed:
    a. Is the descending speed lower or equal to 12 m/s?
    b. Is there a possibility of the parachutes tangling in hostile weather conditions?
    c. How will the CanSat behave in bad weather?
    d. What is the spread of the microsatellites?
2. Because we haven't decided whether we want a round or a ram-air parachute the tests will be carried out on both to choose the one with better results to fit our demands.

Communication system range tests

1. In an environment similar to the one in which the mission will be completed we will carry out a test to check the maximum range of our transmitter on the height that the mission will be performed
2. A range test while freefall will also be performed

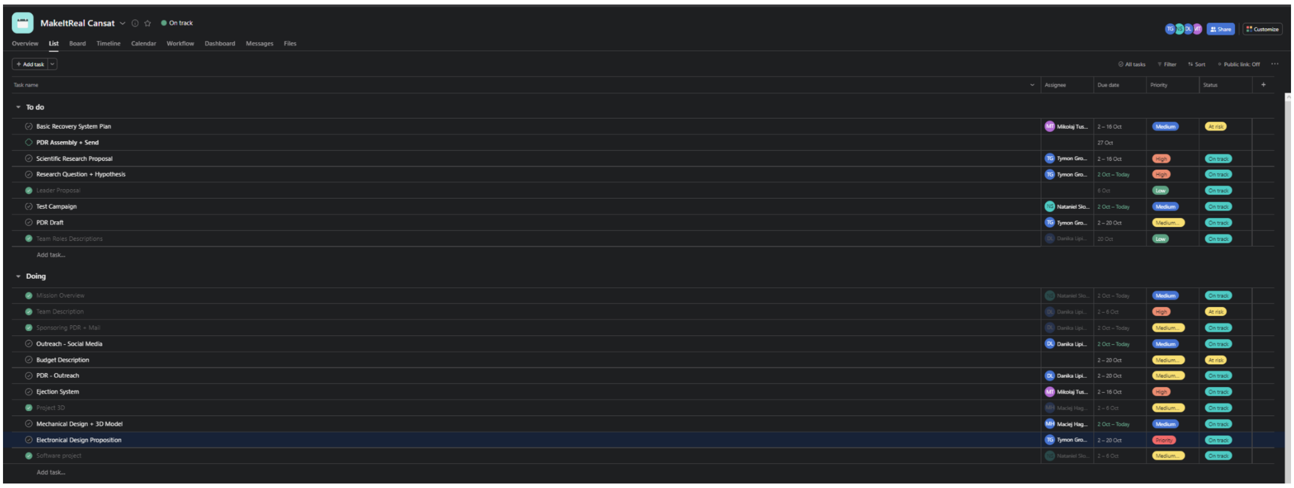
Energy budget tests

We are planning to use the battery which will be able to provide power for each of our MicroSat's for 4 to 6 hours. To test the battery capacity we will perform a variety of tests including:

1. Calculating battery usage in every mode
2. Verifying battery capacity under normal conditions
3. Verifying battery capacity in low temperature

3 Project Planning

3.1 Task list and Time Schedule



In a program called Asana, we managed to create a task list that helped us to organize our work while working on this report.

The team's decision was not to create a schedule for later stages of the project. We will include it in later reports.

3.2 Resource estimation

3.2.1 Budget

Based on our calculations one full prototype will cost about 100 euros. The list is still not perfect, it doesn't include batteries which we have not chosen yet. We tried to include as many PCB parts as possible but we had no way of checking the exact price. Figure and figure 3.1 presents necessary cansat parts and their costs (Described in detail here). This is a minimal amount of money needed for a successful prototype.

Component:	Price zł:	Price euro:	Price(x3)
FS1000A (Tx i Rx)	3,72 zł	€0,78	€2,34
RA-02 (LoRa)	39,00 zł	€8,19	€24,57
DS18B20 (Temperature sensor)	4,7	€0,99	€2,96
AMS1117 (Voltage regulator)	2,46 zł	€0,52	€1,55
BMP280 (Pressure sensor)	33,90 zł	€7,12	€21,36
Capacitor 0.1µF x2	0,06 zł	€0,01	€0,04
Capacitor 100 µF	0,11	€0,02	€0,07
Capacitor 100 nf	0,30 zł	€0,06	€0,19
Capacitor 22 nf	0,09 zł	€0,02	€0,06
Capacitor 22 pf	0,65 zł	€0,14	€0,41
Resistor 3.3 K ohmów x4	0,18	€0,04	€0,11
Resistor 100 Ohmów	0,09 zł	€0,02	€0,06
Resistor 220 Ohmów	0,16	€0,03	€0,10
Resistor 4.7 K	0,06 zł	€0,01	€0,04
HC/49US (quartz clock) ESC-160-S-4	1,70 zł	€0,36	€1,07
MEM2067-02-180-00-A (SD Card)	5,48 zł	€1,15	€3,45
74LVC125APW (line driver)	2,31	€0,49	€1,46
ESP1010 (power switch)	2,17 zł	€0,46	€1,37
Stabilizator 5V L7805CV	1,70 zł	€0,36	€1,07
Atmega238p-pu	59,90 zł	€12,58	€37,74
Nylon Fabric	2,48 zł	€0,52	€1,56
Canopy Lines	3,14 zł	€0,66	€1,98
Springs for ejection mechanism	41,00 zł	€8,61	€25,83
Springs for ejection mechanism	41,00 zł	€8,61	€25,83
Filament PETG CARBON 33g	18,00 zł	€3,78	€11,34
Steel dovel	0,89 zł	€0,19	€0,56
Filament Iglidur 150-PF 20g	8,64 zł	€1,81	€5,44
Batteries (not chosen yet)	-	-	-
Suma:	**158,74 zł**	**€33,34**	**€100,01**
			481,03 zł

The base support cost is estimated at 130 euros + antenna cost + laptops.

3.2.2 External support

We started our outreach program by making a Facebook and Instagram page. It will help us gather financial funds and achieve our goal of collecting 1500.00€ and build interest in our project.

We are planning to get funds by finding sponsors. We are looking into Mbank's company program for talented young people called "*M jak matematyka*" (M like maths). It is aimed at helping students who are mathematically gifted and want to make maths interesting for everyone. We are also open to more options and finding some additional sponsors who can make achieving our goal easier. We have already prepared draft emails that are ready to be sent to potential sponsors after we qualify for the next stage.

In addition to that, we are planning to make a fundraising campaign that will be promoted in our school community and among our friends and family members. It is going to help us to collect money easily and to start working early.

Outreach Programme

We are planning on posting on our social media once a week while working on the project. This will include making at least once a month a report on our progress and milestones in our work.

In our school, we organised a competition to choose the best logo design for our project. It helped to spread awareness about our participation in the competition.

We are also planning to promote our project on the school's forum to get more people interested in our project.

4 CanSat characteristics

Characteristics	Figure
Height of the CanSat	115 mm
Diameter of the CanSat	64 mm
Mass of the CanSat	-
Estimated descent rate	8m/s
Radio transmitter model and frequency band	LoRa RA-02 SX1278 433MHz
Estimated time on battery (primary mission)	4-6 hours
Cost of the CanSat	Budget