cansats in europe

# Preliminary Design Review

S C A N C A N

**Team Name: ScanCan**

**Country: Poland**

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# 1 CHANGELOG

- We decided on our secondary mission. CanSat is now supposed to make photos of the ground below. We will then proceed to make a 3D model of the terrain using photogrammetry.
- We changed our team's name, it is now called ScanCan not RealDeal

Fig. 1 Side view of CanSat with parachute

# 2 INTRODUCTION

## 2.1 Team organisation and roles

Maciej Kobyliński - Team leader, hardware, writing:
- Background: General knowledge of python, java, javascript, html
- Field of work: Team leader, assisting in Hardwere, writing reports
- Hours dedicated at school: 4h
- Hours dedicated after school: 4h

Jakub Banach - Lead software engineer:
- Background: Open source contributor and hobbyist machine learning engineer
- Field of work: Lead software engineer, writing code for ground station and CanSat
- Hours dedicated at school: 4h
- Hours dedicated after school: 4h

Andrzej Borys - Lead hardware engineer:
- Background: math enjoyer, extended subject math, german, computer science
- Field of work: General hardware, all hardware that is in our CanSat goes through his hands
- Hours dedicated at school: 4h
- Hours dedicated after school: 4h

Bartosz Purta - hardware engineer, physics:
- Background: math enjoyer, extended subjects: math, computer science, python programmer
- Field of work: General hardware, all calculations from physics field are done by him
- Hours dedicated at school: 4h
- Hours dedicated after school: 6h

Mateusz Szczotka - 3D modelling, hardware, finance:
- Background: 3D modeling enjoyer (Blender, Fusion), high math experience, C++ and Python programmer
- Field of work: 3D modelling, sourcing funds , help with hardware
- Hours dedicated at school: 4h
- Hours dedicated after school: 7h

Maja Gustowska - finance, writing, social media promotion, art:
- Background: Experience with 3D modelling (Blender, Fusion360, Maya), animation and graphic design. English,Spanish, Math and Chemistry enthusiast.
- Field of work: Sourcing sponsors to found our CanSat, building teams presence online, making logo design and writing reports
- Hours dedicated at school: 4h
- Hours dedicated after school: 3h

Jerzy Piwkowski - teacher:
- Background: STEM teacher, Automation and Robotics M. Eng at Warsaw University of Technology, interest in mechanical engineering, climate and DIY
- Field of work: Mentoring the team, substantive support
- Hours dedicated at school: 4h
- Hours dedicated after school: 2h

## 2.2 Mission objectives

We picture a scenario in which our CanSat will be dropped on an alien planet. It will gather information about the planet and what's most important, it will make a 3D model of CanSat's landing site. The model will allow for precise choice of landing site for bigger aircraft in need of a flat surface to land safely. After the tests, which we describe in the paragraph "secondary mission tests", we estimate that the model will be depicting a 500m x 500m area. The closer to the landing site, the better the model will be.

### *2.2.1 Primary mission:*

Our primary mission is to measure atmospheric pressure and temperature. To gather this information we will use the BME 680 sensor, while also using a GPS module to locate the CanSat after landing and to track its position during its descent. In the environment of the scenario presented earlier the BME sensor data will provide essential environmental information about the alien planet.

### *2.2.2 Secondary mission:*

For our secondary mission we will make a 3D model of CanSat's landing site. To accomplish that, our CanSat will take photos of the ground beneath the can, which will be used later to create an accurate representation of the landing site. The photos need to be as undisturbed as possible so we will use a Raspberry Pi global shutter camera and IMU. Camera will provide a clear image while the IMU will be a key factor for classifying if the photos are going to be used in the 3D model. This will provide us with a model of an uncharted alien terrain, which is necessary for locating a safe landing area for bigger aircrafts transporting humans.

To consider the launch successful the following parameters shall be met:

- The parachute needs to open and slow down CanSat's descent correctly.
- Camera needs to take at least 15 good quality photos.
- Bme 680 needs to correctly measure temperature and atmospheric pressure
- The LoRa module will be able to send data every second.
- The whole CanSat needs to resist impact at landing.
- Cansat needs to have enough battery reserves to send photos to base.
- Data needs to be saved on the micro SD card.
- We need to be able to locate our CanSat after the landing to retrieve all of data.

# 3 CANSAT DESCRIPTION

## 3.1 Mission overview

Our goal is building a CanSat which will be deployed from a rocket at an altitude of 1,5 to 2,5km. Our primary mission is to measure and record atmospheric pressure and temperature throughout the CanSat’s descent. The CanSat should not exceed falling speed of 8m/s as we estimated it as an optimal speed for taking photos with high enough quality, to ensure our 3D model’s accuracy. Photos are going to be taken at a frequency of 5Hz to make sure we have enough adequate photos for the model. Every photo will be saved on a micro SD card and logged with the time of the picture's creation and CanSat’s tilt which will be used later to identify which photos are good to use in making our model. Primary mission data is stored alongside photos on the micro SD card.

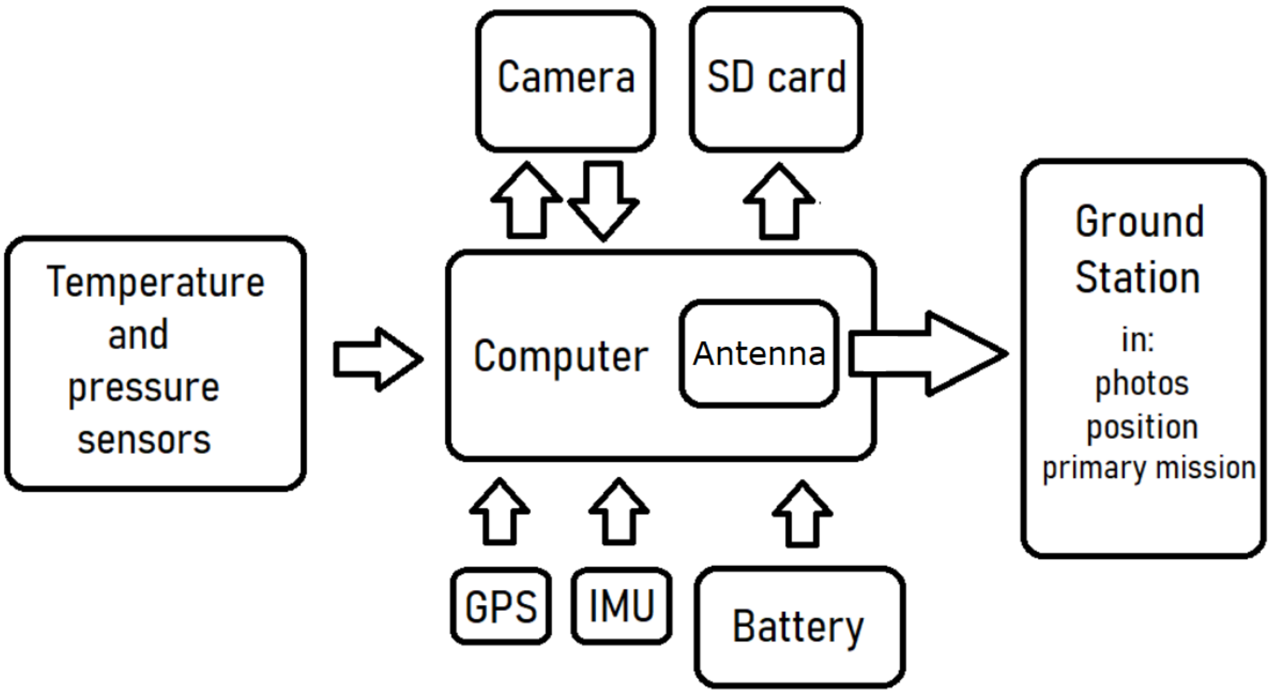


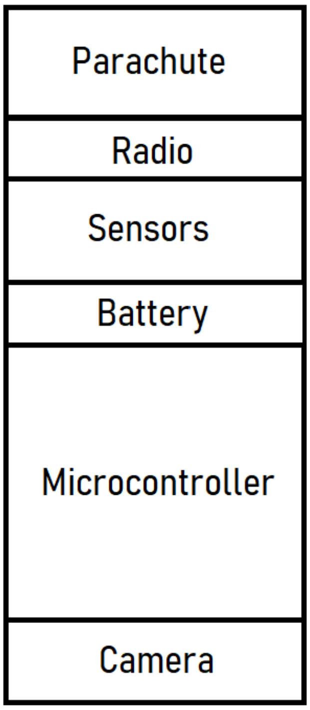

Fig. 2 block diagram of CanSat’s electronics

## 3.2 Mechanical/structural design

### *3.2.1 Materials*

Our CanSat's shell will be made out of PLA plastic which is a filament used in 3D printers that we have access to. For connecting the parts together we plan on using threaded bolts and nuts. smaller components of our CanSat will be attached with small screws or inserts for plastic.

### *3.2.2 Component layout*




Parachute - This section contains a parachute to slow down the CanSat's descent

Radio - This section contains a LoRa module

Sensors - This section contains our sensors:

GPS - for finding CanSat's location

IMU - an inertial measurement unit for image classification based on CanSat's orientation

BME 680 - a sensor providing temperature and pressure readings

Battery - this section contains 2S 18650 Li-Ion batteries with BMS

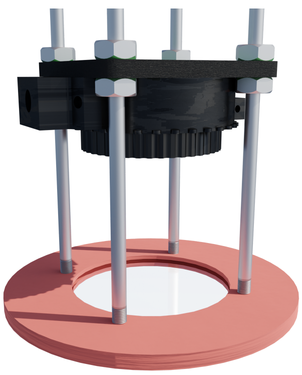
Microcontroller - this section contains Raspberry Pi Zero 2W, our computer

Camera - This last section contains our camera used to procure images for our secondary mission. We plan on using Raspberry Pi global shutter camera

Fig. 3 CanSat's component layout

## 3.3 Mechanical solutions

### *3.3.1 Camera stabilisation*



We will use an adequate type of parachute to make our CanSat more stable. We chose to use a Raspberry Pi global shutter camera to prevent rolling shutter effect. Pictures are taken at the speed of 5 fps. We will also use a thin layer of plexiglass to protect fragile camera lens from being damaged during start and landing.

Fig. 4 Raspberry Pi global shutter camera mounted to bottom of our CanSat

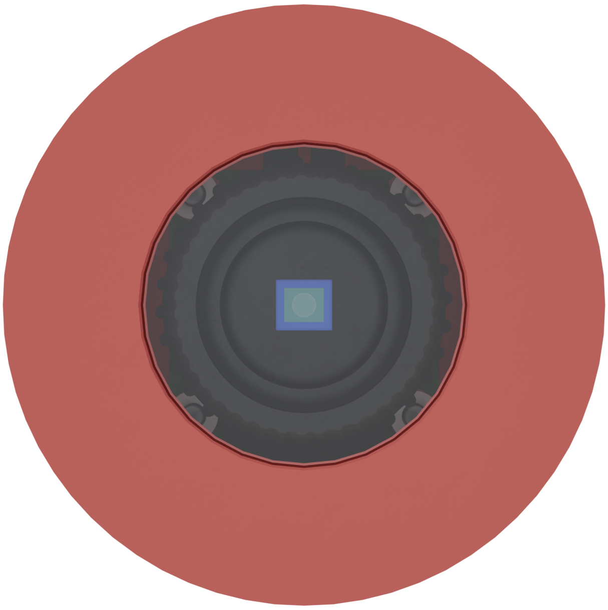


Fig. 5 Raspberry Pi global shutter camera view from below

Fig. 6 Inside of CanSat with camera module only

## 3.4 Electrical design

### *3.4.1 Primary mission devices*

Temperature sensor BME 680 - this sensor will be used to measure pressure and temperature throughout the fall of our CanSat.

Adafruit RFM96W LoRa Radio Transceiver - Radio will transmit data and photos from CanSat to the ground station.

A micro SD card will be used for storing the data collected by our CanSat.

### *3.4.2 Secondary mission devices*

Camera - Raspberry Pi global shutter camera - Special type of camera that prevents the occurrence of shutter roll effect. (measurements: 38 x 38 x 19,8 mm)

IMU - a sensor that will measure the angle at which CanSat is currently at, and log tilt of the CanSat to help identify photos that can be used in making a 3D model.

### *3.4.3 Power supply*

This section is dedicated to our calculations regarding power in our CanSat.

- Raspberry Pi Zero 2 W ~ 0.7 W
- Raspberry Pi Global Shutter ~ 0.7W
- Adafruit RFM96W LoRa Radio Transceiver ~ 3W (at peak power usage) or 0,1W (at lowest power usage)
- BME680 ~ 0,1W
- GPS ~ 0,1W
- IMU - Negligible

Total ~ 4,5W

While calculating needed energy we established that the LoRa module will be at its peak power usage for at most 3 hours. With that in mind 1,6 W X 6h gives us 9.6Wh also 3W times 3h gives us 9Wh in total that is 18.6 Wh needed to power our CanSat for 6h.We plan on using two Li-Ion batteries which will provide 24,4Wh. Our CanSat consumes 18,6Wh at the span of 6 hours. This gives us a safety margin equal to 5,4Wh, that is enough to power our CanSat for an additional hour.

### *3.4.4 Communication system*

We will perform a one direction communication (CanSat -> ground station) using an Adafruit RFM96W LoRa radio module to send data and a yagi-uda antenna to receive it. Data will be sent at a frequency of 433Hz.

### 3.5 Software design

- We intend to use C++ for low level control over hardware elements as well as libcamera for controlling camera
- We plan to take pictures with resolution of 1456x1088 and store them on a micro SD card on board
- We can use libcamera-jpeg to get jpg image output, the single file size is estimated to be 323kb
- To minimize possible points of failure we want to frequently take pictures and log the output of IMU to later select outputs which are going to be used in the 3D model.
- 32GB micro SD card can hold ~100.000 images
- Marginal change in IMU and pressure data will detect landing, it will be communicated to Raspberry Pi which will then stop taking pictures
- Send data to the ground station

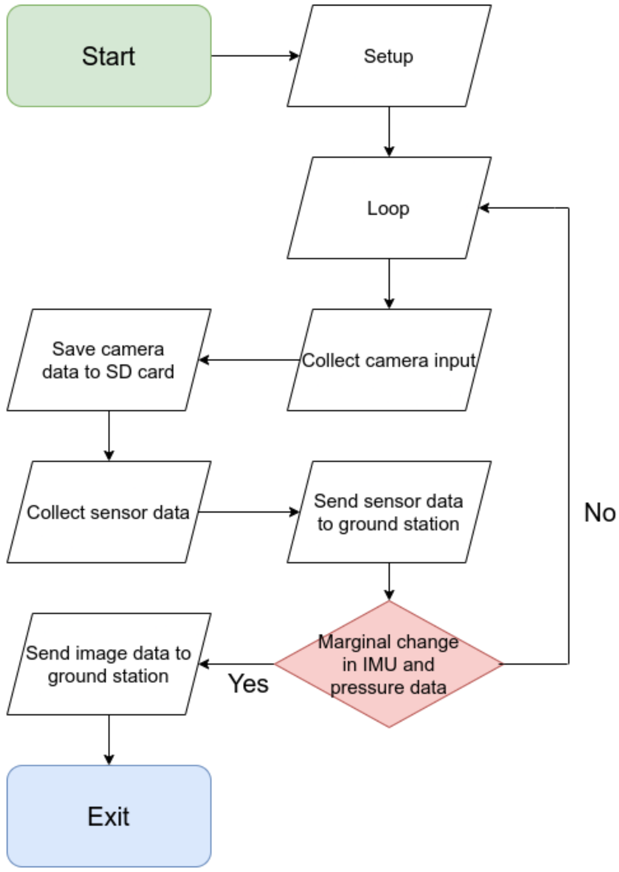



Fig. 7 Flow chart of CanSat's program

### 3.6 Recovery system

Our method to create a model of the ground beneath the aircraft - photogrammetry requires many high quality photos with specified location and relative offset. To achieve this we will need as little movement to the sides and rotation as possible.

Because we need high quality photos, a direct form of stabilisation such as a gimbal would be very hard to fit together with a big camera. That’s why our plan to stabilize the camera is to use an adequate type of parachute.

With a stable enough flight, there will be no need for further stabilisation. From our research the exact type that we need is the one based on military parachutes which had a very similar purpose to our needs. It is a basic circle shaped parachute with a spill hole at the top for extra stability thanks to additional air flow.

The parachute will be made out of ripstop nylon to save weight and space, thanks to its low aeration. Because we don’t want too much movement to the sides we want our CanSat to fall around 8 m/s. According to our calculations the parachute’s canopy surface will need to be 0,047 $m^2$ big assuming we want our CanSat to go 8 m/s.

The formula for terminal velocity is: $v = \sqrt{\frac{2mg}{pACd}}$

We can transform it to get a equation with A: $A = \frac{2mg}{pC_d v^2}$

| where: | in our case: |
|---|---|
| v = velocity | v = 8 m/s |
| m = mass | m = 0,330kg |
| g = gravity | g = 9,81 m/s$^2$ |
| p = air density | p = 1,225 kg/m$^3$ |
| A = area | A = ? |
| Cd = drag coefficient | $C_d$ = 1,75 |

$$A = \frac{2\cdot 0{,}33kg\cdot 9{,}81\frac{m}{s^2}}{1{,}225\frac{kg}{m^3}\cdot 1{,}75\cdot 64\frac{m^2}{s^2}}$$

$$A = \frac{6{,}4746\frac{kg\cdot m}{s^2}}{137{,}2\frac{kg\cdot m^2}{m^3\cdot s^2}}$$

$$A \approx 0,047m^2$$

### 3.7 Ground support Equipment

*3.7.1 Our ground support equipment will contain:*

- Yagi-Uda directional antenna for communication with our CanSat
- Laptop for processing data received from the CanSat and mission supervision
- adafruit RFM96W LoRa module to transfer the data between the antenna and the computer

# 4 TEST CAMPAIGN

## 4.1 Primary mission tests

We will use a BME 680 sensor mounted to our CanSat Shell. We plan to test if our sensors work correctly with our CanSat design by dropping a fully working prototype from a drone from an altitude of about 100m.

## 4.2 Secondary mission tests

For our secondary mission we chose to use Meshroom, an open source photogrammetry software which allows for 3D reconstruction from images. To test the capabilities of this program we performed four tests.

The first test used 40 frames of stock drone flight footage recorded in very high quality (3840x2160). To ensure the distance between all images we collect every 20th frame. This confirmed that Meshroom is capable of creating high quality models. The following image is the result of our first test:

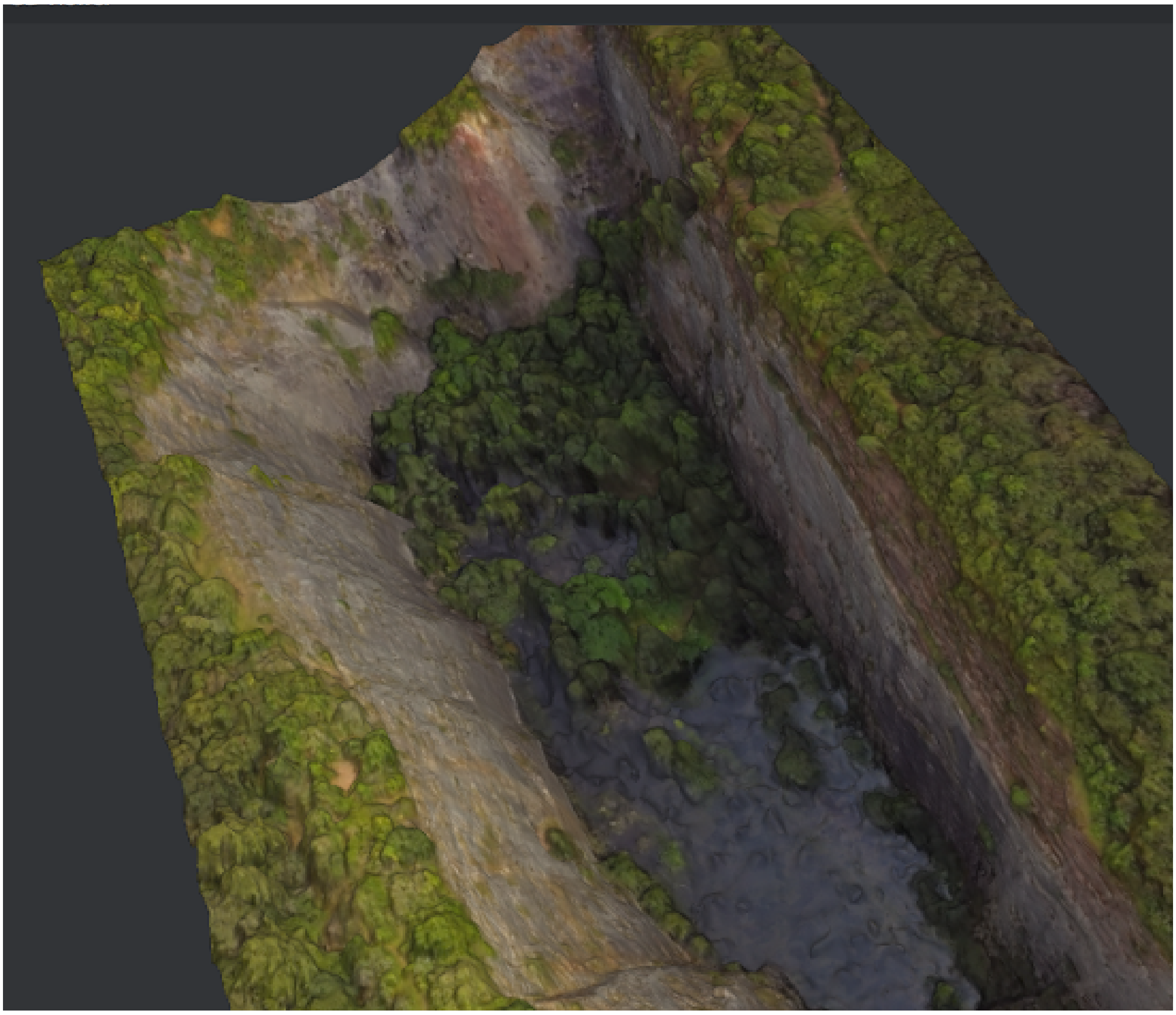


Fig. 7 Results of the first tests of our photogrammetry software

Our second test was concerned with the quality of the images. We used the same images, downscaled to 817x460 and added gaussian blur. We observed lower quality in textures, however the result was still very promising.

Fig. 8 Results of the second tests of our photogrammetry software

Third test was specifically about falling down and how Meshroom performs in vertical motion. This didn't work. We think the geometry was hard to depict because of the chimney. This can be investigated further.

Fig. 9 Results of the third tests of our photogrammetry software

The last test was concerned with heights that we will be operating on. Using a Skydive parachute video, we tested that Meshroom can successfully operate big scales if provided with enough images.

Fig. 10 Results of the fourth tests of our photogrammetry software

In conclusion, Software we currently plan on using is perfectly capable of creating a 3D model with satisfying texture quality.

### 4.3 Tests of recovery system

In the near future, we plan to conduct many different tests to see how our parachute performs under different conditions. The most important thing we want to test is our parachute's flight stability in reference to its connection with our CanSat. We want to see if spreading the connection points with the parachute evenly on the CanSat's top, gives us more flight stability. Another thing that we want to test is how descent speed affects the quality of photos made by our CanSat. Our theory is that the faster the CanSat goes the less time it has to change its horizontal position, which is optimal for photogrammetry. On the other hand, high speeds can cause unwanted turbulence which can worsen the quality of pictures taken. The only solution to this dilemma is to test different descent speeds and compare the differences in quality of photos made during each flight.

### 4.4 Communication system range tests

We need to figure out if our LoRa module is capable of performing the difficult task of sending a photo to the ground station. To test that capability we plan on sending pictures and data collected by our CanSat through the LoRa module. The test will be conducted in different distances to ensure that no matter how far the CanSat will be we'll be able to transfer the data. We will measure the time it took to transfer all of the data and based on the results adjust capabilities of our CanSat.

### 4.5 Energy budget tests

We are planning a test campaign to be sure if our calculations regarding power are correct. The tests will consist of leaving the turned on CanSat to work at the mode which uses the most power. The expected life of our CanSat's battery is around 7h. If the results will vary from our expectations we will need to take action and adjust CanSat's power system to be able to perform as expected.

# 5 PROJECT PLANNING

## 5.1 Time schedule

The table below covers our work plan to the Final Design Review

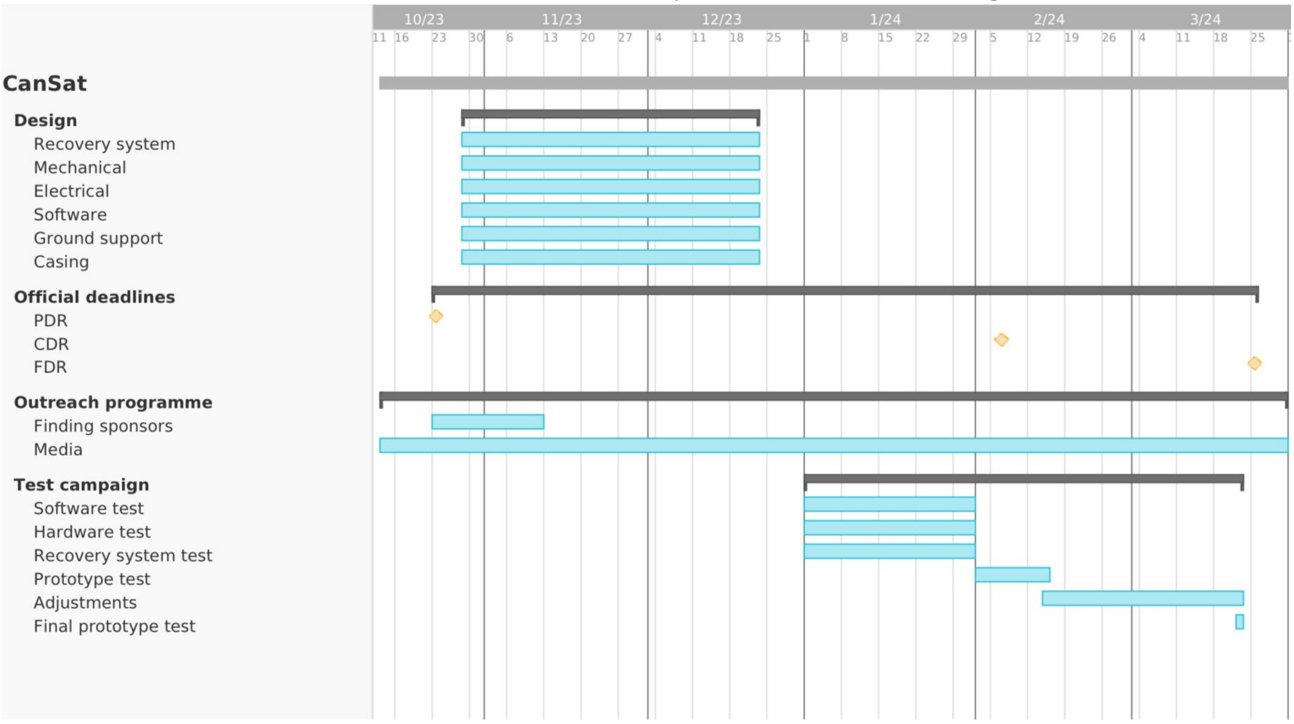



Fig. 11 Gantt chart showcasing our work plan

## 5.2 Task list

| Topic | Person | Topic | Person |
|---|---|---|---|
| **Hardware:** | | **Test Campaign:** | |
| CanSat design | Mateusz Szczotka | Softwear | Jakub Banach |
| Power calculations | Andrzej Borys | Hardwear | Maciej Kobyliński<br>Andrzej Borys<br>Bartosz Purta |
| Mechanical structure | Maciej Kobyliński<br>Andrzej Borys<br>Bartosz Purta | Recovery system | Whole Team |
| Electronic design | Bartosz Purta | Structual tests | Maciej Kobyliński<br>Andrzej Borys<br>Bartosz Purta |
| **Software:** | Jakub Banach | **Media/outreach:** | |
| **Recovery system:** | | Promotion | Maja Gustowska |
| Parashute | Mateusz Szczotka | Social media | Maja Gustowska |
| **Ground station:** | Mateusz Szczotka<br>Bartosz Purta | Finances | Maja Gustowska<br>Mateusz Szczotka |

Fig. 12 Tasklist

## 5.3 Budget

The table below summarises known costs of our CanSat.

| Budget | Total cost PLN - 1173,28 PLN | Total cost euro - 262.84 € |
|---|---|---|
| **Item** | Cost-PLN | Cost-Euro |
| **Filament** | About 10 PLN | 2.24 € |
| **Lora module** | 220.58 PLN | 49.42 € |
| **GPS module** | 78.80 PLN | 17.65 € |
| **IMU module** | 150 PLN | 33.60 € |
| **BME 680** | 100 PLN | 22,40 € |
| **Raspberry PI zero 2 W** | 84,90 PLN | 19,02 € |
| **Raspberry Pi global shutter camera** | 279 PLN | 62,50 € |
| **Raspberry Pi global shutter camera lens** | 250 PLN | 56.01 € |

Fig. 13 Budget

## 5.4 External support

In Poland, schools obtain monthly governmental subsidies for each student diagnosed with autism. One member of our team is eligible for such funding. The headmaster of our school has allowed us to use part of that money to buy some of the needed resources. Despite that funding we have planned an outreach programme. We will apply for educational grants and seek financial support from sponsors.

# 6 OUTREACH PROGRAMME

We want to give our viewers a possibility to get to know more about us and the project. Our plan includes active posting on social media, such as:

**Facebook:** Posts with updates of our work, educational posts explaining technical aspects of our probe.

**TikTok&Instagram:** Posts with general information about CanSat, humorous posts about team members and our work process.

**Twitch:** Regular streams aimed at showing the team's daily work.

In addition we want to apply for a radio show and make our appearance on school events such as open days or PTA meetings.