CanSat 2021
Preliminary Design Review (PDR)
OSATeam, Poland

VIII Prywatne Akademickie Liceum Ogólnokształcące w Krakowie

TABLE OF CONTENTS

CHANGELOG 2
INTRODUCTION 2
Team presentation 2
Team organisation and roles 2
Mission objectives 3
Cansat Description 3
Mission overview 4
Mechanical/structural design 5
Carousel 5
Servomechanism 5
Pumping System 6
Probes 6
Casing 7
Electrical design 7
General architecture 7
Primary mission devices 8
Secondary mission devices 8
Electrical scheme 9
Power supply 10
Communication system 10
Transceiver part of OSACan 10
Ground Receiving Station 10
Software design 12
Recovery system 14
Ground support Equipment 15
Laptop 15
Ground receiving station 15
Chromatograph 15
Basic set of tool and spare parts 15
TEST CAMPAIGN 15
Primary mission tests 15
Measurement tests 15
Data download tests 16
Sending/receiving tests 16
Secondary mission tests 16
Measurement tests 16
Sting System tests 16
Endurance tests 16
SD card test: 17
Tests of recovery system 17
Communication system range tests 17
Energy budget tests 17
Test equipment: 17
Project Planning 18
Time schedule 18
Task list 19
Resource cost estimation 19
Budget 19
External support 20
Outreach programme 20
CanSat characteristics 20

1. CHANGELOG

- One member of OSATeam resigned. The team has now 4 members and faculty advisor.

2. INTRODUCTION

2.1. Team presentation

OSA (in Polish “Opadający Satelita Atmosferyczny” is loosely translated into “Falling Atmospheric Satellite”) is a project of 4 students from one class out from one of Cracow’s high schools, who decided that, apart from school, they wanted to take on a serious project. Together, they decided to take part in the CanSat competition.

2.2. Team organisation and roles

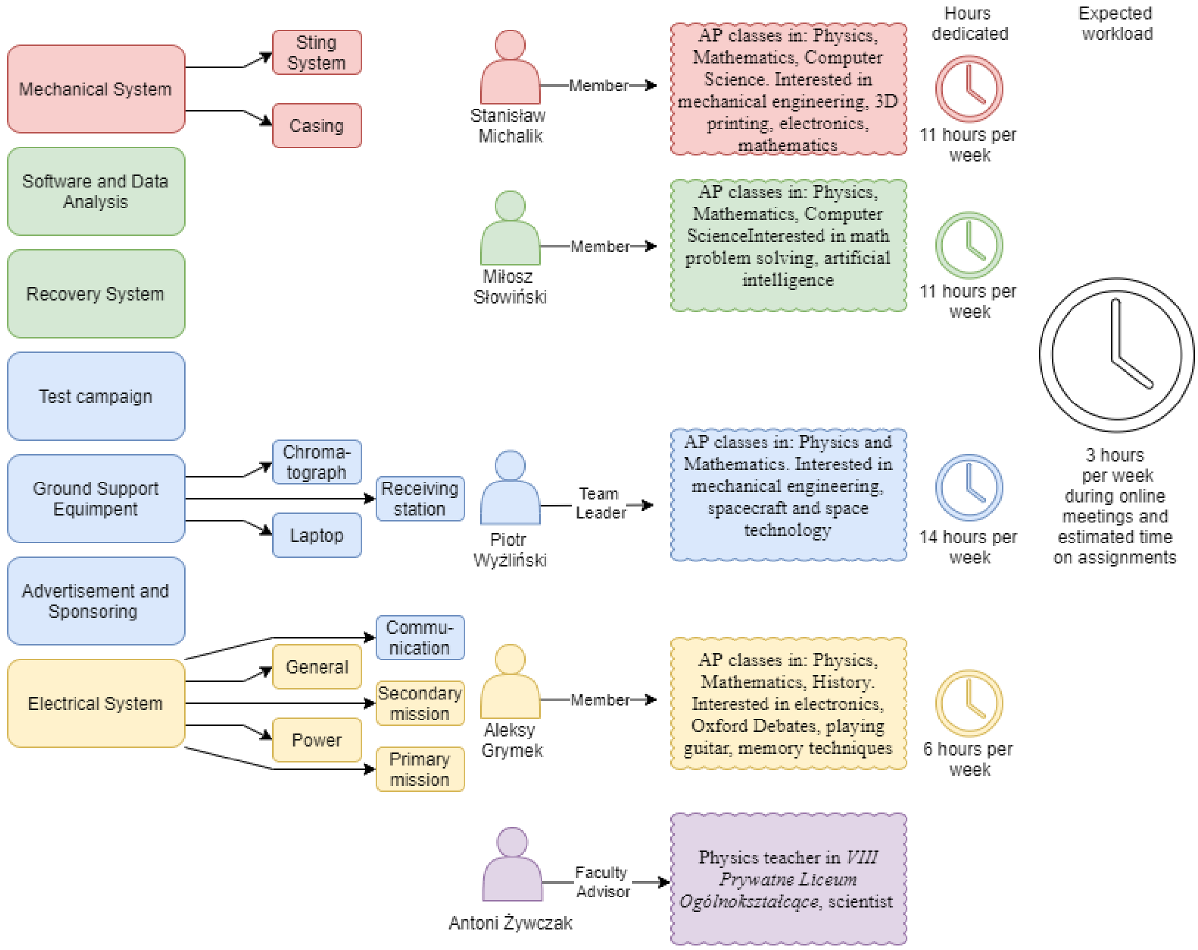


figure 1

2.3. Mission objectives

CanSat's primary mission is to measure the pressure and the temperature of the atmosphere during its descent and to send those measurements to a radio ground station every second. These data will be simultaneously saved in the local CanSat's memory so that it can be analyzed after the satellite lands.

The data from the primary mission will be used to calculate the height from which the CanSat will have been dropped and to calculate live altitude, and hence the speed and the time of the descent. Based on these calculations, there will be adjusted times when the next atmosphere samples are going to be collected (The first sample will be taken when the descent begins. We plan to decide if it will be detected by an accelerometer or by a different device)

The satellite will also provide the GPS location, necessary to locate CanSat after landing. Additional data related to the measurement process itself will be collected at the time of sampling, that is recording initial pressure in tanks, final pressure, filling time of tanks and diagnostic data of the filling mechanism. After analysis, this data will be used to control the filling process. At least 6 atmospheric sample containers are expected to be filled and delivered to ground, and process related data recorded.

The second mission was inspired by information from a recent Venus study, which detected phosphine that could indicate that there was life on this planet. OSATeam wants to test the Earth's atmosphere sampling system so that later a similar solution could be applied to a real mission.

The purpose of our second mission is to show that it is possible to collect samples without building satellites equipped with expensive and heavy research equipment, instead, samples can be effectively collected to be analyzed in an external specialized laboratory. Instead of investing in satellites with multiple sensors, you can invest in building many cheap satellites that collect valuable material for later analysis. The mission aims to demonstrate that this is realistic and that samples can be collected and safely delivered this way.

To ensure the success of the mission, the following goals must be met:

- Recovery system: the parachute must open and ensure a safe CanSat landing
- Electronic system and mechanical structure must work: after flight conditions (rocket acceleration),during descent (changes in pressure, temperature, humidity) and survive landing (impact)
- Sampling system: it must be hermetic, keep the tanks ariditile until sampling, it must not be damaged,
- Communication system: must ensure at least one-way communication (satellite -> ground station) during the flight and after landing,
- Software: must correctly implement the assumed algorithm, save all delivered data and send it by radio.
- Power supply system: must be safe, the energy reserve must be sufficient for the assumed number of working hours.

Optionally, samples collected during the tests will be tested for their composition in external laboratories. The analysis of the Earth's atmosphere could, for example, show that air pollutants (carbon dioxide, methane, ozone, freons, microplastics) can be detected in the air not only at the Earth's surface, and that the amount of pollutants varies depending on air humidity, altitude.

3. CanSat Description

3.1. Mission overview

The OSACan is designed to be launched and dropped from a rocket or drone from an altitude of 500-2500 meters. After equalizing the forces, CanSat should drop at a speed of about 6 meters per second. The most important task of CanSat is to collect atmospheric samples into sealed containers while falling, using a sampling and filling mechanism at various heights. The samples are meant to be safely delivered to Earth, which requires proper protection of the probes against damage or leakage.

CanSat will descend on a parachute that will expand spontaneously as soon as it is dropped out of a rocket or a drone.

The satellite will be equipped with sensors to measure the parameters of the atmosphere outside the satellite (pressure, temperature and air humidity) and the parameters of the collected samples (pressure in the tank). The on-board computer will be responsible for the acquisition of data from sensors, their recording on the SD card and control of the radio communication system. It will also be responsible for starting and checking the air filling system for containers.

The radio communication system is designed to send these data at least once a second using a radio transmitter to the ground station, both during descent and after landing.

The GNSS module connected to the on-board computer will provide information about the current CanSat position based on the reception of GPS, Galileo or Glonass signals. The signal will be transmitted for at least 5 hours to make it easier to find CanSat after landing.

The *Mechanical Subsystem* (sampling and probe filling) is a key element of the second mission. A special sting system has been designed to fulfil the purpose of filling. An atmosphere sample at a certain altitude will be sucked from the outside of the CanSat by a gas pump. The gas, compressed to about 0.5 atm, will be forced into the vacuum tube by means of a needle piercing the sealed stopper. Several test tubes will be arranged around the CanSat circumference so that samples at atmospheres of different heights can be collected. In order to fill the next tube, a rotating system (the so-called carousel) was designed, driven by a stepper motor. The vertical position of the needle will be servo-controlled. The moment the tube is full will be identified by the pressure sensor. The mechanical subsystem is controlled by the **Microcontroller Subsystem** based on CanSat Kit pcba and additional pcba shield. All are powered by battery and **Power Supply System.** The microcontroller subsystem sends data to **Ground Receiving Station** using the LoRa radio module. Block diagram (figure 2) presents the proposed architecture of the whole system.

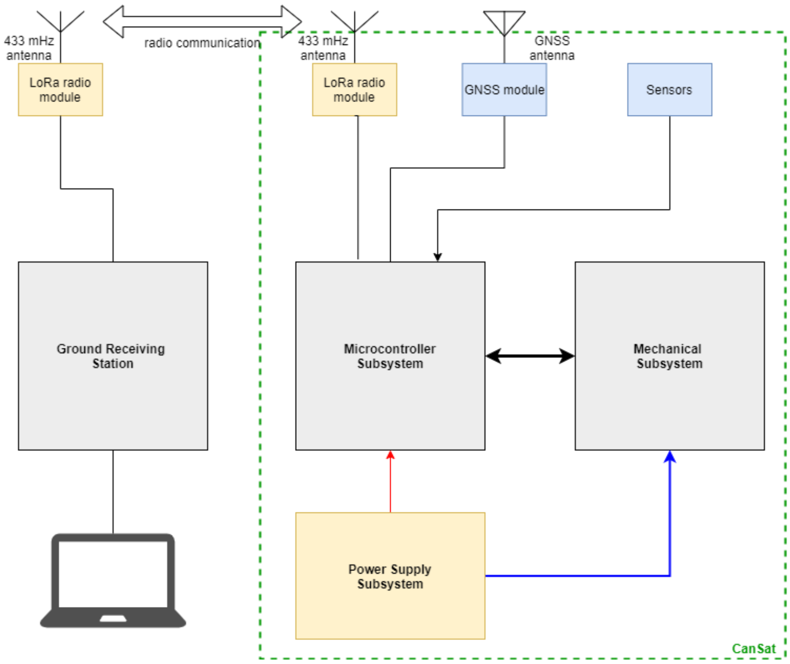


figure 2

3.2. Mechanical/structural design

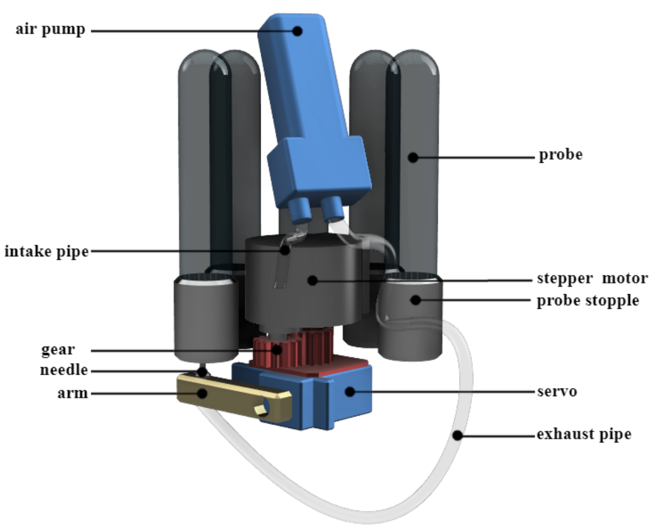


Figure 3 presents the Sting System. A pump will be used to collect air samples. Its inlet will lead to the outside of the CanSat and its outlet will lead to the needle. The needle will be driven into the test tubes by a servo with a special arm. To fill another tube, the servo will be rotated by a stepper motor.

← figure 3

3.2.1. *Carousel*

The carousel (figure 4) is designed to turn the servo. It uses a stepper motor and a gear. The motor does not have a centered shaft, therefore a gear consisting of two gears will be printed on a 3D printer.

28BYJ-48 stepper motor (figure 5): It was chosen due to the fact that it is the smallest stepper motor on the market with low voltage supply in a reasonable price range in the shape of a cylinder.

- Supply voltage: 5 VDC
- Current consumption per coil: 100 mA
- Number of phases: 4
- Gear: 64: 1
- Number of steps per full revolution: 64
- Rotation angle per step: 5.625 °
- Torque: 0.3 kg * cm (0.03 Nm)
- Frequency: 100Hz
- Resistance: 50? ± 7%
- Weight: 35g
- Price: 1.94 €

The motor is pressed onto the body, also holding the test tubes around it (figure 6).

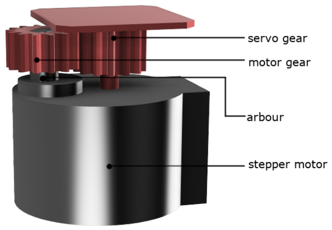


figure 4

figure 5

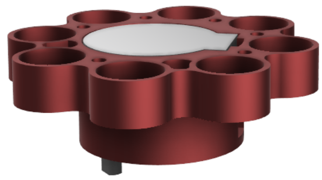


figure 6

3.2.2. *Servomechanism*

The servomechanism (*figure 7*) is designed to stick the needle into the next test tubes. The main part is a micro servo that moves the arm along with the needle, which is connected to the pump by a rubber tube. The micro servo will be glued to one of the gears (*figure 8*).

Servo Hitec HS-55 - micro (figure 9): it was chosen for its low supply voltage, high quality and reliability, extreme accuracy, metal gears and very small dimensions.

- Supply voltage: 4.8 V to 6.0 V
- Range of motion: 0° to 180°
- Dimensions: 23 x 12 x 24 mm
- Cable length: 160 mm
- Weight: 8 g
- Parameters for 4.8 V:
- Power consumption:
    - 5.5 mA - idle state
    - 150 mA - movement without load
    - Torque: 1.1 kg * cm (0.108 Nm)
    - Speed: 0.17 sec / 60 °
- Price: 12.91 €

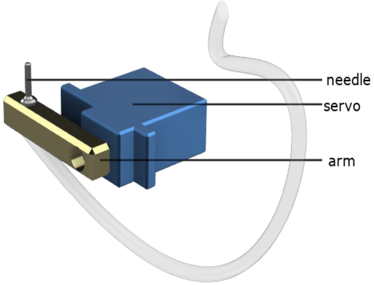


figure 7

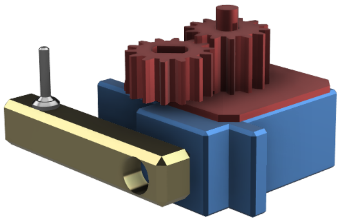


figure 8


figure 9

3.2.3. ***Pumping System***

The pumping (figure 10) system is designed to collect an air sample at a specific height. One inlet gas is withdrawn and the outlet is blown into the tube through the needle.

[Boden Micro Pump BD-1004BV](#) (figure 11): The pump has a pressure of approx. 0.5 atmosphere. It has been pre-selected due to its small dimensions, and two outlets, one taking in air, the other blowing it out.

- Pressure: -50kpa, Low Pressure
- Voltage: 3V / 6 VDC
- Power: 2 ~ 3W
- Rated Volt: DC3.0V
- Current: ≤400mA
- Flow: ≥0.6LPM
- Inflating time: ≤30S (100CC)
- Noise: ≤60dB (A)
- Dimension: 47mm x 21mm x 12mm
- Weight: 20g
- Price: 8.44 €

The pump will be attached to the body as shown in *figure 12* (beveled as it fits diagonally), and the air supplied and exhausted is as shown in *figure 13*.

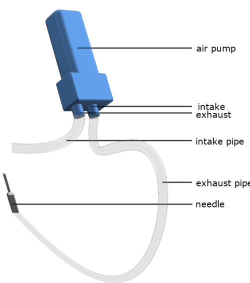


figure 10

figure 11

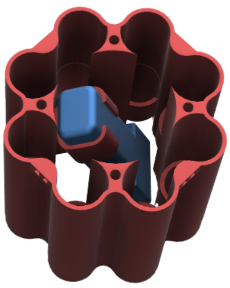


figure 12

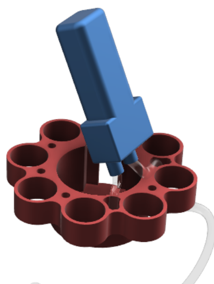


figure 13

3.2.4. ***Probes***

They are a container for air samples. They are made of thin glass and plastic closures. *The Vacumed® probówka neutralna na 4 ml krwi 13x75mm ja łowa, korek czerwony* (figure 14) model was chosen. Tubes are sterile, vacuum sealed, and used in blood collection systems. Filling is done by puncturing the stopper with a needle. After removing the needle, the hole seals itself. Their price is: 9.68 € for 100 pieces. It is important that the container (test tube) has no contamination, it should be as sterile as possible and empty of gases. The test tubes will be attached to the casing by pressing (figure 15 & 16), so that they can be easily removed and the samples can be examined. To replace with new tanks, just remove the casing, take out the old ones and replace with new ones.


figure 14

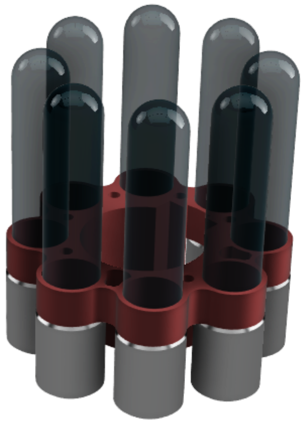


figure 15


figure 16

3.2.5. ***Casing***

The entire casing *(figure 17)* will be printed on a 3D printer, in addition, the most delicate elements will be additionally secured with a sponge.

The casing is designed to:

- provide the basis for mounting the satellite components,
- protect mechanical and electronic components from damage,
- prevent CanSat elements from moving, protect them from high G-force.
- protect the test tubes from breaking and, if they do break, protect them from injuring people who find OSACan after landing
- provide quick access to the CanSat interior, including the battery
- enable any mechanical elements to operate freely,
- protect the inside of the satellite from outside conditions (temperature, humidity, air momentum when falling)

The casing has no bottom, as more space was needed for the movement of the arm with the servo.Figures 18, 19, 20 show 3 parts of casing. Reason for using 3 different parts is to ease access to inner elements. All mechanical and electrical components will be inside the main part as well as above CanSat Kit.


figure 17

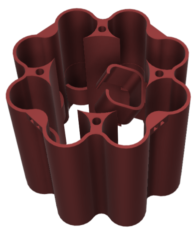


figure 18

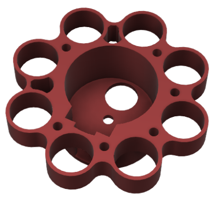


figure 19

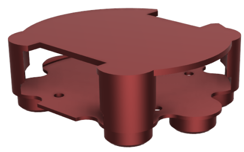


figure 20

3.2.6. **Electrical design**

3.2.6.1. ***General architecture***

The general architecture is presented on the following diagram. The concept of the microcontroller subsystem is based on ready-to-use CanSat Kit and pcba shield with additional elements.Elements are marked in:

- yellow - located in the main pcba (CanSat Kit)
- blue - pcba shield (to be developed)
- violet - outside pcba, mounted directly to the housing body.

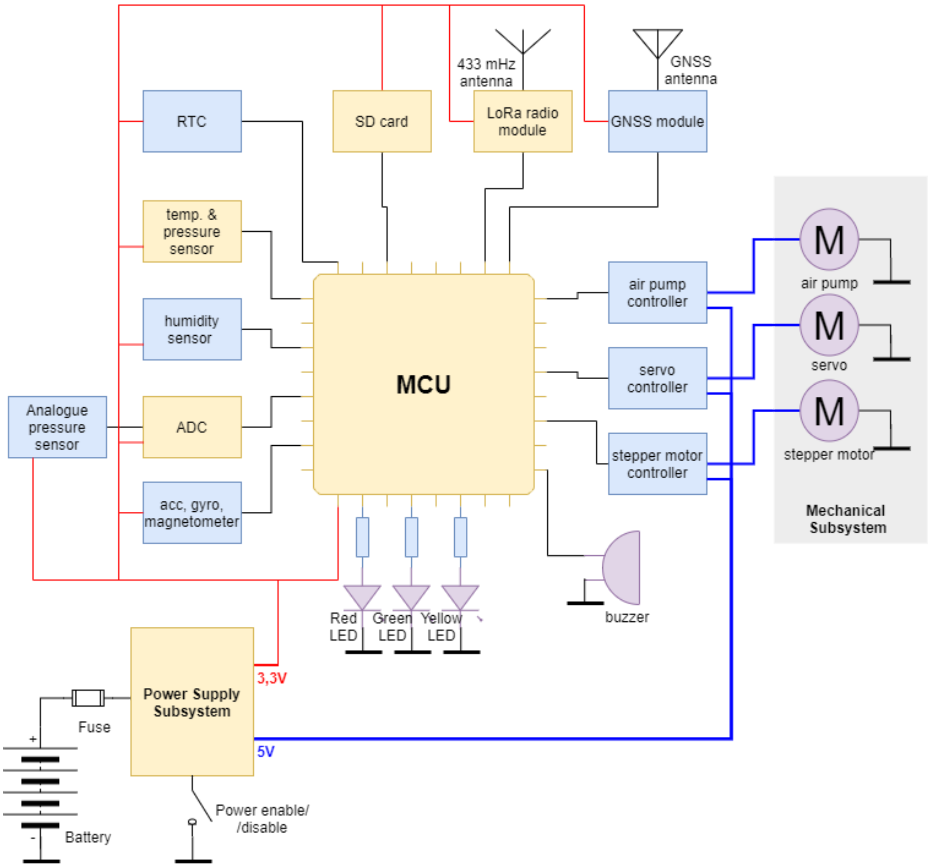


figure 21

Some elements are selected, other elements will be selected during the prototype phase.

3.2.6.2. ***Primary mission devices***

- Temperature sensor: Model - LM 35 (figure 22)
    - Used for measuring temperature at certain height
    - Temperature range - (-55*C)-150*C, Measuring in Celsius, Accuracy to 0,5*C, Voltage: 4V-30V
    - We are using this particular one because it is attached to the integrated circuit
    - Price : 0,33 €
- Atmospheric Pressure sensor: Model - BMP280 (figure 23)
    - Used for measuring atmospheric pressure at certain height
    - Atmospheric pressure range - 300-1100 hPa, Accuracy to 1hPa, Voltage 3,3 V
    - We are using this particular one because it is attached to the integrated circuit
    - Price : 0.52 €
- Radio module: model SX1278 RA-02 LoRa 433MHz
    - (described in 3.2.6.5.1, communication system Transceiver part of OSACan)

3.2.6.3. ***Secondary mission devices***

- Pressure sensor: model - MPXM2202AS (figure 24)
    - Output Type - Analog, Pressure Range (kPa) 0-200, Pressure Rating (MAX) (psi) - 29, Supply voltage [typ] (V) - 10.
    - It's purpose is to measure pressure inside the probes
    - Price : 9,60€

- Humidity Sensor: model - [HIH-4030](figure 25) (figure 25)
  - 4-5.8VDC voltage supply, All pins broken out to a 0.1" pitch header, Laser trimmed interchangeability, Low power design, typical current draw of only 200µA ,Enhanced accuracy, Fast response time, Stable, low drift performance, 0.75 x 0.30 " (19.05 x 7.62 mm .
  - It is very small, durable and quite enough accurate
  - Its purpose is to measure air humidity inside the probes
  - Price : 23.99€
- Accelerometer, magnetometer, gyroscope - LSM9DS1 (figure 26)
  - Used for checking weather the parachute is open or not
  - Voltage: 1,9V - 3,6 V
  - 3 axis x,y,z
- Boden Micro Pump BD-1004BV
  - (described in Pumping System)
- Servo Hitec HS-55 - micro
  - (described in Servomechanism)
- stepper motor - 28BYJ-48
  - (described in Carousel)
- Location system
  - not selected yet ; dependable on other variables


figure 22

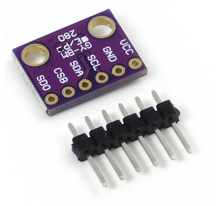


figure 23


figure 24

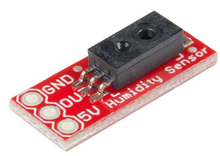


figure 25

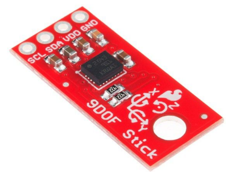


figure 26

3.2.6.4. ***Electrical scheme***

We started drawing the electrical schematic of pcba shield in KiCad software. The preliminary version is presented in the figure 22

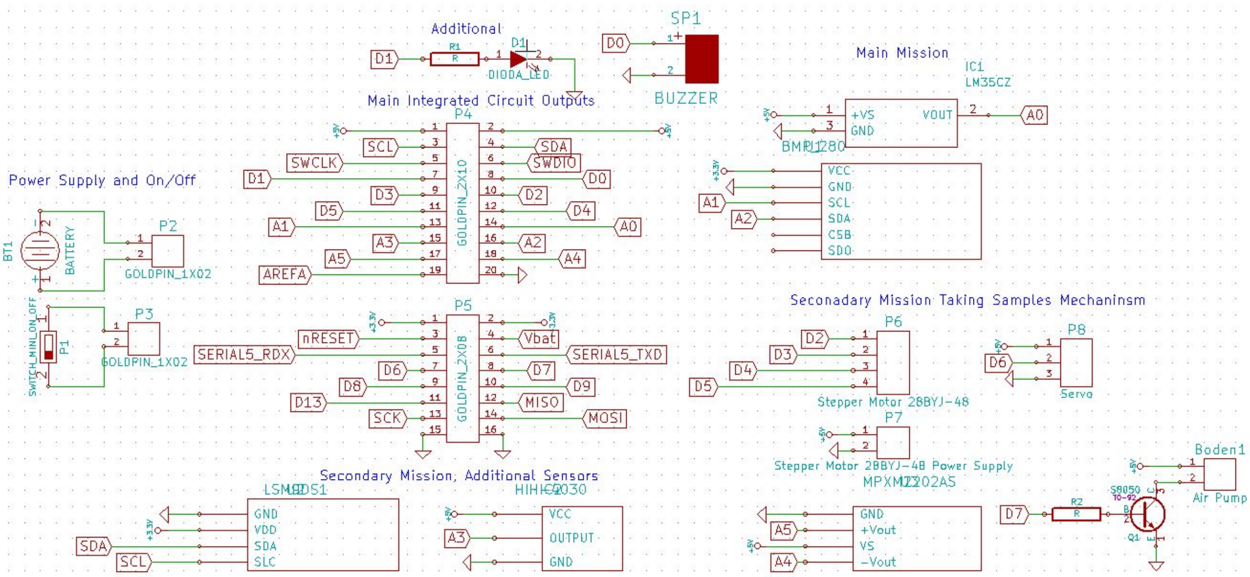


figure 27

3.2.6.5. ***Power supply***

Batteries will be selected in the next phase of the competition to fit our demands after we conduct tests regarding the electrical modules.

3.2.6.6. ***Communication system***

The following assumptions were made for the communication system:

- communication between the satellite and the ground receiving station is one-way, that is from CanSAT to the ground station
- communication takes place in the 433 MHz public band
- the radio layer of communication will take place with the use of ready-made LoRa modules
- power cannot exceed 20 dbm (as required)
- the satellite antenna must fit in the assumed dimensions of the satellite, it must extend to a certain length along with the parachute deployment.

To achieve the goal it is necessary:

- Equipping the satellite with a LoRa micro-transmitter with an antenna.
- Building a ground receiving station with a directional antenna.

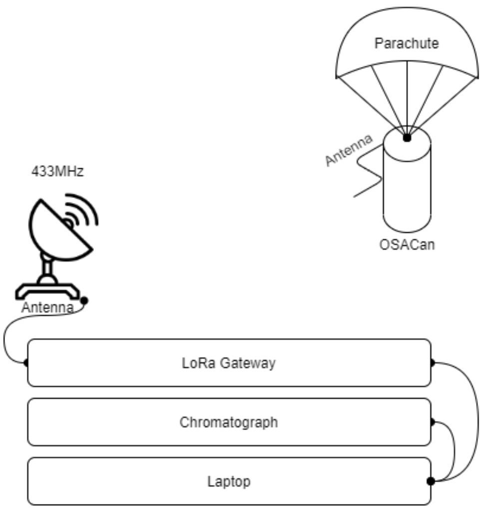


figure 28

3.2.6.6.1. Transceiver part of OSACan

SX1278 RA-02 LoRa 433MHz module - installed in CanSat Kit:

- Range: 10-15km
- Sensitivity: -148dBm
- Transmission speed: up to 300kbps
- Working frequency: -148dBm
- Supply voltage and work: 1.8-3.7v
- Working temperature: -40- + 80 ℃
- Communication method: LoRa
- RF transmitter power: + 20dBm-100mW
- Communication: SPI
- Price: Included in the CanSat Kit price

3.2.6.6.2. Ground Receiving Station

will consist of:

- LoRa Gateway
- directional antenna,
- antenna cable (50 Ohm)
- the necessary software ensuring the receipt of messages,

LoRa Gateway

A ready-made LoRa Gateway solution can be used as the receiving device. There are many such devices on the market, the final purchase decision will be made depending on availability at the time of implementation and delivery time. Examples of available devices:

LoStik open source USB LoRa device by Ronoth (figure 28)
LoStik by Ronoth is an easy to use, open source USB LoRa device. It was chosen because of the best documentation of all available devices, open source software and programmable leds.

- Frequency Range:433/868Mhz
- Connectivity: USB 2.0
- Power Consumption: 140 mA typical TX, 20 mA idle (with power LED)
- Dimensions:80 mm x 25 mm x 12 mm
- Receiver Sensitivity: down to -146 dBm
- TX Power: adjustable up to +14 dBm
- Chip: Microchip RN2483
- Range: 5-15 km
- Price: 38.92 €

iFrgoLab LoRa USB gateway (figure 29)
for Raspberry Pi, Linux, Windows, Mac LoRa, LoRaWAN, IOT, 433/868Mhz, SPI Data Interface Sensitivity: -137dBm, Output Power: +20dBm is alternative for USB LoRa device by Ronoth.

- Frequency Range: 433/868/900/915 Mhz
- Connectivity:USB 2.0
- Power Consumption:unknown
- Dimensions: unknown
- Receiver Sensitivity: down to -137 dBm
- TX Power: adjustable up to +20.0 dBm
- Chip: Semtech SX1272
- Range: up to 15 km
- Prize: 50.69 €

Both LoRa gateway devices are connected to the USB 2.0 port and can work with Linux / Windows operating systems. If you need to bring the gateway closer to the antenna, you can use a USB extension cable for example:
Delock USB 10.0m czarny (figure 30)
A USB extension cable is needed to connect LoStik to a laptop. It was chosen due to its availability in the country, length and the appropriate price and quality.

- Standard: USB
- Ending 1:1 x USB 2.0 (typ A)
- Ending 2: 1 x USB 2.0 gniazdo (typ A)
- Length: 10 m
- Price: 15.25 €

Gateways are standard equipped with a broadband omnidirectional antenna, which is most likely to have a poor signal gain for communication with CanSAT. The antenna is not permanently attached, an extension cable with an impedance of 50 Ohm can be connected to the derived SMA antenna connector, to which the directional antenna will be connected:
Delock RP-SMA male / RP-SMA female 2m black (figure 31): Flexible and easy-to-use antenna extension cable allows you to position the antenna anywhere. The HF cable is characterized by its low-loss.


figure 28

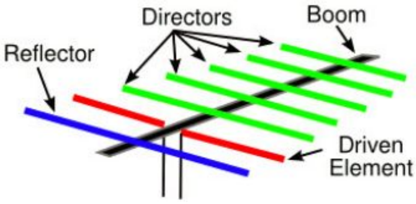

photo 29

photo 30


photo 31

Ground station directional antenna

A sensitive receiving circuit is required over long distances. One way to increase the sensitivity is to use an antenna with a good gain. Antennas with directional characteristics work well in such applications, for example [the Yagi antenna]:



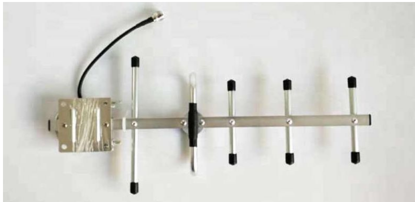
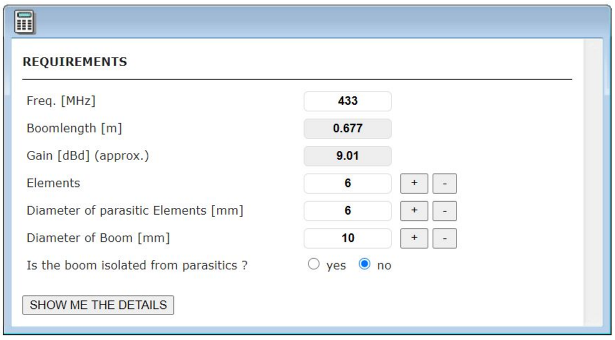


figure 32 figure 33

We plan to build such an antenna ourselves. It will be built of a boom made of a rectangular metal profile 10 x 10 [mm], it will be equipped with transverse active elements made of aluminum tube 6x6 [mm] and folded dipoles also made of aluminum tube 6x6 [mm]. The construction and dimensions will be calculated using "Yadi Una Antenna Calculator". For example, for a 6-element antenna we need a mast length of approximately 0.7 m and it will be possible to obtain a gain of approximately 9 dB.



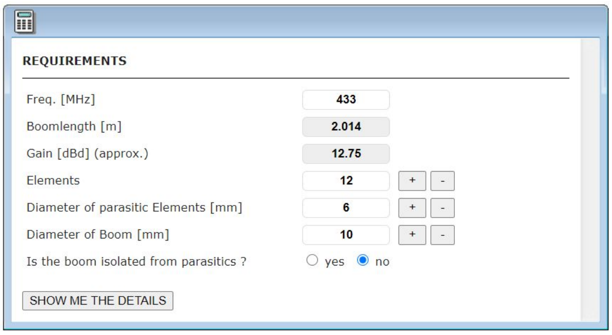


figure 34 figure 35

A gain of 12 dB requires a 12-element antenna with a length of 2 m.
The CJU type antennas also have very good parameters, which we can also try to make ourselves.

Satellite radio system

The transmitting antenna in the simplest case is a wire of appropriate length, being the wavelength λ or its fraction (eg λ / 2, λ / 4···). It is important to tune the antenna, that is, cut the cable to the correct length. For a wave with a frequency of 433 MHz we have a wavelength according to the formula

$$\lambda = c*T = c/f$$

where c = 299 792 458 [m / s] is the speed of light, T is the period, f = 433 [MHz] is the frequency which gives the following possibilities:

- for a full-wave antenna (λ) we have the antenna length 69.24 [cm]
- for a half-wave antenna (λ / 2) we have the antenna length of 34.62 [cm]
- for a quarter-wave antenna (λ / 4) we have the length of the antenna 17.31 [cm]

It will be best to use a full-wave or half-wave antenna, we anticipate that it will develop along with the parachute lines. The length of the antenna will be finally selected during the implementation of the recovery system (parachute).

3.3. Software design

Software should cover the support of CanSat Kit Hw v.1.4 and our additional shield with planned pheripherials. Our team will develop the software on microcontroller using the Arduino toolchain.

The preliminary software architecture is described in figure 36:

- state-1: CanSat in this state is waiting for deployment. No primary and secondary activities, due to battery capacity limitation. Main loop is waiting for trigger signal (parachute deployment)

- state-2: satellite realizes primary and secondary missions. This is the crucial part of our software. Details on Diagram. We assume that the unit runs in state-2 no longer than 10 minutes. After the landing it finishes missions and goes to next state
- state-3: unit send periodically the GPS position to the ground receiving station and switch on the buzzer.

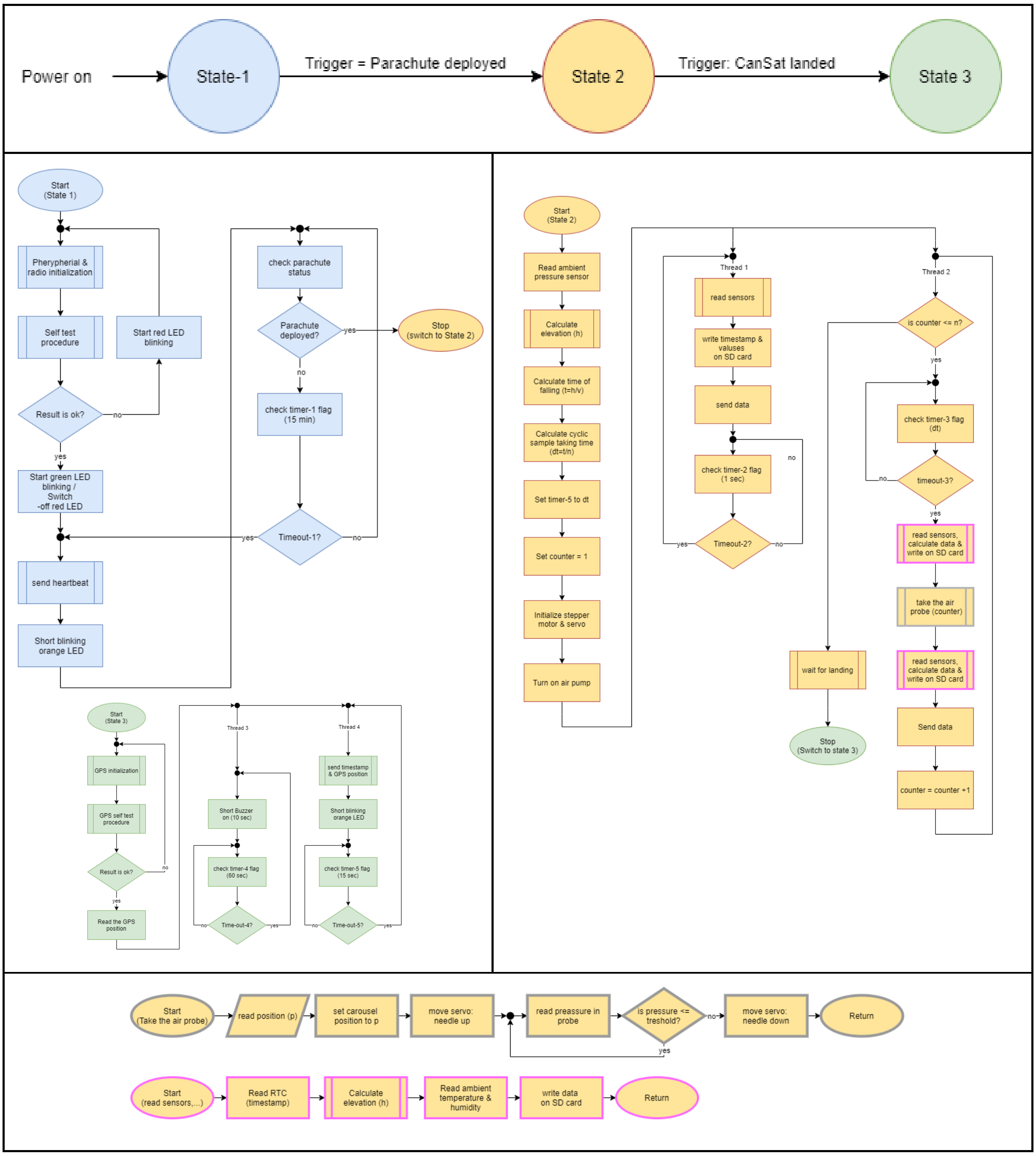


figure 36

3.4. Recovery system

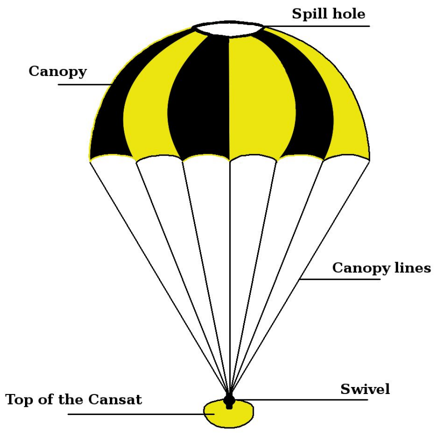


figure 37

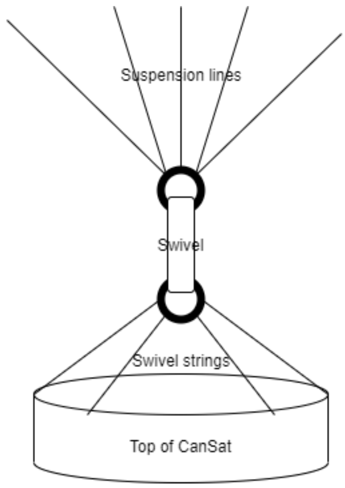


figure 38

As a recovery system we have decided on using a parachute. The drag force, which can be easily calculated, will allow our precious cansat to fall with targeted speed. We did not want our cansat to drift too far into the distance, however we needed for our probes to land relatively safely so we decided on terminal velocity equal eight meters per second. Using the terminal speed equation we can figure out the area of the chute. Out of the most popular parachute canopies such as square, cross or round canopy the last has the highest drag coefficient thus will assure the lowest area. In the middle of the canopy there will be located a spill hole that will keep the chute from tilting sideways. The ratio between spill hole area and canopy area will measure 1/20. Furthermore we will be connecting canopy lines to the cansat using a ball bearing swivel that will help prevent line entanglement. The length of the canopy will be 20% longer than the canopy radius.

- Air density approximation ρ = 1.225 [kgm3]
- Gravity acceleration approximation g = 9.81 [ms2]
- Cansat mass approximation m = 0.35 [kg]
- Drag coefficient for round type canopy Cd = 1.3
- Terminal velocity of Cansat V = 8 [ms]
- Pi constant approximation π = 3.1415
- A - area of the canopy
- R1 - radius of the canopy
- R2 - radius of the spill hole

$$V = \sqrt{\frac{2 \times m \times g}{C_d \times \rho \times A}}$$
$$A = \frac{2 \times m \times g}{C_d \times \rho \times V^2};$$
$$A = \pi \times (R_1)^2 - \pi \times (R_2)^2$$
$$A = \pi \times (R_1)^2 - \pi \times (R_1)^2 \times 5\%$$
$$A = \pi \times (R_1)^2 \times 95\%$$
$$R_1 = \sqrt{\frac{A}{0.95 \times \pi}}$$
$$5\% \times A = \pi \times (R_2)^2$$
$$R_2 = \sqrt{\frac{0.05 \times A}{\pi}}$$

Parachute will be made out of:

- swivel: Apogee 220# ball bearing swivel (figure 39)
  - weight: 4.2 [g]
  - price: 3.83 €

  Swivel will be hitched with 4 strings, attached to the top of CanSat (scheme 7). The reason for using a swivel is to make sure lines will not muddle.
- canopy fabric: ripstop nylon fabric 1.5 x 1.5 [m] (figure 40)
  - weight: 64.42 [g/m²] - (parachute canopy itself will weight around 9[g])
  - price: 9.83 €
- canopy lines: 25/50 / 100FT 550 Paracord Parachute Cord (figure 41)
  - price: 0.87 €

figure 39

figure 40

figure 41

3.5. Ground support Equipment

The ground support system will consist of the following components:

- Laptop
- A ground receiving station, consisting of:
  - directional antenna,
  - antenna cable (50 Ohm)
  - LoRa Gateway,
  - the necessary software ensuring
  - the receipt of messages,
- spare battery pack for CanSat
- optional laboratory facilities
- portable chromatograph,
- data analysis software.
- basic set of tools and spare parts.

3.5.1. Laptop

Any model with Linux or Windows, suitable computing power and a USB input. It will have special software installed to present the data collected on the mission.

3.5.2. Ground receiving station

(described in communication system)

3.5.3. Chromatograph

The chromatograph is a very expensive device, we are not going to buy it. We decided on borrowing it from one of the sponsors or from the university[1] [2] [3]. That is the reason we do not have a specific model inscribed yet.

An alternative is also to deliver the collected gas samples to the sponsor's laboratory or the university (if the loan approval could not be obtained).

3.5.4. Basic set of tool and spare parts

4. TEST CAMPAIGN

4.1. Primary mission tests

4.1.1. Measurement tests

- **pressure sensor test**: this will involve exposing the used sensor to a pressure change and comparing the results with a reference device. A special pressure chamber will be used for this type of tests, from the AGH laboratory. In the event that such equipment is not accessed, the target and reference sensors will be inserted into a sealed container where the pressure will be increased by a compressor or both sensors will be taken upwards where the pressure will decrease with increasing altitude. It is estimated that the test will last 6 hours, which is the assumed maximum time that CanSat should be

[1] http://www.wggios.agh.edu.pl/badania-naukowe/laboratoria-i-aparatura/laboratorium-chromatografii-gazowej/
[2] https://www.jagiellonskiecentruminnowacji.pl/laboratoria/laboratorium-chromatografii-i-spektrometrii-mas/
[3] https://kghmcuprum.com/o-nas/zaklady-badawcze/laboratorium-zagrozen-pylowo-gazowych-i-klimatycznych-nl-3/

found after a fall. The test will be considered positive when both sensors show the same pressure without measuring errors.

- **temperature sensor test**: it will consist in checking whether the target device and the reference device will show the same temperature within 24 hours

4.1.2. Data download tests

- After positive results of the measurement tests, the data download system will be checked. The device will be turned on successively longer and longer periods and left for measurements. After this time, the collected data on the SD card will be validated for completeness and the occurrence of errors.

4.1.3. Sending/receiving tests

- The first test will be multiple initiation of communication (connect / disconnect). Once everything is running, the communication system will undergo a long-term test of continuously sending and receiving data one by one. It will be checked whether all the data has arrived and whether there have been any delays. Finally, the system will be tested for radio interference. Signals of a similar frequency will be sent from another transmitting device. Ultimately, this should not affect the received data, but it may introduce delays.

4.2. Secondary mission tests

divided into measurements tests (pressure, humidity, location), Sting System tests, saving data to SD card tests:

4.2.1. Measurement tests

- **Analogue pressure sensor test**: (described in 4.1.1 - Measurement tests, pressure sensor test)
- **Humidity sensor test**: will be tested in an airtight container where the humidity will be increased by the evaporating water. The measurement should be the same as on the reference sensor.
- **Location test**: the measurement from the GNSS system will be compared to that from a smartphone.

4.2.2. Sting System tests

The test consists of a mechanical system test and general endurance tests.

- -mechanical system test:
- -stepper motor with gear in terms of precision and speed of rotation
- -the servo will be checked together with the arm. The needle should hit the rubber opening of the test tube precisely without breaking
- -pumping system: tubing system, pump and tubes must be tight. In a closed system, it will be tested whether the appropriate pressure will be achieved (0.5 atm). Additionally, it will be measured whether this pressure is obtained in a timely manner.

4.2.3. Endurance tests

- **Drop resistance test**: OSACan will be attempting a crash test. Under normal conditions, when the parachute opens, no element, including the casing, should be damaged, especially important when yanked when the parachute is unfolded as well as when hitting the ground. Also, all internal components should not move, the electronics should work continuously. To test this, CanSat prototypes will be dropped from a height sufficient to achieve the descent speed (from a tower or drone). A fall test without a parachute is also planned, from a height such as to obtain a falling speed 2-3 times faster than assumed. Optionally, it is envisaged to add a 3-axis accelerometer to the electronics board (if within budget and weight constraints) to record any G-force.
- **Long-term G-force tests**: during rocket transport, G-force up to 20G may occur. In order to simulate such G-force, we plan to perform an experiment consisting in placing the satellite model on a carousel or string, introducing the satellite into rapid rotation. It is possible to achieve the required overload due to the centrifugal force.

$$G = \omega^2 R$$
$$G = \frac{4\pi^2 n^2}{\Delta t^2} R$$

G - gravitational acceleration
ω - angular velocity
R - string length
n - quantity of rotations
t - time of rotating

- **Shock resistance test**: CanSat will be put into a special shaker (AGH equipment). Ultimately, during long-term shocks (tests on the order of 1 hour), no element is to be damaged, slipped out or significantly moved.

4.2.4. ***SD card test:***

will be tested for correctness of writing, storing and reading data (test program)

4.3. **Tests of recovery system**

- **Parachute deployment test**: this will consist of mounting the parachute to a load equal to the weight of the CanSat, and then dropping it from ever greater heights. Initially, it will be thrown from buildings and hills. When tests at higher altitudes are required, a drone will be used to drop it, to which a specially designed CanSat detachment system will be connected. Ultimately, the parachute must fully open within the specified time. to make any possible amendments, the testing process will be recorded and analyzed on this basis.
- **Parachute test for various weather conditions**: parachute with the weight attached will be dropped during: rain and / or wind. The test result will be recognized as successful only if the parachute is fit for reuse
- **The flight path and its speed test**: The dummy-mass model during the fall will be recorded and then analized in *Tracker by Physlets* in terms of flight stability and falling speed. Additionally, the moment of opening the parachute from the analysis should be consistent with that of the accelerometer.

4.4. **Communication system range tests**

- The signal strength test will be performed, whether we achieve the assumed radiation power, but also whether we do not exceed the permissible amount of emitted power as well as electromagnetic disturbances. Such tests are performed in anechoic chambers designed to measure EM emissivity. The necessary measuring equipment (chamber, carrier wave generator, exposure emitter, analyzer) is beyond our reach, we intend to reach a professional laboratory (AGH, Sponsor)
- The maximum achievable range of CanSat under different conditions is measured:
  - In open space - expected measurement 10 km
  - in urban built-up space - expected measurement 3 km
  - measurements should be consistent with the calculations of Fresnel zones
- Additionally, a range and communication test will be performed during: freefall, a balloon or a drone flight. Ultimately, communication with CanSat should be up to 3 km vertically, it will probably be difficult to reach this height, however based on measurements at a lower altitude and the theory of wave propagation in the atmosphere, we plan to estimate the result .

4.5. **Energy budget tests**

The power supply system must guarantee the supply of the entire system for the duration of the mission, according to the recommendations, we expect that the battery will last for 8 hours of operation, but we divide this time into the following periods (modes):

1. from satellite activation to deployment (Basic Mission functionality enabled) - 4 hours
2. from deployment to landing (full functionality enabled: primary + secondary mission) - up to 10 minutes (down from 2,500 km by parachute)
3. From landing to being found (Basic Mission functionality with GPS data enabled) - up to 4 hours

In order to test whether the capacity of the selected type of battery that will be determined at a later stage - is appropriate, we will perform:

- measurement of current consumption by systems and components in modes 1,2, 3 and calculation of energy consumed
- checking the actual capacity of the battery by loading it with a simulated resistive receiver
- under normal conditions
- at low temperatures (the battery
- may lose its properties)

Maximum device operating length test under real conditions, covering all 3 modes

- we assume that the battery will be discharged to a maximum of 80%, and the voltage of cells connected in series will not drop below 5V.

4.6. **Test equipment:**

- reference sensors (pressure x2, humidity, temperature),
- phone - gps,

- recommended sensors inside the satellite (accelerometer, battery voltage)
- voltmeter + ammeter
- Power Supply

5. Project Planning

5.1. Time schedule

For the project schedule we plan to use the web Gantt tool https://app.teamgantt.com/ . The basic tasks were divided into a few week periods and planned, the effect is shown on figure 42. Main steps are:

- Ideation - finished
- Design - work-in-process
- Prototyping - work-in-process
- Tests (prototype) - to be defined (tbd) in details
- Construction (Run A) - tbd
- Test campaign (Run A) - tbd
- Construction (Run B) - tbd
- Test campaign (Run B) - tbd
- Competition - we hope to participate

Run A will be the first of our construction, probably with a set of mistakes. Run B means the second and final construction, improved after Run B. We plan to order the whole BOM twice to support both Run A and Run B.

At the same time we plan to carry out activities related to:

Outreach programme:

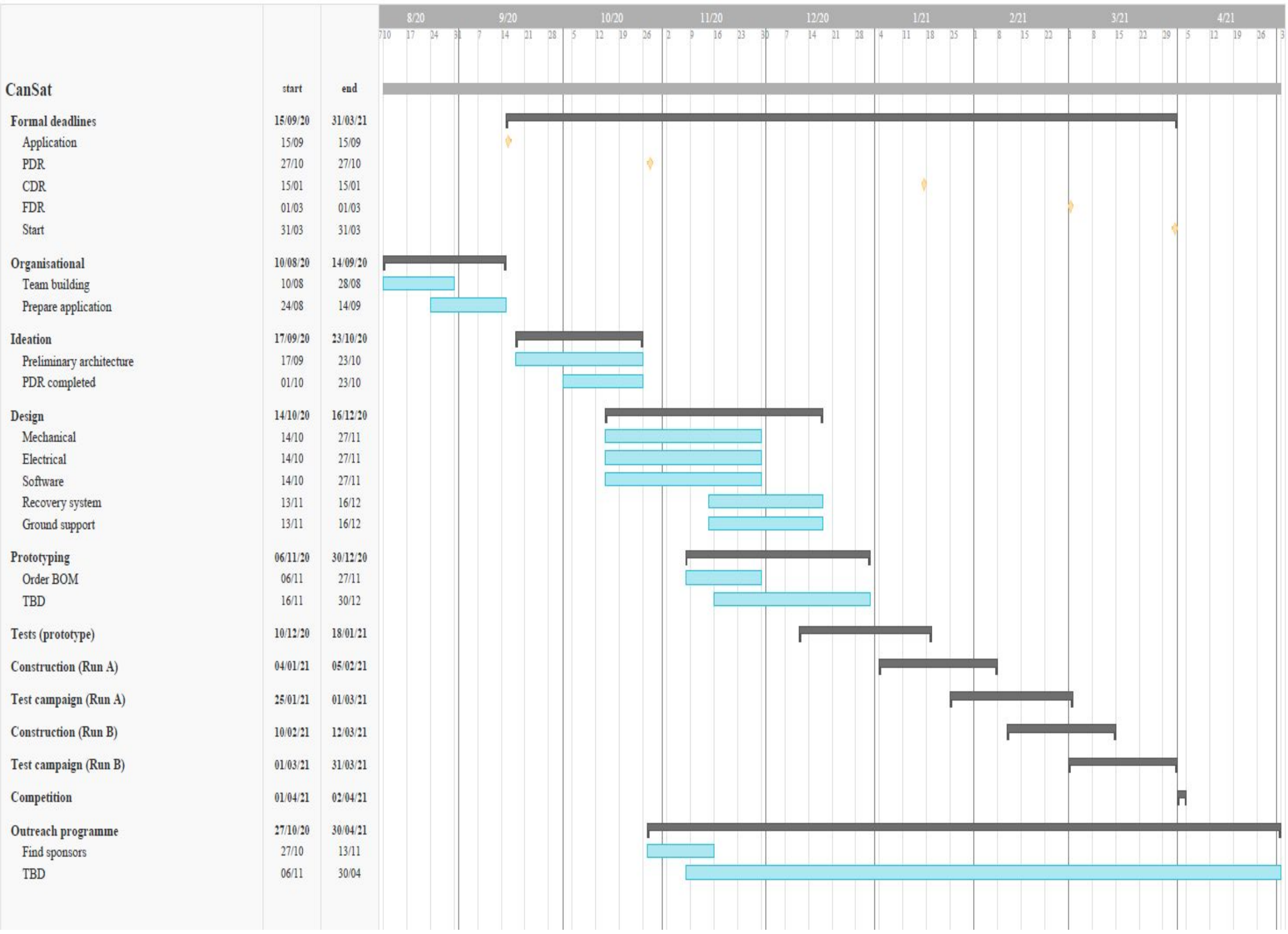


figure 42

5.2. **Task list**

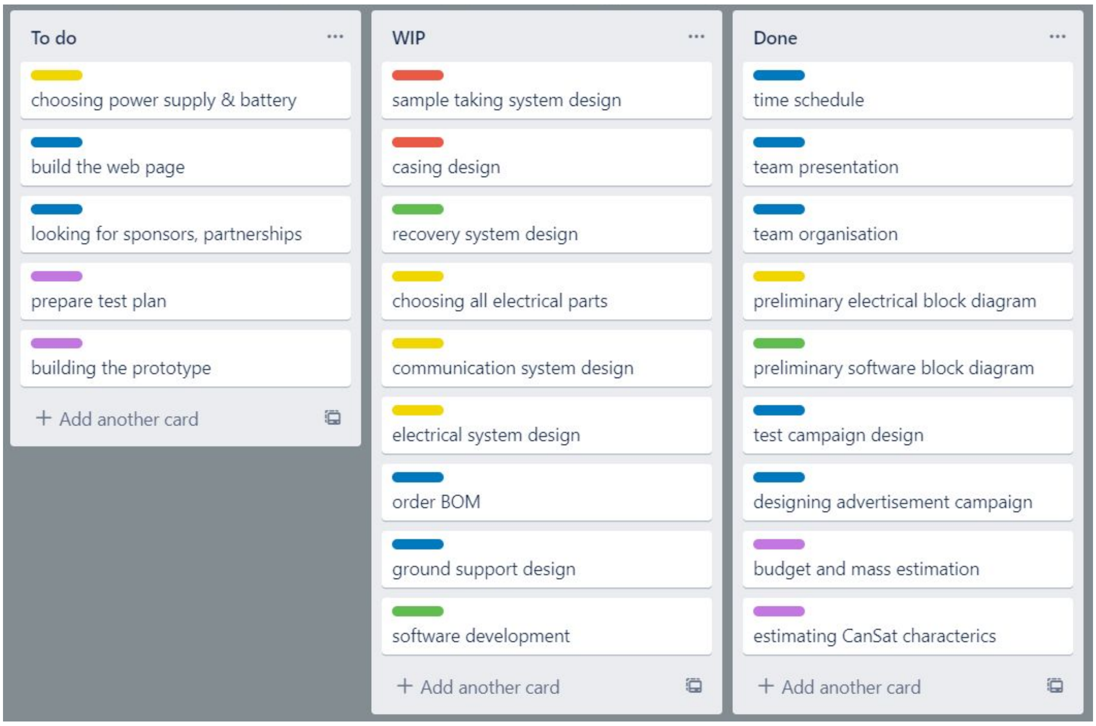


Figure 43
(colors refer to the figure 43. with addition of purple which is the responsibility of the whole team)

5.3. **Resource cost estimation**

5.3.1. ***Budget***

Cansat:	Ground station:
• 28BYJ-48 stepper motor : 1.94 € • motherboard - 38.19 € • Servo Hitec HS-55 - micro - 12.91 € • Boden Micro Pump BD-1004BV - 8.44 € • The Vacumed® probówka neutralna na 4 ml krwi 13x75mm jałowa x 100 - 9.68 € • Swivel- 3.83 € • canopy fabric - 9.83 € • canopy lines- 0.87 € • Temperature sensor - 0.33 € • Atmospheric Pressure sensor - 0.52 € • Radio module - 2.47 € • Humidity Sensor - 23.99 € • Pressure sensor - 9,60 € • GPS module - not selected yet sum: 122.60 € + the cost of a GPS module	• LoStik open source USB LoRa device by Ronoth - 38.92 € • iFrgoLab LoRa USB gateway - 50.69 € • Delock USB 10.0m - 15.25 € • Antenna- value not yet estimated

total sum: 227.46 € + the cost of a GPS module + the cost of antenna

5.3.2. ***External support***

We plan to start our outreach program to get funds, access to equipment and laboratories and also professional technical support.

Our actions will contain following activities:

1. Firstly ask for support in the circle of family, friends and their closest,
2. Secondly we will try to reach sponsors conducting regular activity on different communication channels and social media (details described in next section: "Outreach programme")

Our goals are to realize following achievements:

- get funds 1000.00 €,
- get access to laboratories and equipments,
- find the experts in mechatronic to ask for review of our ideas.

We got in touch with following institution and hope to improve our relation:

- **AGH University of Science and Technology** (al. Mickiewicza 30, 30-059 Krakow, Poland)
- **Fideltronik Poland Sp. z o.o.**, Engineering Centre (ul. Cystersów 19, 31-553 Kraków, Poland)

6. Outreach programme

We plan to public project status, progress and news at least twice per month.

At present, we have established the website and took care of the logo (presented on the document header)

We plan the promotional activities at the school, due to pandemic limitations, remotely.

Our outreach actions performed and media coverage are shown in the picture below (Picture 14).

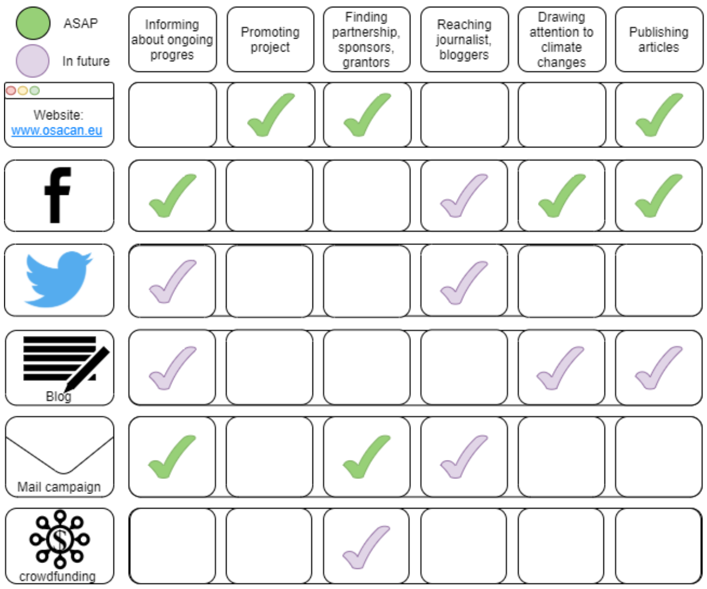


figure 44

7. CanSat characteristics

Estimated characteristics	Figure
Estimated height of the CanSat (main space) and its parachute (additional space)	114.4 [mm] - main space 40[mm] - additional space
Diameter of the CanSat	65.6 [mm]
Mass of the CanSat	279 [g]
Estimated descent rate	6 [m/s]
Radio transmitter model and frequency band	SX1278 RA-02 LoRa 433MHz
Estimated time on battery (primary mission)	5 [h]
Cost of the CanSat	122.60€