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CanSat 2021
Final Design Review (FDR)
OSATeam, Poland

VIII Prywatne Akademickie Liceum Ogólnokształcące w Krakowie

1. CHANGELOG

- Aerogels had been added to the secondary mission
- We changed probes
- We changed team organisation
- Redesigned construction
- Remade parachute
- Added GPS system
- Added endstop to mechanism

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 organization and roles

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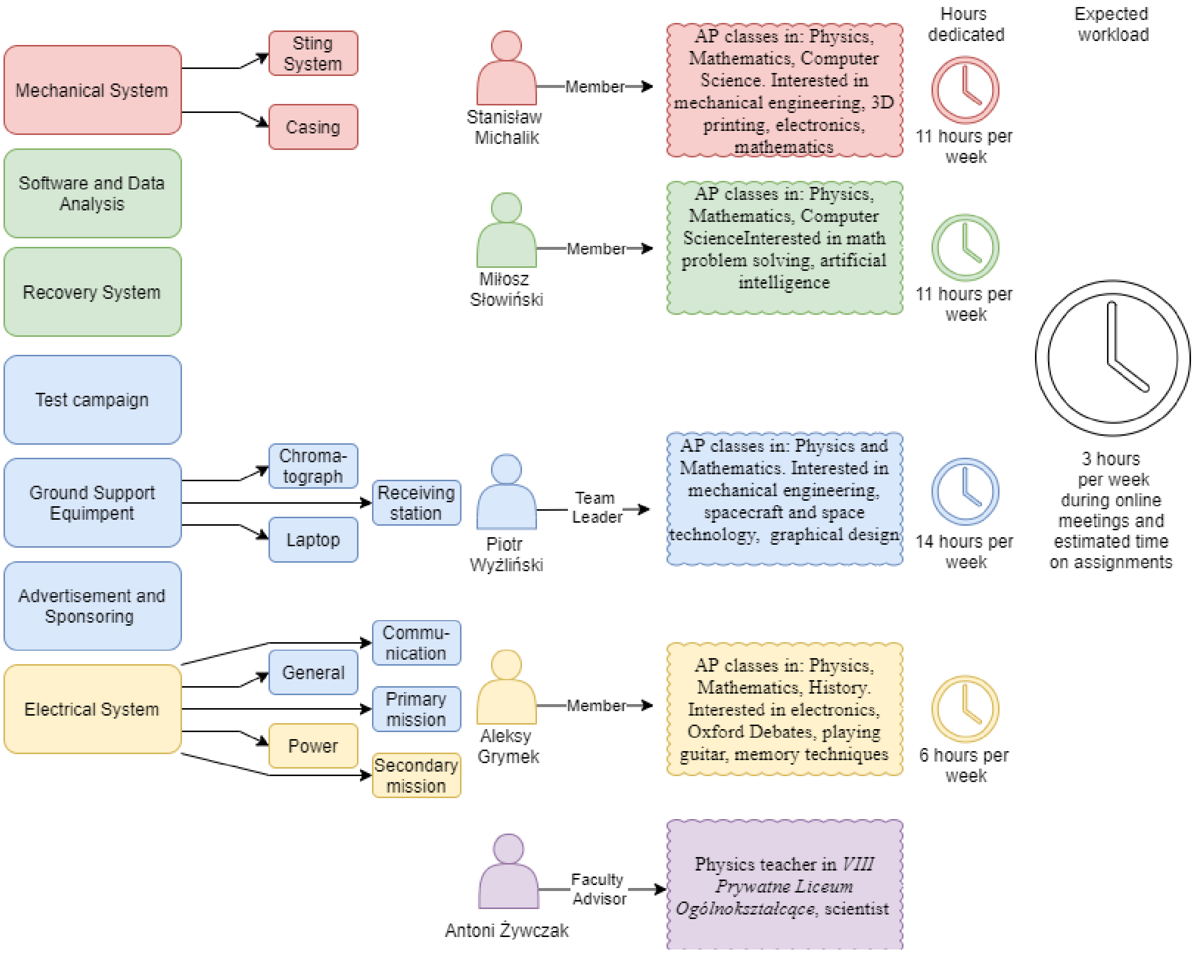

Figure 1. Team organization, hours dedicated, expected workload

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 has been equipped with a 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,

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- 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.

CanSat will contain two different samples of aerogels to the satellite. Aerogels should be delivered to the ground safely. The purpose is to show that OSACan also can carry substances, which can be examined how atmosphere or gravity loads will influence them. We were very inspired by the NASA stardust project: https://stardust.jpl.nasa.gov/tech/aerogel.html.

2.4. 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 is responsible for the acquisition of data from sensors, their recording on the SD card and control of the radio communication system. It is also 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 is designed to provide information about the current CanSat position based on the reception of GPS, Galileo or Glonass signals. The signal is to 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 fulfill 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 are arranged around the CanSat circumference so that samples at atmospheres of different heights can be collected. 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 is 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 a 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.

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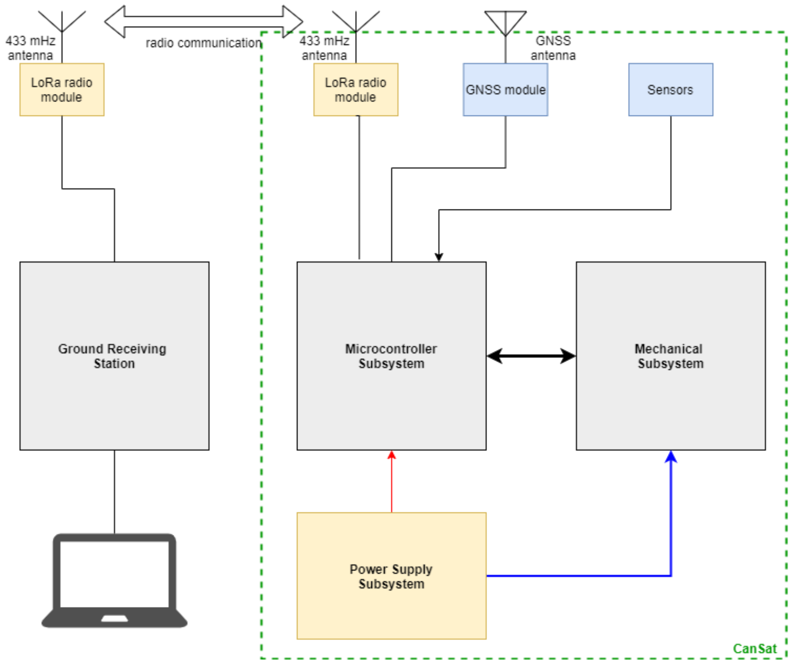

Figure 2. electrical system diagram

CanSat will contain two different samples of aerogels to the satellite. Aerogels are the lightest materials in the world with an extremely low density. Thanks to their unique structure, they have properties that work well in a wide range of applications. These materials result from the removal of liquid from the gel by applying a temperature and pressure higher than the critical point of the liquid component. By using this drying method, the aerogels retain the gel structure and can have a density as low as 0.004 g / cm3, high porosity (85% or higher) and a relatively large number of pores. They can be used, among others, as insulating or sorption materials to catch, for example, dust from a comet's tail.

3. Mechanical design

Mechanical was designed in fusion 360. The full project is available to watch with this link: https://a360.co/3m6YfiX

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

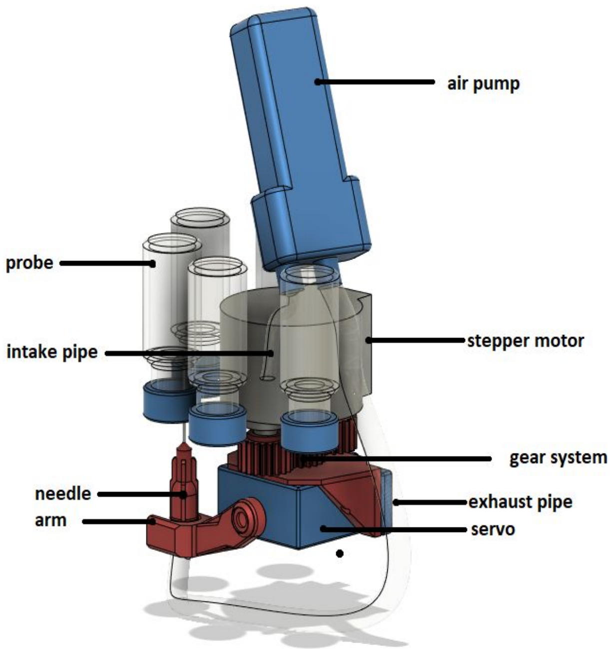

Figure 3. structural design scheme

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3.1. Carousel

3.1.1. Description

The carousel (figure 4.) is designed to turn the servo. It uses a stepper motor and three gears (ratio 1:1:1). The motor does not have a centered shaft, therefore a gear system consisting of three gears has been printed on a 3D printer. Servo gear is located in the middle and it holds the servo. On one side there is motor gear that is attached to the stepper motor. On the opposite side, there is support gear that makes the mechanism work with lower backlash.

3.1.2. Electronics

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.
Parameters: 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: 3,29 €

3.1.3. Attachment

The motor is pressed onto the body, also holding the test tubes around it (figure 6.). The middle part of the casing prevents the motor from falling out.
Servo gear is printed in place with the base of the case as one part. It is mounted on the round body (figure 9.), so it holds together. Support gear is printed as a separate part. While the base is printing the printer stops at the right height so we can manually add support gear (figure 7.).

3.1.4. Tests

We tested many different gears designs, ways of locking them in place and printing tolerances to print in place (figure 10.). The final result put into the main project works well and servo gear is strongly connected with the base part while easily spinning. The stepper motor is strong enough to power the carousel. On 5V sometimes it blocks for a moment. On 12V it works smoothly. (https://www.youtube.com/watch?v=stfIQN0hxSM)

3.1.5. Figures

figure 4. carousel scheme

figure 5. stepper motor

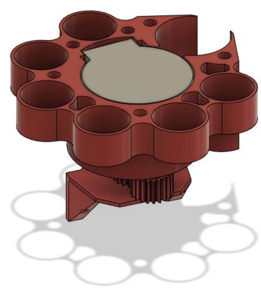

figure 6. stepper motor attachment to the casing

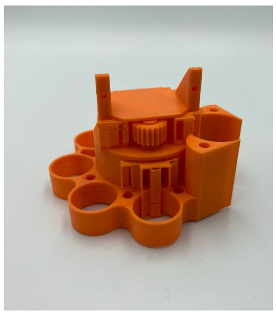

figure 7. base with supports

figure 8. base

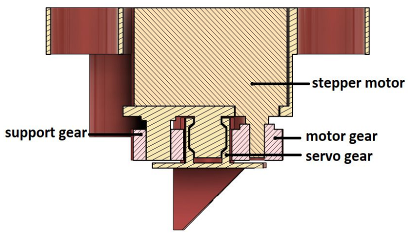

figure 9. carousel intersection

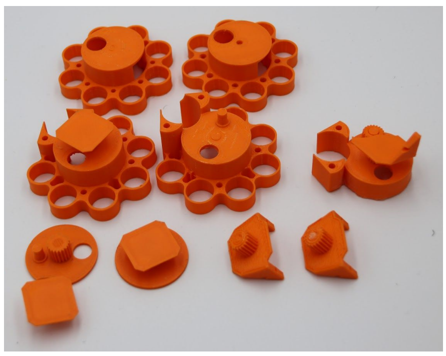

Figure 10. gears tests

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3.2. Servomechanism

3.2.1. Description

The servomechanism (*figure 11.*) 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 servo is mounted on the servo gear.

3.2.2. Electronics

Servo SG90s (figure 13.): it was chosen for its low supply voltage, high quality and reliability, extreme accuracy, metal gears and very small dimensions.

Parameters: Supply voltage: 4.8 V to 6.0 V, Range of motion: 0° to 180°, Dimensions: 22.8 x 12.2 x 28.5mm, Cable length: 175 mm, Weight: 13.4 g, Parameters for 4.8 V - power consumption: 5.5 mA - idle state, 150 mA - movement without load, Torque: 1.8 kg * cm (4.8V), 2,2kg/cm(6V), Speed: 0.1 sec / 60 °, Price: 5.44 €

3.2.3. Attachment

The micro servo is attached to the servo gear by two screws. (*figure 12.*). Needle slides into slots in the arm. The blocker slides after the needle to hold the needle in place, then through a plastic adapter the needle connects with the pipe.

3.2.4. Arm

The arm is designed to keep the needle in a precise position by moving the servo. Both arm and blocker were 3D printed. Design is available here.

3.2.5. Tests

The servo mechanism was tested with two arm variants and on two different prob types

- Probe with 6 mm thick tough rubber.
  - Both of the tested arms failed to pierce the rubber with a needle.
- A small probe with soft rubber
  - The first arm did not hold the needle strong enough.
  - The second arm worked well without any issue (figure 11).

3.2.6. Figures

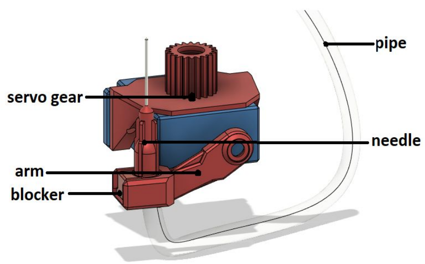

figure 11. servo scheme

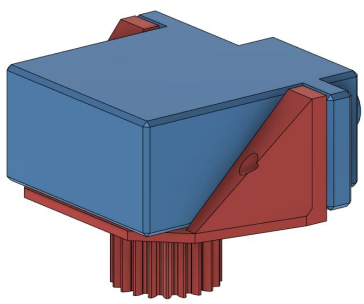

figure 12. servo attachment to the gearing

figure 13. MG90S

3.3. Endstop

3.3.1. Description

The endstop is a limit switch that allows the stepper motor to know its initial position and to calculate any other. The mechanism has to be precise so an endstop is necessary.

3.3.2. Electronics

Endstop is a simple electronic switch connected with a processor (D0) and ground.

3.3.3. Attachment

Endstop is attached to the bottom battery lock by two M3 screws(figure 15).

3.4. Figures

phase

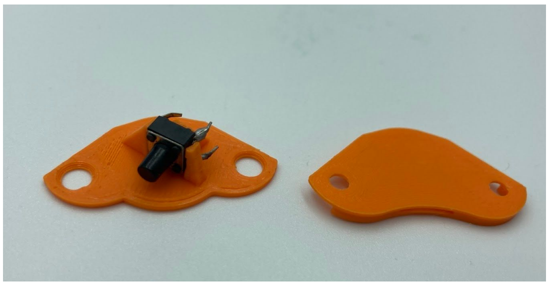

figure 14 endstop

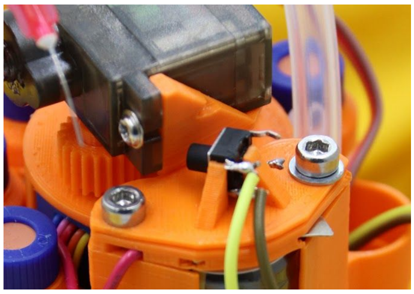

figure 15 endstop mounted on cansat

3.5. Pumping system

3.5.1. Description

The pumping system (figure 16 & 16) 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.

3.5.2. Tests

We tested 5 different air pumps, all of different sizes and power. To test the maximum pressure we used target probes (figure 16) and an analog air pressure sensor. We built a special system (figure 17) built of pipes molded tee, needle and seals. Electronics are Arduino Due, SSCDANV030PASA3 HONEYWELL air pressure sensor and power supply built of bench supply and special circuit (figure 18).

We used a needle of 0,6 mm in the were we pumped 500 ml container we obtained the following results (figure 22)

Then we executed a test of pumping a real 4ml probe. The maximal pressure was the same as in the previous test. Was reached after about 3 seconds. The result is shown in figure 25.

3.5.3. Electronics

The test showed that the best model is a 3,0V motor AJK-B03V1405C (figure 21.): The pump has a pressure of approx. 1,65 atmosphere and fills a 500 ml container (bottle) with air in 150 seconds. The maximum current in the motor circuit was 220mA.

3.5.4. Attachment

The pump is attached to the body as shown in figure 22. (beveled as it fits diagonally), and the air supplied and exhausted is as shown in figure 19

3.5.5. Figures

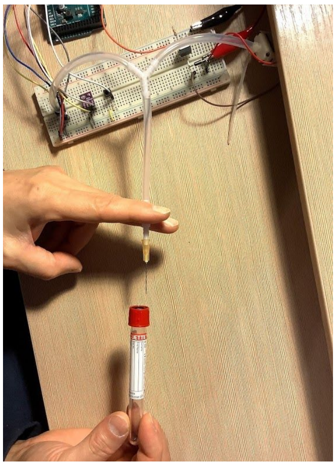

figure 16. - testing filling probes

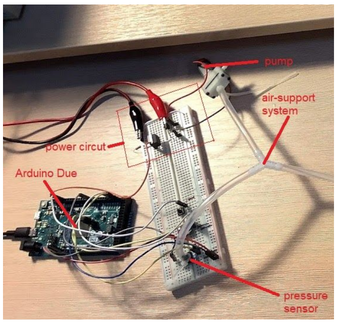

figure 17. - pumps testing system

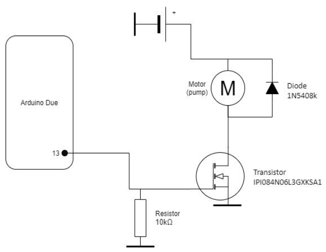

figure 18. - power circuit

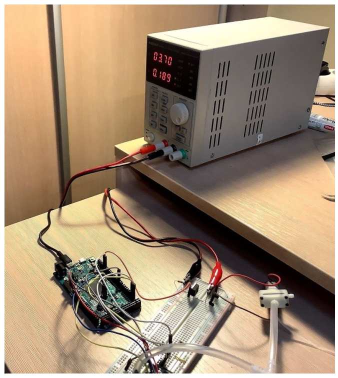

figure 19. - bench supply

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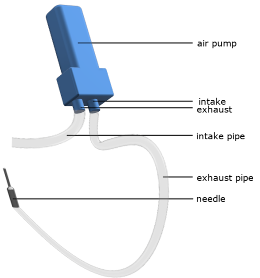

figure 20. air pump scheme

figure 21. air pump photo

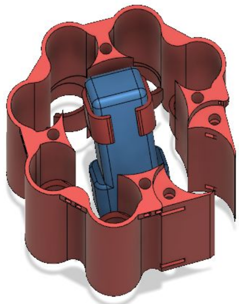

figure 22. pump attachment to the casing

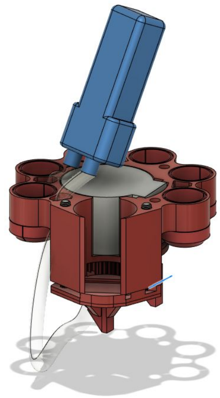

figure 23. intake and outtake pipe attachment to the casing

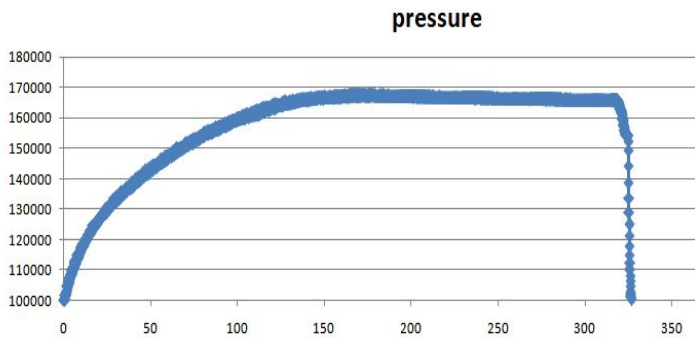

figure 24. pressure in the container graph

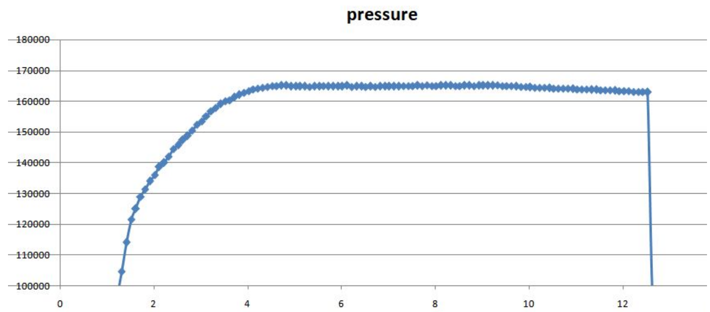

figure 25. pressure in the probe graph

3.6. Probes

3.6.1. Description

They are containers for air samples. They are containers for air samples made of thin plastic and plastic closures.

3.6.2. Model

The probes: Fiolki szklane z gwintem krótkim "7-0675" "Fiolki z gwintem krótkim ND9 Szkło przeźroczyste, z polem na opis i oznaczeniem poziomu napełnienia" (figure 26.) the model was chosen. Tubes are sterile but not vacuum-sealed. We will use AGH's equipment to remove air from those probes. The filling is done by puncturing the stopper with a needle. After removing the needle, the hole will seal itself. Their price is 15,39 € for 100 pieces. The container (test tube) must have no contamination, it should be as sterile as possible and empty of gases.
The screw caps to the probes: Nakrętki gwintowane "7-0690" "Kauczuk naturalny czerwono-pomarańczowy/TEF przezroczysty" were selected. Their cost is 19,54 € for 100 pieces.

3.6.3. Attachment

The test tubes will be attached to the casing by pressing the probe adapter into the base(figure 28. & 29.) so that they can be easily removed and the samples can be examined. They stick to the casing strongly, so they won't fall out. To replace with new tanks, just remove the casing, take out the old ones and replace them with new ones.

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3.6.4. Figures

figure 26. probes photo

figure 27. probes screw caps photo

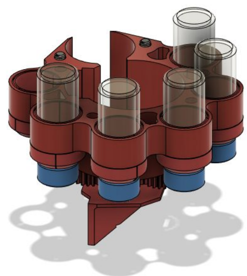

figure 28. probes attachment to the base

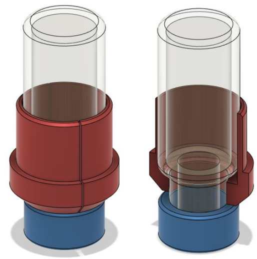

figure 29. probes adapter

3.7. Aerogels

3.7.1. Description

We have the following two samples for you to take:

1) SiO2 aerogel - commercial LUMIRA LA1000 aerogel Cabot (electron microscope photo figure 30)
2) LUMIRA LA1000 aerogel Cabot - Airgel enriched with -NH2 groups more prone to dust capture, synthesized by the research group from ACMIN AGH (electron microscope figure 31)

3.7.2. Attachment

Samples will be located in the main casing body and in place of the sixth probe that we decided not to use.

3.7.3. Figures

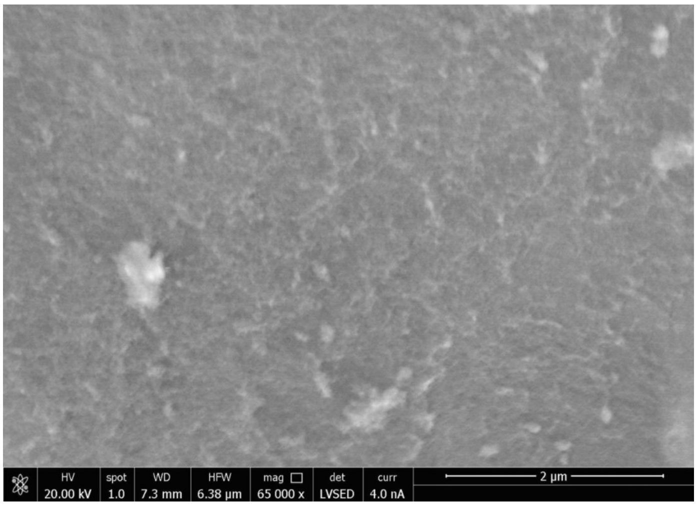

figure 30 - SiO2 airge

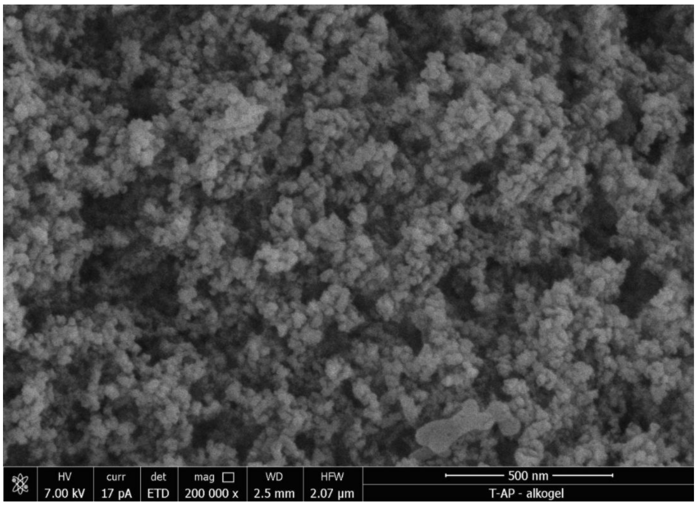

figure 31 - LUMIRA LA1000 airgel cabot

3.8. Casing

3.8.1. Description

The entire casing (figure 27.) has been printed on a 3D printer, also, the most delicate elements will be additionally secured with a sponge. For tests, we use [fiberlogy easy pla](). For the final mission, we will use [carbon filament]() to make sure that everything is strong enough.

3.8.2. Aims

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

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OSACan after landing:

- provide quick access to the CanSat power switch, probes, 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)
- be as easy to print as possible

3.8.3. Construction

The casing has no bottom, as more space was needed for the movement of the arm with the servo. Figures 28, 29, show 2 parts of the casing. The reason for using 2 different parts is to ease access to inner elements and to be as easy to print as possible. Except for servo and sensors, all mechanical and electrical components will be inside the main part as well as between CanSat Kit and the universal board. The main part is designed to print without any support to make the print cleaner and to save on printing time.

The main part is connected with the base by two screws and two metal, 3mm diameter wires. In the main casing body, there are slots for M3 nuts. two electronic boards are connected with the main casing body by three M3 screws.

3.8.4. Battery mount

To save on space and for better access to the battery instead of using a bought battery case we designed our own which is part of the CanSat case. The battery is located on the side of CanSat because it's too big to fit inside. Two screws connect the bottom battery lock, base and main casing body (figure 31.). Two more screws connect the top battery lock with the main casing body. Two metal parts that convey energy from the battery to the electronic board are placed in the bottom and top battery locks (figure 32.). We didn't use springs so our CanSat won't reset over to load factors.

3.8.5. Figures

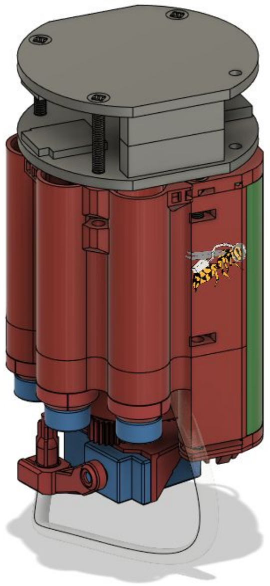

figure 32. casing

figure 33. main casing body

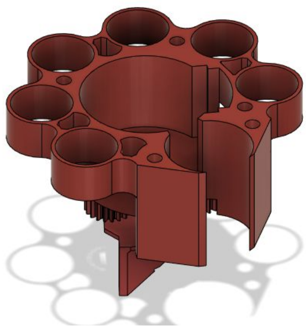

figure 34. base probes casing part

figure 35. main-top electronics casing part

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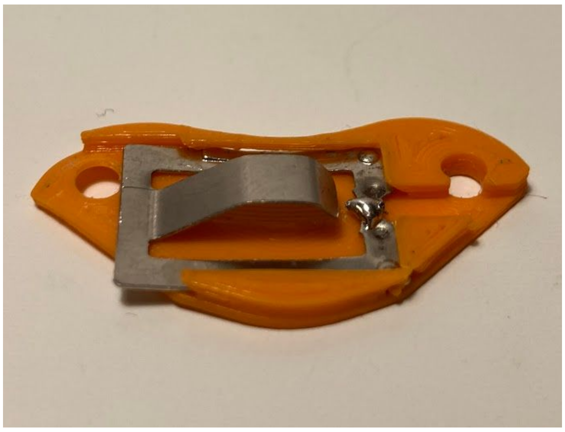

figure 36 top battery lock

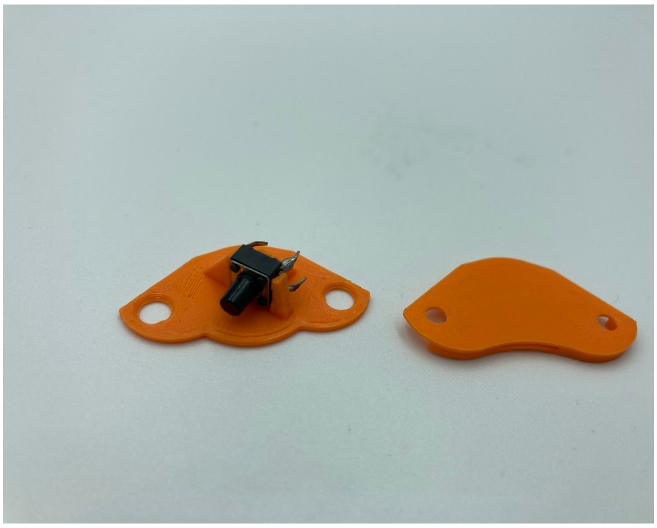

figure 37 bottom battery lock with endstop

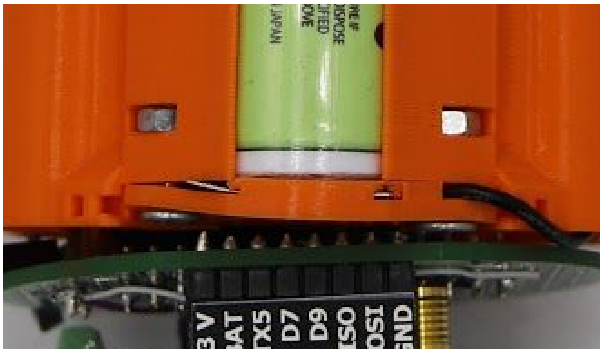

figure 38. top battery lock

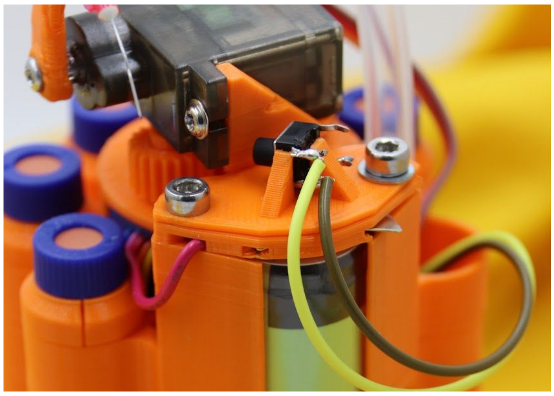

figure 39.Bottom battery lock

3.9. *Sting system tests*

Working of a full mechanism that takes air samples was calibrated in software. We noticed that the stepper doesn’t make precise one rotation while making 4096 steps as it should so we changed it to the right number. After many tests the sting system is calibrated. The video shows the working mechanism.

4. Electrical design of OSACAN

4.1. 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.

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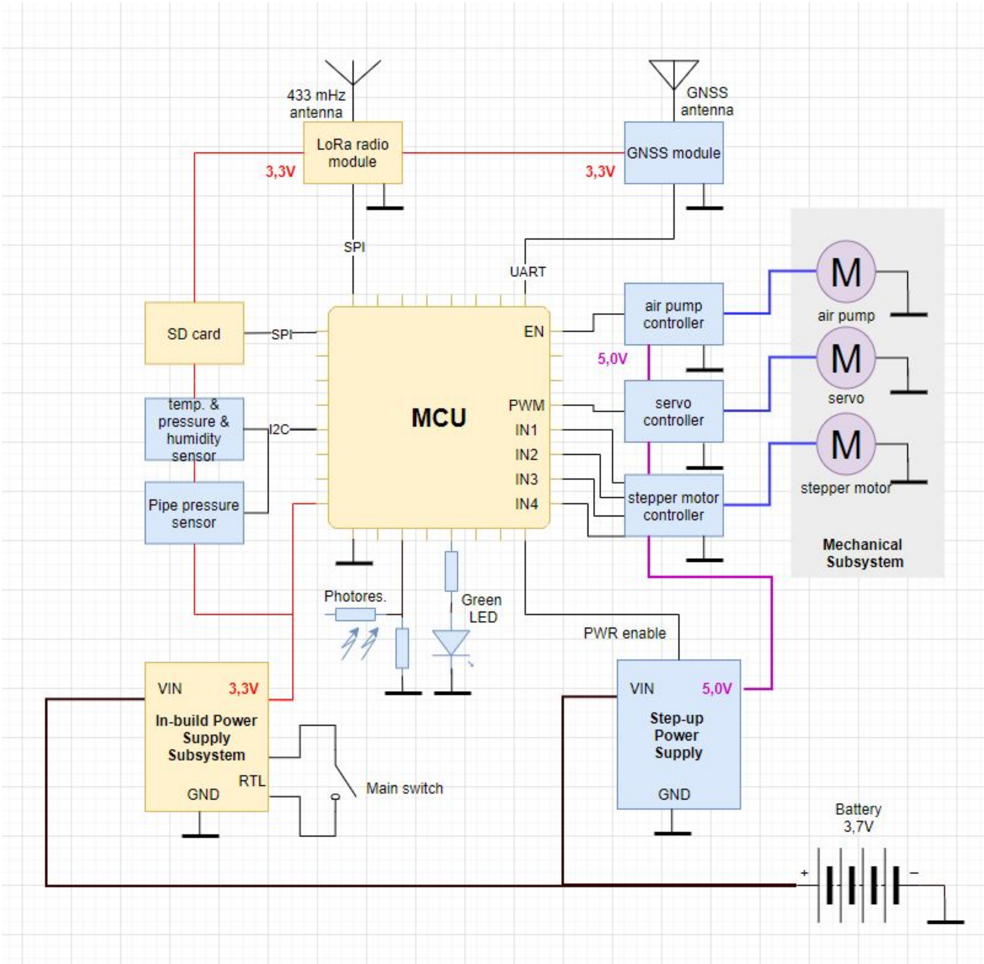


figure 40. electronics topology

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

4.2. Motherboard

We use the CanSat kit as a motherboard. It provides MCU, LORA radio and all needed devices. To program it we can use Arduino libraries which make it easier. Parameters shown in the documentation.

4.3. Sensors

4.3.1. BME280

4.3.1.1. Description & functions

Atmospheric: humidity, temperature and pressure sensor: Model - BME280 (figure 35)

- Used for measuring atmospheric pressure and humidity 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 : 4,41 €

4.3.1.2. Tests

atmospheric temperature, pressure, humidity measurements tests using BME280

- We tested readings of the BME280 sensor connected via I2C line Probes were sampled every 1 second and were sent via USB to the terminal program on the laptop. The laboratory setup was very similar to described in 3.2.3.2, but we used a CanSat board.
- The test lasted 7 hours, no samples went missing, intervals were kept at 1 sec.. The results from the BME280 sensor were reliable relating to the weather station and room temperature. The results are shown on figures 76, 77, 78
- the same test was repeated in an external environment on the roof
- Test of measurements credibility weren't executed yet, because we lack reference devices

phase

4.3.1.3. Figures

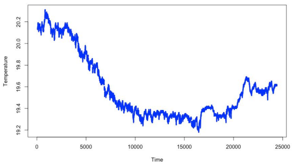


figure 41. - temperature graph

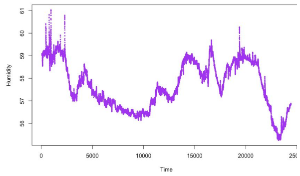


figure 42. - humidity graph

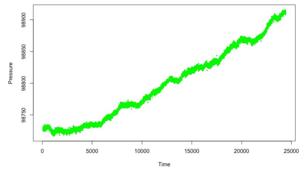


figure 43. - pressure graph

figure 44 - BME280

4.3.2. [Honeywell SSCDANV030PASA3]

4.3.2.1. Description & functions

Will be used to measure pressure inside the probes to fill the probe to the full Price : 28,06 €

4.3.2.2. Tests

was tested on version with SPI. It was decided to change it to the same sensor but with I2C, so it does not collide with SD card and LORA radio.

- with the same frequency as BME280
- in the preliminary test we changed pressure manually using syringe
- secondly it was tested together with a motor pump test described in 3.3.4

4.3.2.3. Figures

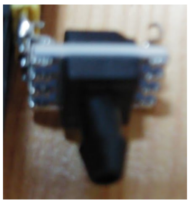


figure 45 - Honeywell SSCDANV030PASA3

4.3.3. Photoresistor 50-100k Ω GL5539

4.3.3.1. Description & functions

The purpose of the photoresistor is to detect the moment of parachute deployment. It will be the moment when missions start.

4.3.4. Adafruit ultimate GPS

4.3.4.1. Small GPS module: Model - Adafruit ultimate Gps breakout

- Used for calculating current height of the Can Sat.
- Used for tracking the Can Sat position.
- precision of positioning: < 3 meters.
- sensitivity: -165dBm
- frequency of refreshing: 1...10Hz.
- voltage 3.3-5.5 V
- We are using this particular one, because it is very accurate, sensitive and easy to connect with integrated circuit.

4.4. Motors

4.4.1. 28BYJ-48 stepper motor.

described in 3.1.2

4.4.2. Servo Hitec HS-55 - micro.

described in 3.2.2

4.4.3. AJK-B03V1405C air pump.

described in 3.3.2

4.5. Radio

4.5.1. Electronics

CanSat Kit with HDP16A (compatible with SX1278) LoRa 433MHz module:

phase

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 protocol: LoRa, RF transmitter power: + 20dBm (100mW) at 433.00 MHz, Communication: SPI, CS Line: PIN11, Price: Included in the CanSat Kit price

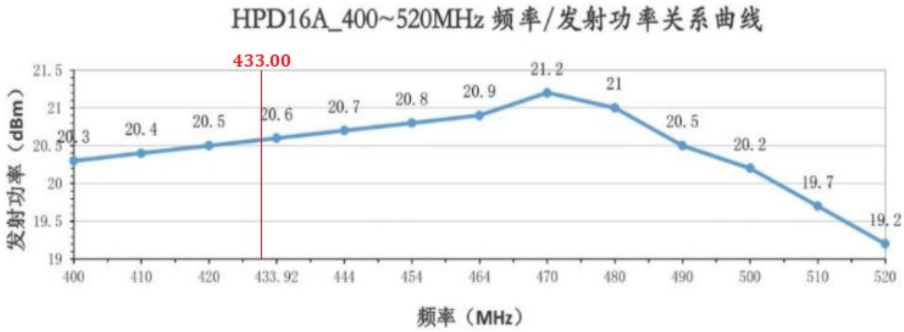


figure 46.

4.5.2. *Antenna*

Wire antenna, length λ/2 = 346 mm (*λ =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), soldered directly to PCB

4.5.3. *Software*

the necessary software ensuring the transmit of messages described in 5.2.3

4.5.4. *Test*

described in 5.4.1

4.6. Power supply

4.6.1. *Battery*

- model NCR18650B made by Panasonic it is a Lithium Ion Rechargeable battery.

4.6.2. *Test*

The tests has shown that the battery could possibly be 2 times smaller and still meet requirements.

5. Communication

5.1. General description

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.

phase

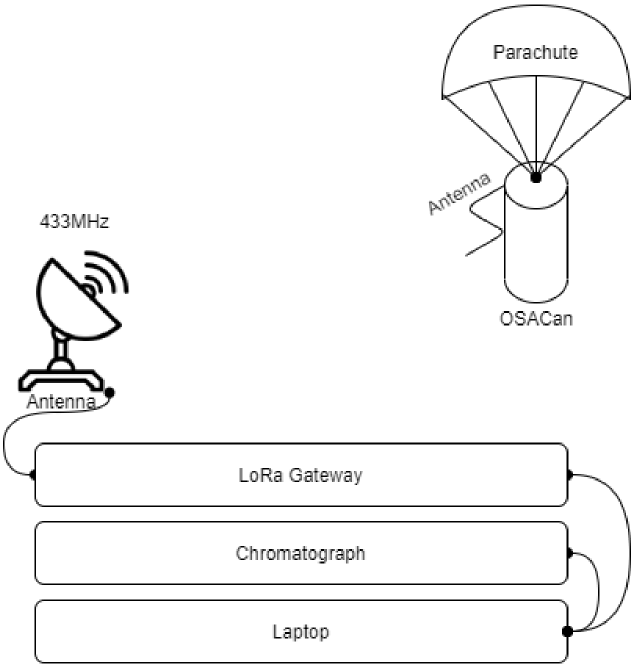


figure 47. - communication scheme

5.2. OSACan part

5.2.1. Description

We designed a prototype of communication using two CanSat boards and antennas (figure 49). The antennas are used for home tests only and designing software.

5.2.2. Construction

Model used a 433M-ANT401 antenna (instead of wire antenna) connected by SMA connector soldered to the PCB.

The BME280 sensor was connected to the circuit using I2C as shown on figure 50 on breadboard (figure 51).

5.2.3. Software

For test purpose transmitter sends example messages including: timestamp (ms), temperature (C degrees), humidity (%), air pressure (Pa) from BME280 sensor

5.2.4. Figures

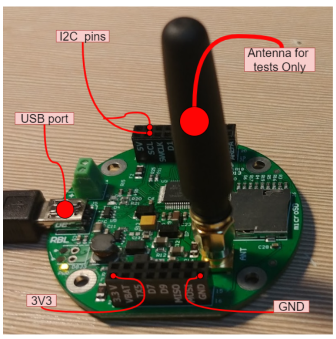


figure 48. CanSat board

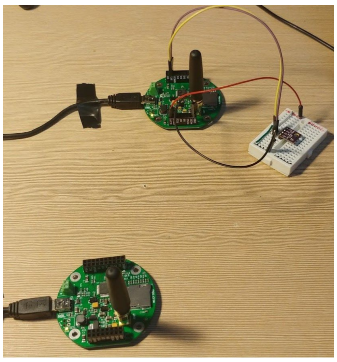


figure 49. communication between two CanSat boards, sending data from BME280

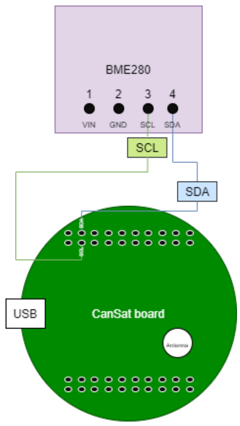


figure 50. BME290 connection

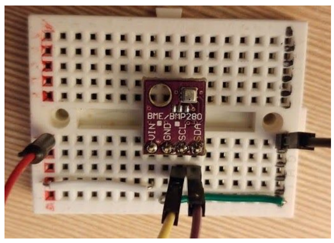


figure 51. - BME280 on breadboard

5.3. Ground receiving station

5.3.1. Description

- CanSat Kit with HDP16A (compatible with SX1278) LoRa 433MHz module **(the same parameters as in transceiver)**
- handmade 9-elements directional antenna (reflector x1, dipole x1, directors x1),

phase

- antenna cable (50 Ohm) ended with SMA connectors (male / female),
- the necessary software ensuring the receipt of messages,

5.3.2. *Directional antenna*

5.3.2.1. Reasons

A sensitive receiving radio 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, we decided to go with the Yagi antenna:

5.3.2.2. Description

We decided to build such an antenna ourselves from scratch. It was built of a boom made of the square aluminium profile 15 x 15 [mm], it was equipped with transverse active elements made of the aluminum tube fi 6 [mm] and dipole made of the copper straight wire 1,5 [mm^2]. Precise parameters of elements are shown below:

Element:	Reflector	Dipole	Director #1	Director #2	Director #3	Director #4	Director #5	Director#6	Director#7
Length:	333 mm	tbd	314 mm	311 mm	308 mm	306 mm	304 mm	302 mm	300 mm
Position: (from reflector)	0 mm	166 mm	218 mm	342 mm	491 mm	664 mm	857 mm	1065 mm	1282 mm
Distance: (from prev. element)	-	166 mm	52 mm	124 mm	149 mm	173 mm	194 mm	207 mm	218 mm

The construction and dimensions was calculated using “Yagi Una Antenna Calculator”.

5.3.2.3. Constructing process

Materials were bought in a hardware shop. We measured them and cut them ourselves so they fit requirements. Also we needed to isolate directors and dipole from the boom. To do it we printed such isolation pieces on a 3D printer. These construction elements are shown on figure 52 and figure 53.

The most important construction element is **dipole with balun** (figure 54**).** It is used to fit the impedance of the antenna. We plan to use copper tubes with bigger diameter (3-5 mm) to stabilize the structure. However, for tests thisl dipole is sufficient. The balun is made of the special plate and transformer JA4220-ALC Coilcraft to strengthen the signal.

Connection between Gateway and antenna is done by SMA-SMF/50/1 cable (figure 55). Cable is connected by SMA directly to CanSat Board .

To ease using the antenna we designed a special holder. It consists of a 3D printed adapter (figure 56) and drill holder (figure 57).

5.3.2.4. Results

Results of finished Yagi Ground Directional Antenna are shown below on figure 58.

5.3.2.5. Figures

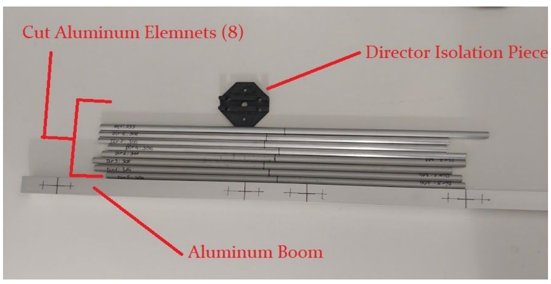


figure 52. antenna’s construction components

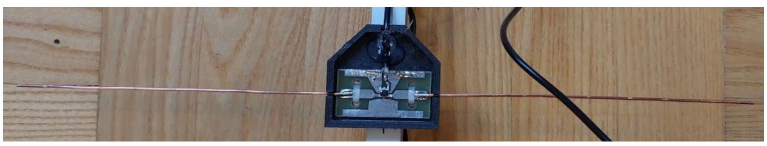


figure 53. dipole with the balun

phase

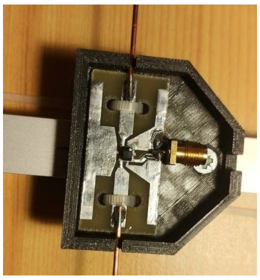


figure 54. - balun pcb and enclosure

figure 55. - SMA

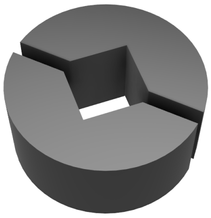


figure 56. - 3D project of adapter

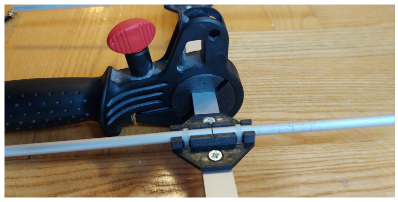


figure 57. - drill holder with adapter mounted to antenna

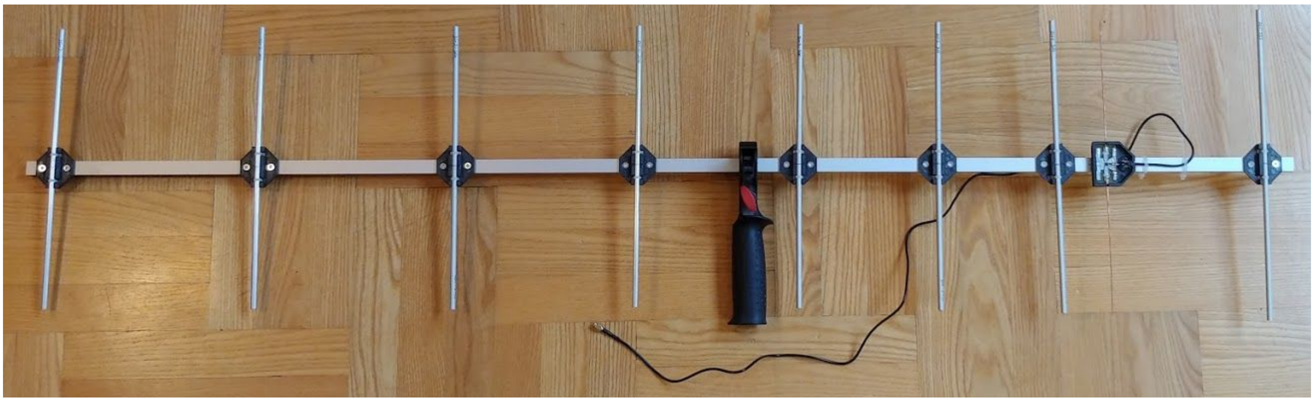


figure 58. OSATeam ground station Yagi antenna

5.4. Tests

5.4.1. Sending/receiving test

5.4.1.1. Conditions & preparation

First test was done in a desk environment. Two CanSat boards were put within about 300 [mm] space between each other as shown on figure 59. With following parameters: Bandwidth 125000, SpreadingFactor 9, CodingRate 4_8. The test lasted 6,75 hours with RSSI about -17.

The tests were done before checking accuracy of the used BME280 sensor, because it wouldn't affect results of sending and receiving tests.

5.4.1.2. Process

Data was uploaded from a BME280 sensor. The main aim was to send and receive data and save it on a personal computer disk as a .txt file. Then convert it to a .csv file, show collected data on graphs. In excel data was checked if any of the measurement was missing using a simple line of excel code shown in figure 60. Fortunately there wasn't any data missing, the test was completed successfully. Example results are shown in the folder on google drive.

The tests were also done on extended data. We checked if the transmitter and receiver got the same data on the SD cards. Again we used the excel formula shown on figure 61. None of data was missing except for the first few seconds when the receiver wasn't plugged to the battery. GPS device needs to 'see' satellites to send data.

phase

5.4.1.3. Figures

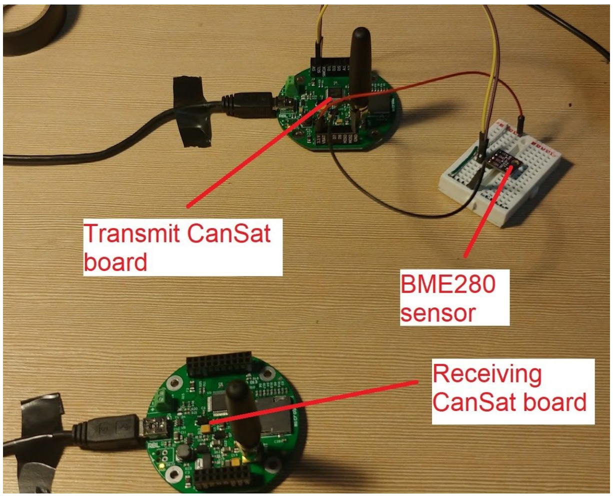
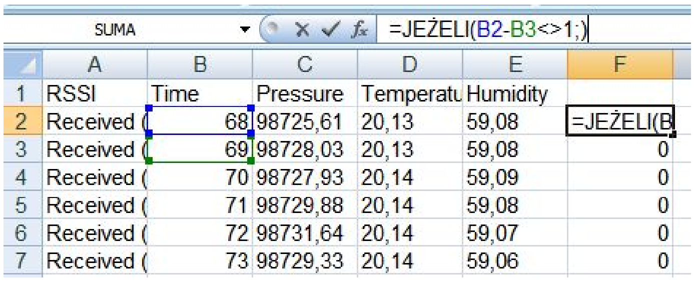


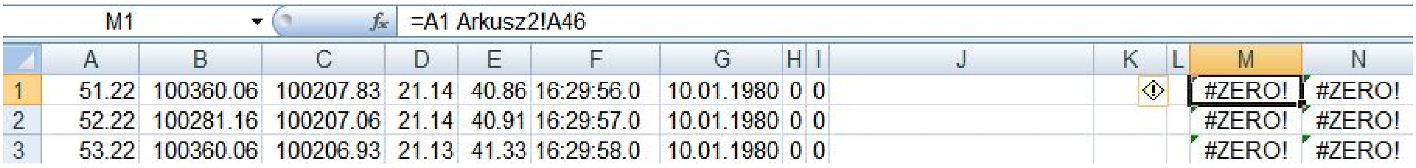
figure 59. - CanSat boards communicating



SUMA | =JEŻELI(B2-B3<>1;)

	A	B	C	D	E	F
1	RSSI	Time	Pressure	Temperatu	Humidity	
2	Received (	68	98725,61	20,13	59,08	=JEŻELI(B
3	Received (	69	98728,03	20,13	59,08	0
4	Received (	70	98727,93	20,14	59,09	0
5	Received (	71	98729,88	20,14	59,08	0
6	Received (	72	98731,64	20,14	59,07	0
7	Received (	73	98729,33	20,14	59,06	0

figure 60. - checking if any data is missing



M1 | =A1 Arkusz2!A46

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	51.22	100360.06	100207.83	21.14	40.86	16:29:56.0	10.01.1980	0	0				#ZERO!	#ZERO!
2	52.22	100281.16	100207.06	21.14	40.91	16:29:57.0	10.01.1980	0	0				#ZERO!	#ZERO!
3	53.22	100360.06	100206.93	21.13	41.33	16:29:58.0	10.01.1980	0	0				#ZERO!	#ZERO!

figure 61 - checking if data is the same

5.4.2. Communication system range tests (urban built in space)

5.4.2.1. Solutions and improvements

These improvements has been done comparing to CDR:

1) holder: extended bom was added (figure 62). In the future we will add a counterweight at the back to ease holding the antenna.
2) transformer: was replaced. We added lid to protect transformer in the future (figure 63)
3) Dipole was adjusted. Slider is shown on figure 64
4) Dipole arms has been replaced with 6mm copper tubes figure 63
5) We decided to analyze our antenna. We used NanoVNA V2 Vector Network Analyzer (figure 66). We adjusted the length of the dipole arms
6) We decided to connect the CanSat board almost directly to the SMA connector. We added a box to protect it and screw it to the antenna (figure 67)
7) We cut the antenna after the second director (figure 68), so we can be adjusted to be more or less directional. The tests were done on both of the lengths.

5.4.3. Communication system range tests (open and urban space)

5.4.4. Conditions & preparation

This time we put two CanSat boards in protective boxes on the very high place with 7m inbetween (figure 69). We used a half-wave ($\lambda/2$ = 346 mm) wire antennas for both of them. We powered them from the power regulator. Both of them were sending randomized data. One of them every 900 ms with frequncy 432.50 MHz, second every 1100 ms, frequency 433.750 MHz.

To analyze waves we used an RTL-SDR USB stick (figure 65) and SDRsharp software . This combination allowed us to check the strength of the signal. Depending on the environment analyzer showed us different dBm, as its logarithmic scale, closer to “1” the better. Software shows readings on the graphs.

Signal quality:

dBm	Classification

phase

-30 dBm	incredible
-67 dBm	very good
-70 dBm	good
-80 dBm	bad
-90 dBm	unuseful

5.4.4.1. Process

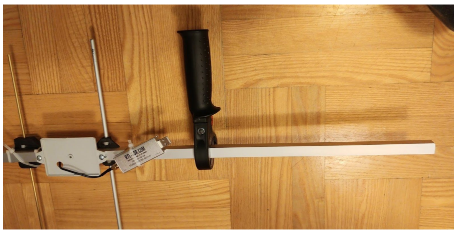
Conditions:	Description:	Figure:
Distance: 400m, urban environment, obstacles, transceiver not covered, shortened directional antenna	At the shown distance with noise about -81 dBm we could get a signal rated down to -76 dBm. This makes quite a good signal. All the data should be collected. Quality depends mostly on the angle of where the antenna was pointing.	figure 70
Distance: 400m, urban environment, obstacles, transceiver not covered, directional antenna	At the shown distance with noise about -80 dBm we could get a signal rated from -76 to -73 dBm. This makes quite a good signal. All the data should be collected. Quality depends mostly on the angle of where the antenna was pointing.	figure 71
Distance 2,81 km, open space, shortened directional antenna	At the shown distance with noise about -80 dBm we could get a signal rated from -79 to -78 dBm. This makes quite a good signal. All the data should be collected. Quality wasn't dependent on angle as much at this distance.	figure 72
Distance 2,81 km, open space, directional antenna	At the shown distance with noise about -80 dBm we could get a signal rated from -78 to -76 dBm. This makes quite a good signal. All the data should be collected. Quality wasn't dependent on angle as much at this distance.	figure 73
Distance 6,67 km, open space, directional antenna	At the shown distance with noise about -80 dBm we could get a signal rated from -80 to -79 dBm. This makes signal quality close to noise.	figure 74

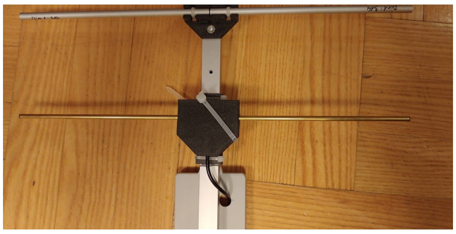
5.4.4.2. Conclusions

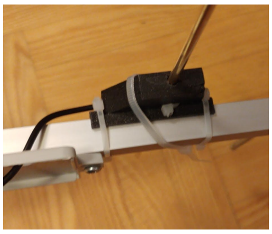
We made an improvement. However it seemed that the signal isn't as good as expected. This wasn't the problem with the antenna but with the RTL SDR stick which isn't as strong as the CanSat board. Improvement we have made will be enough for the finals.

5.4.5. Communication system range tests (open space)

5.4.5.1. Figures







phase

figure 62 - extended bom

figure 63 - lid & thicker dipole arms

figure 64 - slider

figure 65. - RTL-SDR USB stick

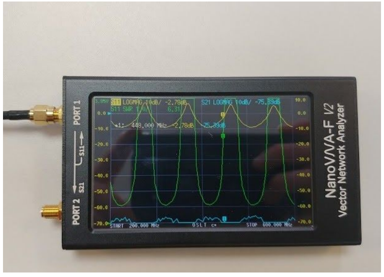


figure 66 - NanoVNA V2 Vector Network Analyzer

figure 67- CanSat board placement

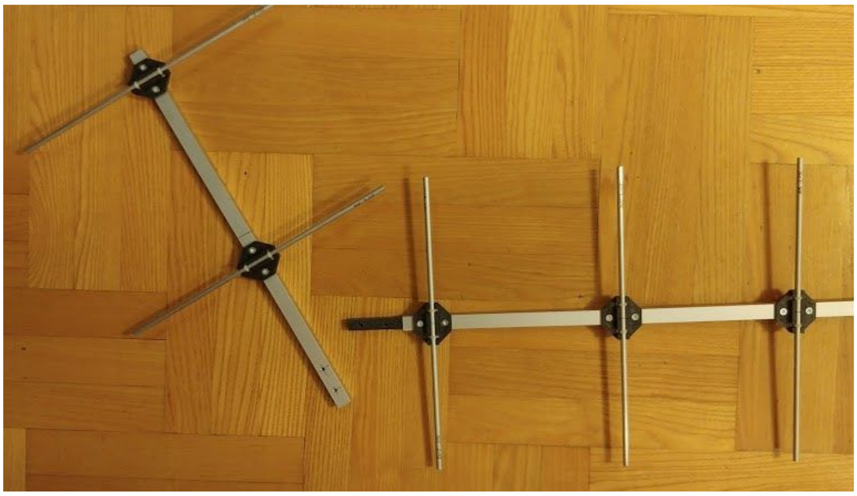


figure 68 - cut, extender and cut part of the antenna

figure 69 - two protective box with CanSat board on the roof in the centre of Cracow

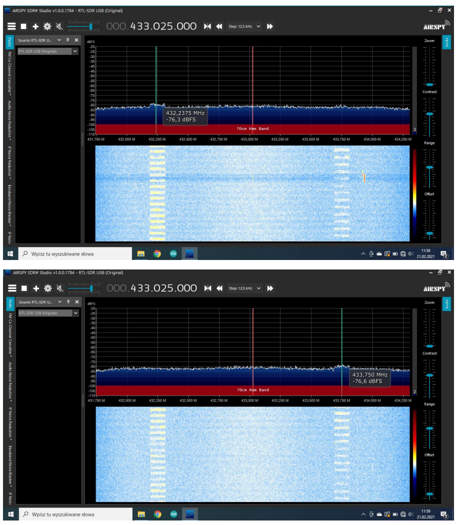


figure 70 - short antenna: 400 m

figure 71 - 400 m

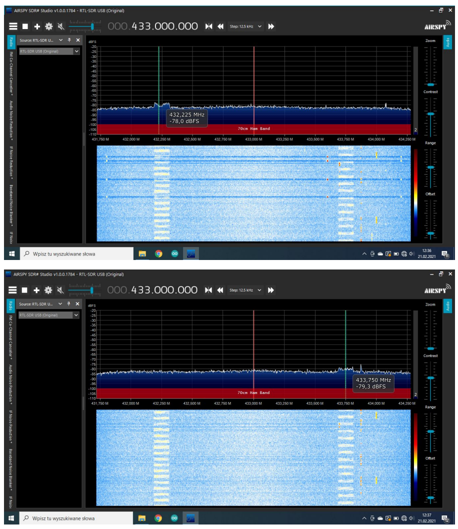
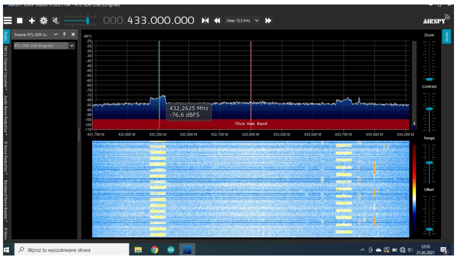
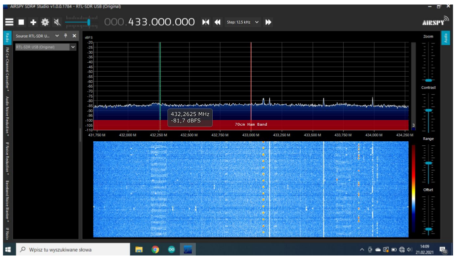


figure 72 - short antenna: 2,81 km

phase





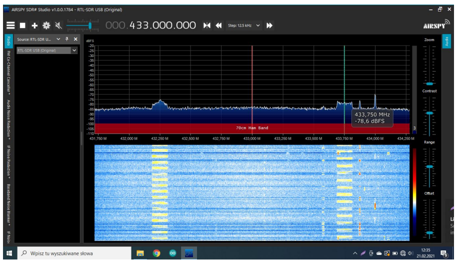


figure 73- 2,81 km

figure 74 - 6,67 km

6. Software

6.1. Description

Software covers the support of CanSat Kit Hw v.1.4 and our additional shield with external pheripherials. Software was developed on a microcontroller using Arduino toolchain.

- 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.
-

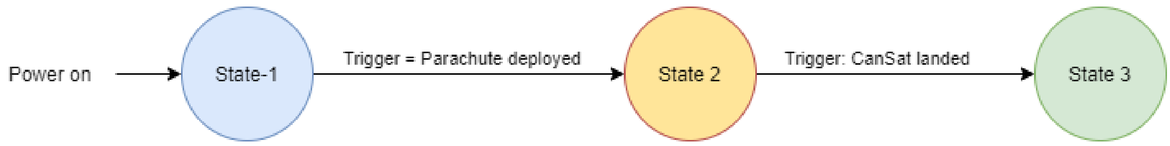


figure 75

6.2. Algorithm

6.2.1. State-1

After powering up, the board initializes all its peripherals and runs a self test procedure. After all the checks are successful, the board starts waiting for the parachute deployment before moving to State 2.

phase

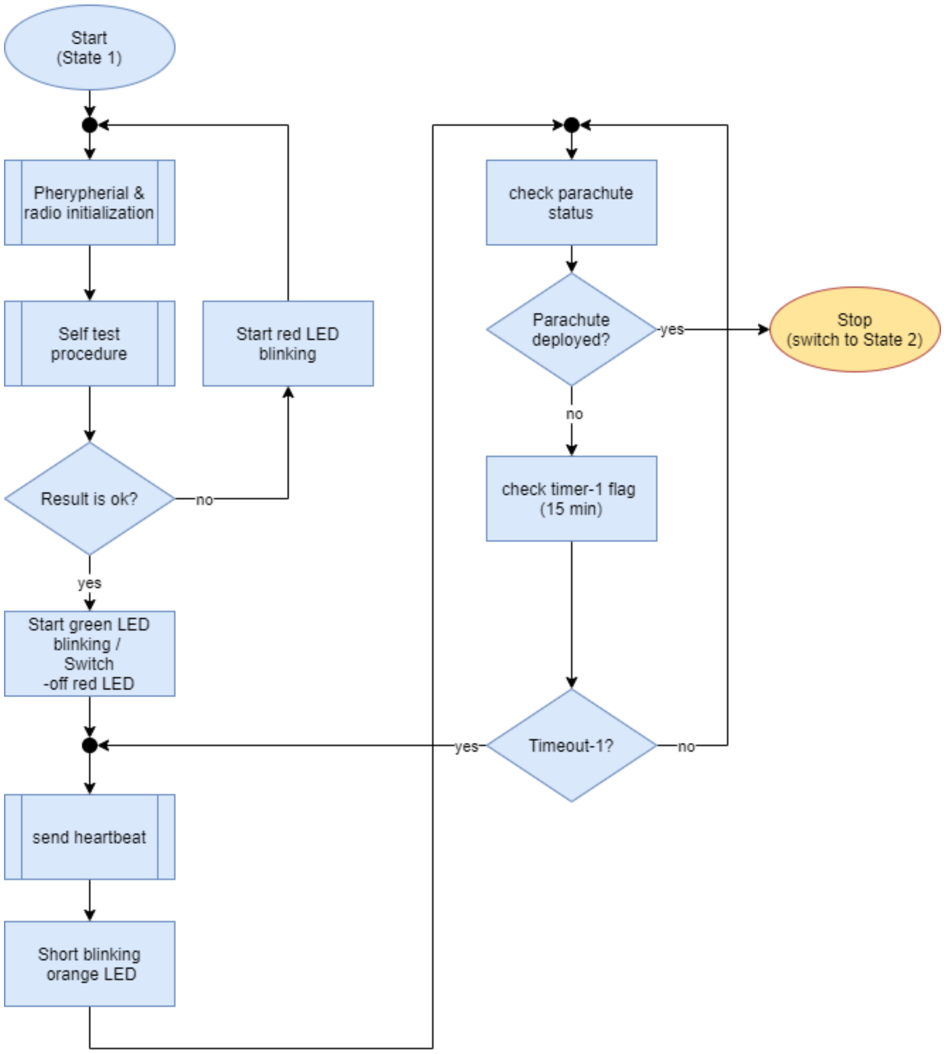


figure 76

6.2.2. state-2

After parachute deployment, the software has to perform two tasks. Firstly, it reads the sensors and writes their values to the SD card. Secondly, it is responsible for scheduling taking the air probes.

phase

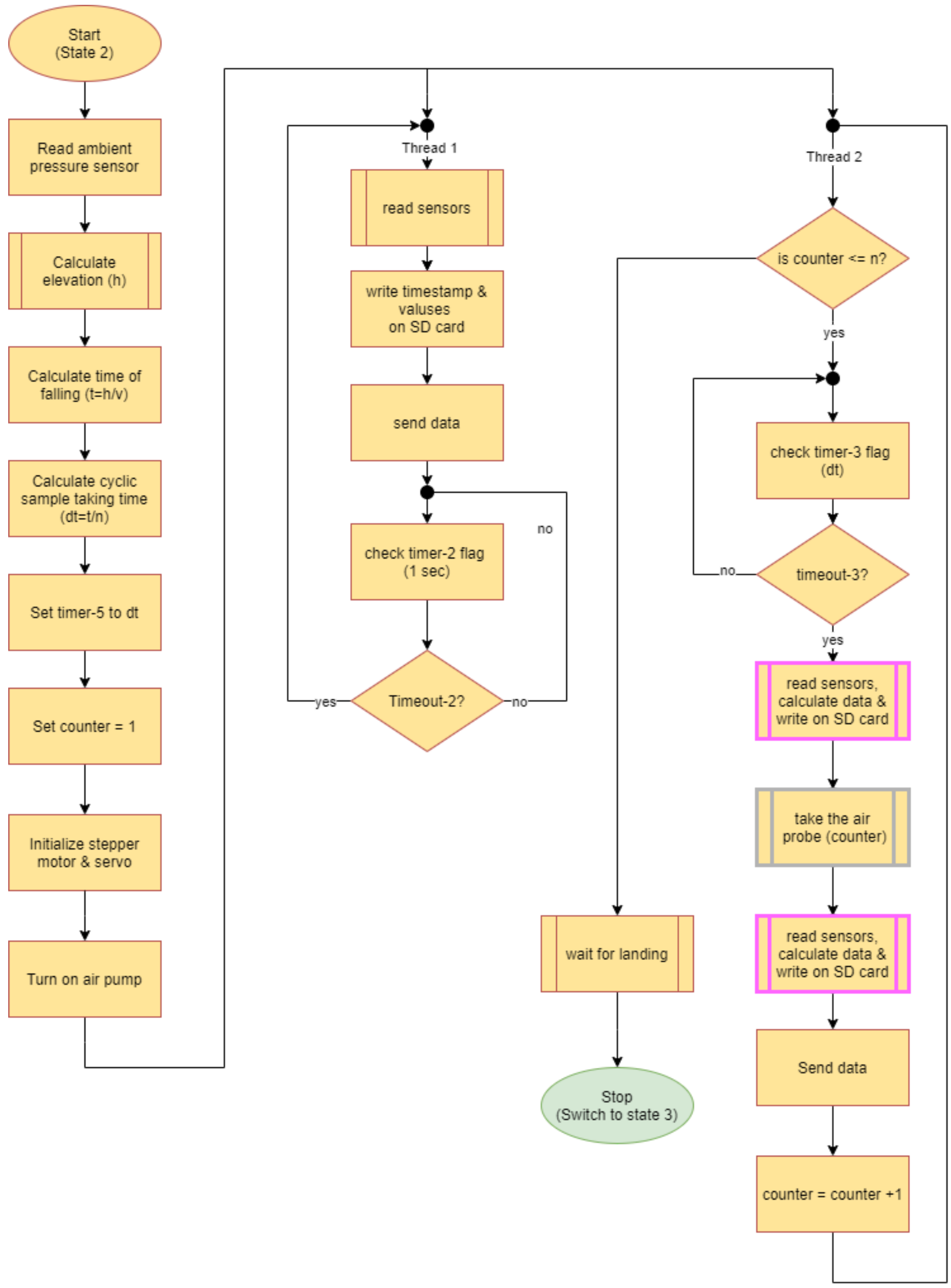


figure 78

6.2.3. state-3

When landing is detected, the board initializes GPS and starts periodically transmitting its position to the ground station. Additionally, every 60 seconds a buzzer is enabled in order to provide an additional way of finding the CanSat.

phase

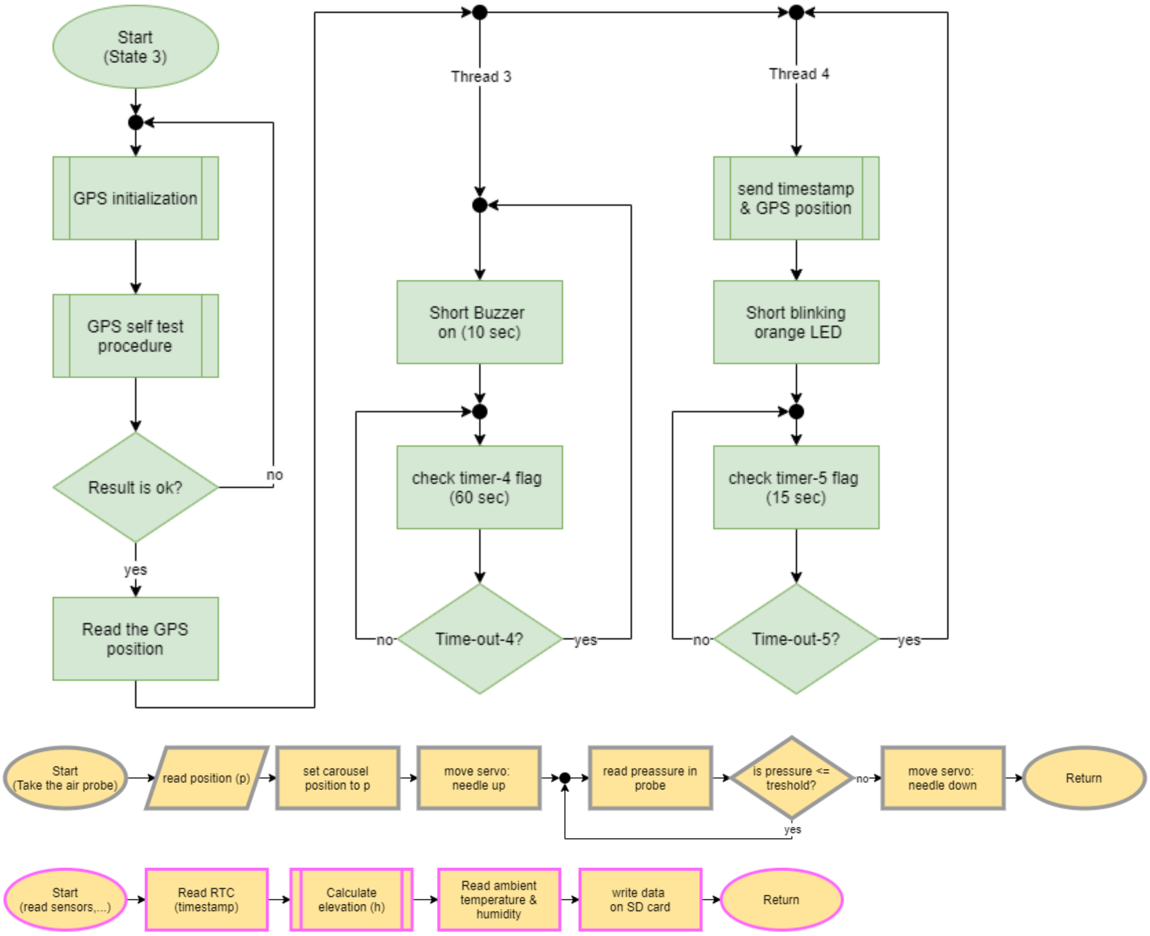


figure 79

6.3. Peripherals

6.3.1. GPS

As a GPS receiver we chose a GPS module connected via UART line. We use the high level Arduino hardware serial libraries. GPS is initialized to work autonomously with ODR = 1 Hz (Output Data Rate). Each cycle transfers the minimal set of NMEA frames to reduce data amount. The baud rate is 9600. Received frames are parsed to internal data format, easy-to-use inside the program.

During development we noticed permanent problems with the GPS fix. Unfortunately the GPS signal inside the building is on the level of noise, so the GPS receiver is not able to calculate the fix. We solve this problem by mounting the special GPS repeater with two antennas:

- one on the roof (receiving antenna)
- second inside the room (repeating antenna)

This solution allowed us to develop the GPS code inside.

6.3.2. SD Card

The SD Card is controlled using the SDIO interface. It is formatted using a FAT-32 file system and a high level Arduino library is used for reading/writing data to the card.

6.3.3. Motors

The A4988 drivers allow a precise control over the stepper motor. With 1.8 degrees steps and 1/16 micro stepping, it’s possible to rotate the motors with 0.11 degrees precision. A limit switch is used to initialize the motor in a home position.

The servo motor that operates the needle is controlled using a PWM signal with a standard 1-2 ms duty cycle on a 50 Hz waveform. Program uses the standard Arduino Servo Library.

phase

6.3.4. Pressure / Humidity / Temperature sensor

The BME 280 sensor is controlled using I2C protocol. Every 1000 ms (parameter) the condition in the main loop reads value via I2C address of the sensor, using a non blocking function.
They are later stored on the SD card and pressure is used for calculating CanSat's altitude.

Similarly, the Honeywell SSC Pressure sensor is controlled using the same I2C line. Pressure is analyzed in real time to control the pump motor. If the pressure reaches the limit of 1,65 atm, the pump motor is switched off.

6.3.5. Parachute deployment detection

When the parachute is opened, a photoresistor detects a change in light intensity and triggers the mission start. Photoresistor is connected to analog input via voltage divider.

6.3.6. LORA

We use standard Lora libraries prepared for CanSat. We are able to work with 432,250 - 433,750 MHz frequency range. Lora radio module is initialized with the following example parameters:

```
Radio radio(Pins::Radio::ChipSelect,
        Pins::Radio::DIO0,
        433.0,
        Bandwidth_125000_Hz,
        SpreadingFactor_8,
        CodingRate_4_8);
Frame measurementsFrame;
```

The radio power is set to 10 dBm (20 mW) and it is the upper limit for public radio range.

We found that the optimal spreading factor is 9 for long distance, but unfortunately our frame is too long to transmit it during 1 s measurement cycle. We had to reduce the spreading factor to 8.

6.4. Measurements

We are measuring following data:

1) time from the moment of turning on the CanSat (miliseconds)
2) ambient air pressure
3) in-pipe air pressure
4) ambient air temperature
5) ambient air humidity
6) GPS
    a) clock & date (UTC)
    b) if gps have a fix (0 - no fix, 1 - fix)
    c) quality of connection (0 - no fix, 1 - 2D coordinates, 2 - 3D coordinates)
    d) coordinates (longitude & latitude)
    e) altitude
    f) number of satellites in-use

Additionally we record for each frame the RSSI signal of LoRa. Frames are saved on SD card and transmitt via LoRa radio to the base station.

7. Recovery System

7.1. Description

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 to six 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

phase

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 50% longer than the canopy radius.

7.2. Calculations

- Air density approximation ρ = 1.225 [kgm^3]
- Gravity acceleration approximation g = 9.81 [m/s^2]
- Cansat mass approximation m = 0.3 [kg]
- Drag coefficient for round type canopy Cd = 0.5
- Terminal velocity of Cansat V = 6 [ms]
- Pi constant approximation π = 3.1415
- A - area of the canopy
- R1 - radius of the canopy
- R2 - radius of the spill hole

$$V = \sqrt{\frac{2 \times m \times g}{C_d \times \rho \times A}}$$

$$A = \frac{2 \times m \times g}{C_d \times \rho \times V^2};$$

$$A = \pi \times (R_1)^2 - \pi \times (R_2)^2$$

$$A = \pi \times (R_1)^2 - \pi \times (R_1)^2 \times 5\%$$

$$A = \pi \times (R_1)^2 \times 95\%$$

$$R_1 = \sqrt{\frac{A}{0.95 \times \pi}}$$

$$5\% \times A = \pi \times (R_2)^2$$

$$R_2 = \sqrt{\frac{0.05 \times A}{\pi}}$$

7.3. Materials

- swivel: Swivel Bushido LUX 2/0
  - weight: 3.4 [g]
  - price: 1.99 €

  Swivel will be hitched with 4 strings, attached to the top of CanSat (figure 81.). 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]
  - weight: 64.42 [g/m²] - (parachute canopy itself will weight around 9[g])
  - price: 9.83 €
- lines: sewing thread
  - we do not calculate in the weight nor the price due to small values

7.4. Making process

The first parachute's shape was selected to be a regular octagon because of its eight corners.The parachute size was calculated and drawn twice onto the fabric. Further the pieces were cut out with excess and after being sewn reversed. The area of the spill hole was decided to be 5% of the whole parachutes area. Connectors were attached to the parachute's corners. Lastly the eight lines were measured and connected to the swivel.

The first parachute test results were a failure. The parachute did open but the drag force did not hold the maximum velocity from reaching 18m/s. We concluded we selected a wrong value for the drag coefficient(it was equal to around 1.3). To determine the correct value of the drag coefficient we created four parachutes with different values of the coefficient(0.5; 0.65; 0.75; 0.9) (figure 82)(figure 83). After two series of recorded drops we cut a spill holes in those parachutes to determine whether they are pointless or not. The holes majorly helped to stabilize the flight. After analyzing recorded footage of those parachutes using"Tracker" made by physlets we selected a coefficient value for which the measured velocity was equal to 6m/s (to clarify- we did not expect for any those parachutes to help us determine the exact value of the coefficient but we were lucky enough to have the largest parachute fall at exactly 6m/s).

Using the newly found coefficient value we created our final parachute. Using the experience gathered creating previous parachutes we were able to maximize probability of succeeding. The lines were connected parallel to each other and were connected to the swivel such that we were able to correct its position if needed(it was). Also the swivel was modified with a safety pin that can be easily connected to the lines on top of the cansat. During our final test the lines did not entangle and the parachute opened and reached its final velocity of 6m/s.

The test can be found on our youtube channel.

phase

7.5. Figures

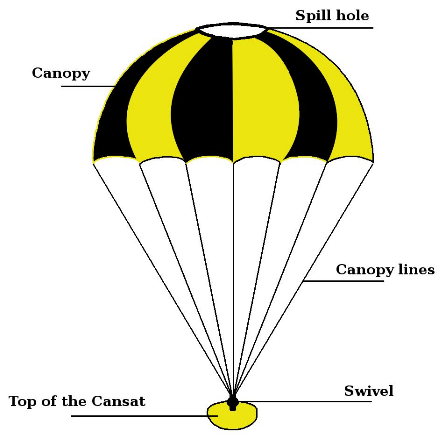


figure 80.

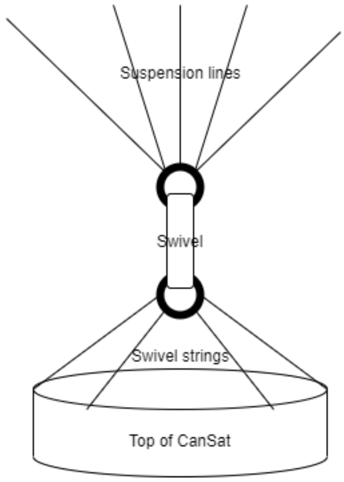


figure 81.

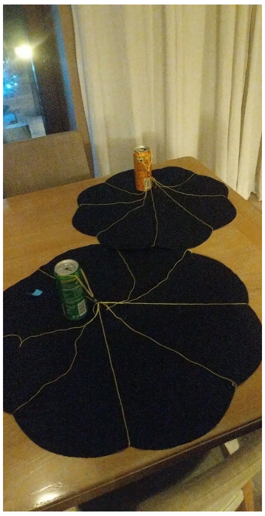


figure 82.

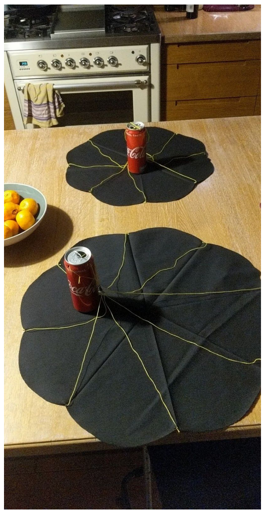


figure 83.

figure 84.

figure 85.

phase

8. Ground support equipment

8.1. Description

The ground support system consists of the following component

- 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.

8.2. 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.

8.3. Ground receiving station

described in 5.3

8.4. Chromatograph/spectrograph

We decided to deliver the collected gas samples to the sponsor's laboratory or the university (AGH).

8.5. Basic set of tool and spare parts

9. Test campaign

9.1. Primary mission tests

9.1.1. Measurement tests

9.1.1.1. Description

- **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 found after a fall. The test will be considered positive when both sensors show the same pressure without measuring errors. - weren't executed because of lack of the access to AGH lab reference devices.
- **temperature sensor test**: it will consist in checking whether the target device and the reference device will show the same temperature within 24 hours

9.1.1.2. Process

weren't executed because of lack of access to AGH lab.

9.1.1.3. Conclusion

9.1.2. Data download test

9.1.2.1. Description

- 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.

9.1.2.2. Process

Data was validated for completeness and the occurrence of errors. We used the excel formula to compare two SD cards which were collecting the same data.

phase

9.1.2.3. Conclusion

Test hasn't pointed out any errors. Saving data on SD cards works 100% correct.

9.1.3. Endurance tests

9.1.3.1. Description

1. **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.
2. **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 - gravitational acceleration
   ω - angular velocity
   R - string length
   n - quantity of rotations
   t - time of rotating

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

3. **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

9.1.3.2. Process

weren't executed yet.

9.1.3.3. Conclusion

9.2. Secondary mission test

9.2.1. Measurement tests

BME280 described in 4.3.1.2

Honeywell described in 4.3.2.2

9.2.2. Sting system test

9.2.2.1. Description

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

- -mechanical system Tests::
- -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.

9.2.2.2. Process

described in 3.1.3 & 3.2.4 & 3.3.2

9.2.2.3. Conclusion

9.2.3. SD card test

9.2.3.1. Description

executed

9.2.3.2. Conclusion

all data works absolutely fine

phase

9.3. Recovery system test

9.3.1. Description

- **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.

9.3.2. Process

described in 7.5

9.3.3. Conclusions

described in 7.6

9.4. Communication tests

described in 5.4

9.5. Test equipment

- reference sensors (pressure x2, humidity, temperature),
- phone - gps,
- recommended sensors inside the satellite (accelerometer, battery voltage)
- digital multimeter
- Power Supply

10. Project planning

10.1. Time schedule

For the project schedule, we decided 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 79. Main steps are:

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

Run A will is the first of our construction. Run B means the second and final construction, improved after Run A?. We decided to order the whole BOM twice to support both Run A and Run B. At the same time, we planned to carry out activities related to:

Outreach programme:

phase

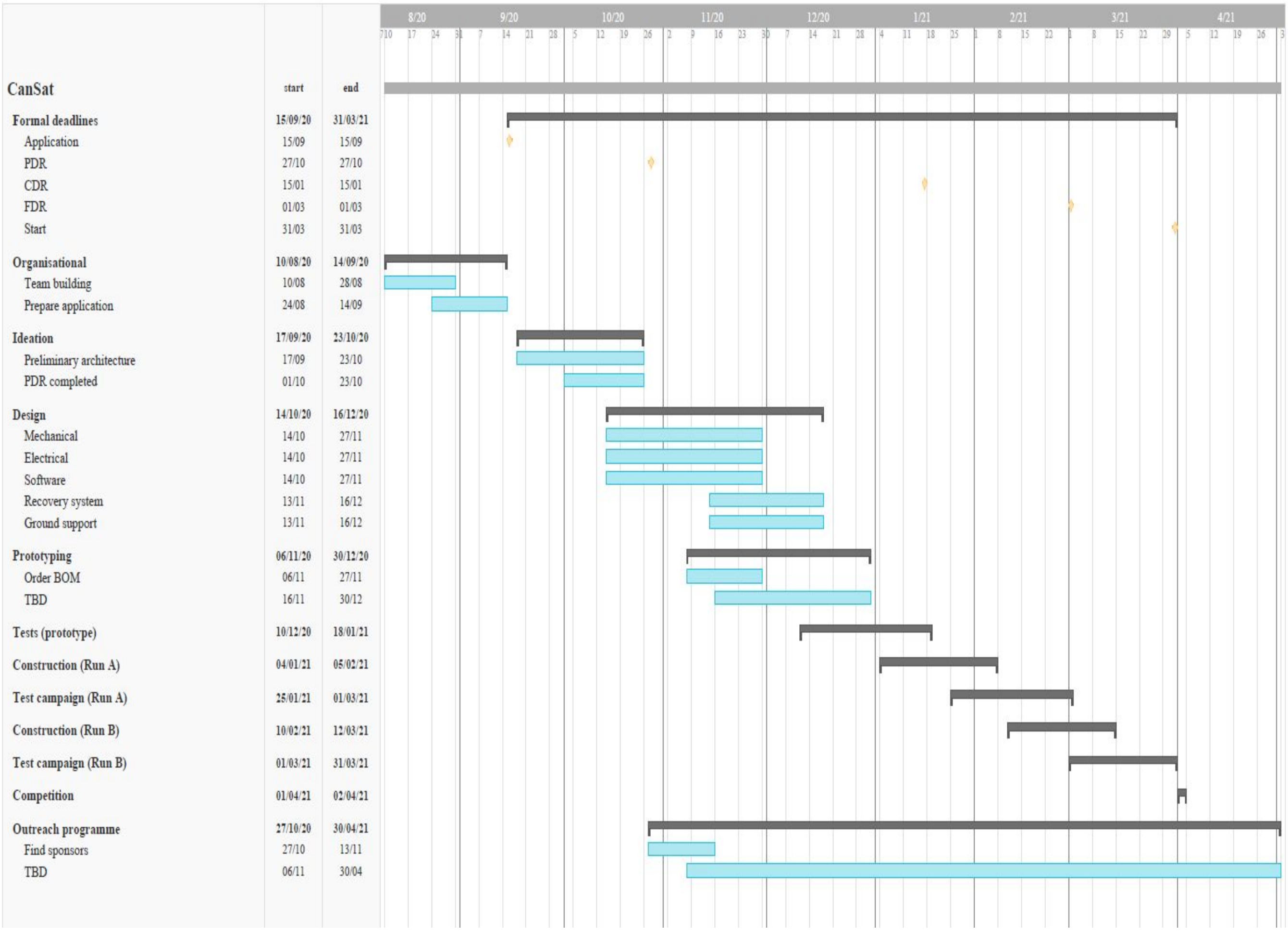


figure 86.

10.2. Resource estimation

10.2.1. Budget

Cansat:

- 5 Probes and nuts - 1.75 €
- Swivel- 1.99 €
- canopy fabric - 9.83 €
- 28BYJ-48 stepper motor : 3.29 €
- motherboard - 38.19 €
- SG90s - 5.44 €
- case - 1€
- electric pump- 3.53 €
- GPS module - 41 €
- DC motor driver - 3.46€
- 5V Voltage Regulator - 8.6€
- Temp, hum, pressure sensor - 4.41€
- Absolute pressure sensor - 28.06€
- Battery - 4.30€
- SD Card - 3.46€
- Power switch - 2.85€
- Gold Pins - 0.15 €
- LED - 0.03€
- Fotoresistor - 0.06€
- Silicon pipe - 0.17€
- PCV tee - 0.66 €
- PCV nipple - 0.33€

phase

● [Wire](#) - 0.11€ sum: 162.67€

10.2.2. External support

10.2.2.1. Accomplishments

- We got 66 EUR from closest relatives for a good start.
- We got 220 EUR from our school Principal
- Our first sponsor we reached is Fitech Sp. z o.o. (Grupa Fideltronik), ul. Kościelna 5, 34-200 Sucha Beskidzka. They declared significant financial support (amount is confidential, as was requested by sponsor)
- We are in touch with another sponsor: CanPack, 31-358 Kraków, ul. Jasnogórska 1
- In order to test the chemical composition of our samples, we established cooperation with Dr. Przemysław Grzywacz (grzywacz@agh.edu.pl) from the Department of Fuel Technology at the Faculty of Fuels and Energy at AGH, which has the appropriate types of chromatographs useful for our purposes. Link to the laboratory: http://home.agh.edu.pl/~kepw/badania/chrom.html#trace
- We have established a scientific cooperation with a research group from ACMIN AGH, with dr inż. Angelika Kmita (akmita@agh.edu.pl) and Dr. Dorota Lachowicz (dbielska@agh.edu.pl).

10.2.3. Outreach programme

Our plan was to promote the idea of taking part in technical competitions. We decided to use facebook.com to upatade our progress. For the sponsor we designed and created the website. We made a small seminar for our school students to explain about our project. Participation was voluntary after lessons.

10.2.3.1. Facebook website

10.2.3.2. Description

We were reporting about our progress throughout all time we were working on the CanSat. Our page had some constant followers who were very active on our post. On average our post reached 66.5 people only from our followers. Also on average 21.2 people interacted with our post.

10.2.3.3. Best posts due to reach

figure 87 - post that reached 130 people

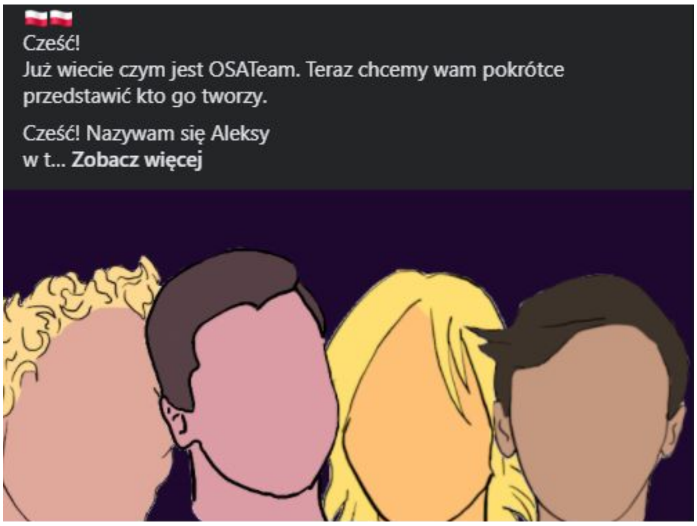


figure 88 - post that reached 103 people

10.2.3.4. Best posts due to interaction

phase

figure 89 - post that 34 people interacted with

figure 90 - post that 32 people interacted with

10.2.3.5. Website

10.2.3.6. Description

We wanted to have a website so people (most importantly sponsors) could have easy access to most important information about our project.

figure 91 - fragment of our website

10.2.3.7. Seminar

10.2.3.8. Description

phase

We made a seminar for our project. We presented what is CanSat competition, about our primary and secondary mission, process of designing and constructing ground system and OSACan itself. It took about 30 minutes and all of it was done by our team.

10.2.3.9. Screenshots

figure 92 - seminar screenshot 1

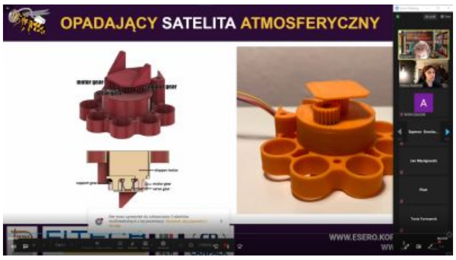


figure 93- seminar screenshot. 2

figure 94 - seminar screenshot 3

11. Summary

Most of the assumptions have been achieved, the design is not perfect, but it is capable of its first flight, many improvements could be made in the future. Having learned from experience, we would change more important things: the battery has too much capacity and size, half the size would be enough. The gear is too imprecise. The power plant in this model is soldered by hand, a dedicated PCB could be designed. What we did not manage to do are the final CanSat drone drop tests. Unfortunately, we do not have such equipment or possibilities. We intend to implement the improvements described above, if possible, before the potential finals. We couldn't manage to design data analysis.

12. 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	304g
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	162.67€ €