cansats in europe

esa

CanSat 2021
Final Design Review (FDR)
OSATeam, Poland

VIII Prywatne Akademickie Liceum Ogólnokształcące w Krakowie

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1 INTRODUCTION

OSA (polish abbreviation of "**O**padający **S**atelita **A**tmosferyczny", 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.

1.1 Team presentation

Team leader - Piotr Wyżliński

Piotr is the framer of the whole project. He came up with the idea of participating in the CanSat competition and proposed a secondary mission. Beyond organising team tasks, he was responsible for the communication system, outreach program and test campaign. Piotr also designed the logo concept ("osa" in polish means "wasp")

Technical lead - Stanisław Michalik

Stanisław is the main designer in OSATeam. Besides mechanical design, he also is responsible for 3D printing and testing the mechanism and casing. In addition, he helped with software development of the OSA backend.

Recovery system and data analysis - Miłosz Słowiński

Miłosz took the responsibility of designing and crafting the parachute that served as the recovery system of the CanSat. He prepared some simple data visualization for the competition that consisted of graph plotting and data interpretation in real time. He designed OSATeam's website as well as many of the social media posts. Miłosz also took most of the pictures documenting our journey.

Electronics - Aleksy Grymek

Aleksy is responsible for the electronic part. He designed electronics schemes and selected all the components. Besides that, he supported some parts of the marketing campaign.

Faculty advisor - Antoni Żywczak

Antoni was responsible for tutoring the whole team and financial management.

Most of the project tasks were done during lockdown because of the pandemic. This is why the team was forced to work mostly online. We dedicated on average 3 hours for meetings per week. Apart from that, some team members worked from 5 to 30 hours per week working on their own with assigned tasks.

1.2 Mission objectives

The satellite mission was inspired by information from one year ago Venus study[1], which discusses detected phosphine that could indicate that there was life on this planet. OSATeam designed a low-cost system to gather atmosphere samples which can be later analysed in terms of composition. The team wants to test the Earth's atmosphere sampling system so that later a similar solution could be applied to a real mission. We were inspired also by the NASA stardust project[2].

The purpose of the mission is to show that it is possible to collect samples without building satellites equipped with expensive and heavy lab equipment, instead, samples can be effectively collected to be analyzed in an external dedicated laboratory, eg. on the rover. Instead of investing in satellites with multiple sensors and onboard laboratories, 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.

Satellites, called OSA, can be used in the future in research of the other planets. They can be used for searching for inhabitable planets or in the search for another life in the

[1] https://www.nationalgeographic.com/science/article/possible-sign-of-life-found-on-venus-phosphine-gas
[2] https://solarsystem.nasa.gov/stardust/overview/index.html

universe. Although they are prepared for Earth conditions only, we hope that after necessary modifications, that could work on other planets. We prepared [a short video] about our idea.

OSA functions are split into two missions: primary and secondary, both working simultaneously.

Primary mission

CanSat's primary mission is in accordance with the regulations of the CanSat competition. The goal 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 are also saved in the local CanSat's memory (SD card), so that it can be analyzed after the satellite lands safely.

Secondary mission

The secondary mission is for us the main task and addresses described ideas around the atmosphere analysis.
The mechanical system consists of a specially designed sampling mechanism. Five sterile, vacuum, cryogenic containers are put on the circle of diameter 66 mm (the size of a standard soda can). The needle is injected one after another to the containers. Each sample is tightly sealed after injection due to rubber membrane.
The data from the primary mission is used to calculate the altitude from which the CanSat is dropped and to calculate live altitude, and hence the speed and the time of the descent. Based on these calculations, the onboard microcontroller will estimate intervals to collect the next atmosphere samples.
The satellite is equipped with a GPS location system, necessary to locate CanSat after landing.

Data and probe analysis

Samples collected during the tests were tested for their composition in the external laboratory. The analysis of the Earth's atmosphere was expected to show that air pollutants (carbon dioxide, methane, ozone) can be detected in the air not only at the Earth's surface and that the amount of pollutants varies depending on altitude and conditions. The analysis confirmed this hypothesis

Project complexity

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 containers 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. We also meet a lot of low-power challenges.
- Power supply system: must be safe, the energy in the battery must be sufficient for the assumed number of working hours.

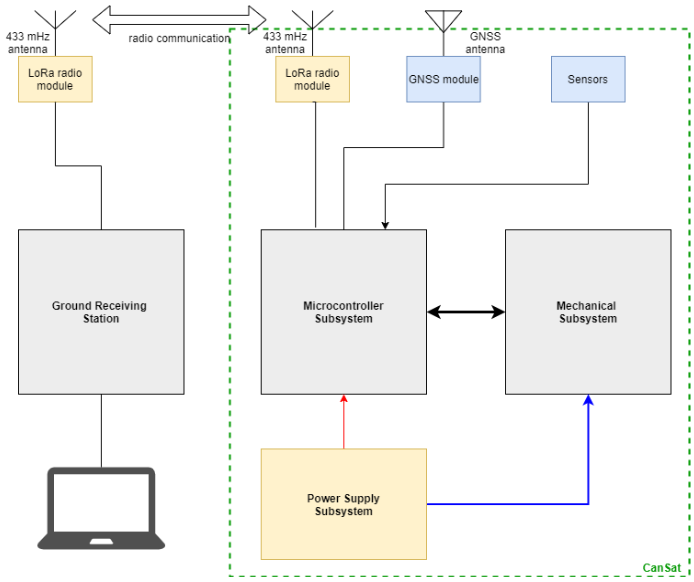
Supplementary mission

We want to demonstrate complex functionalities of our CanSat. At the last moment we decided to prove OSA can carry other substances which can be examined in terms of acceleration and temperature. We decided that CanSat will contain two different samples of aerogels inside.
Aerogels are known to be the lightest materials ever known with an extremely low density. They are porous materials with various potential applications in the space industry due to their unique properties. Since they could be used in future space exploration missions they need to be gravity overload and low temperature-proof.

2 CanSat Description

2.1 Mission outline

The OSA is designed to be launched and dropped from a rocket or drone from an altitude of 500-2500 meters. After stabilization of falling (equalizing the forces), CanSat should drop at an average speed of about 6-7 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 (ground), 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 is 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 onboard microcontroller (mcu) 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.



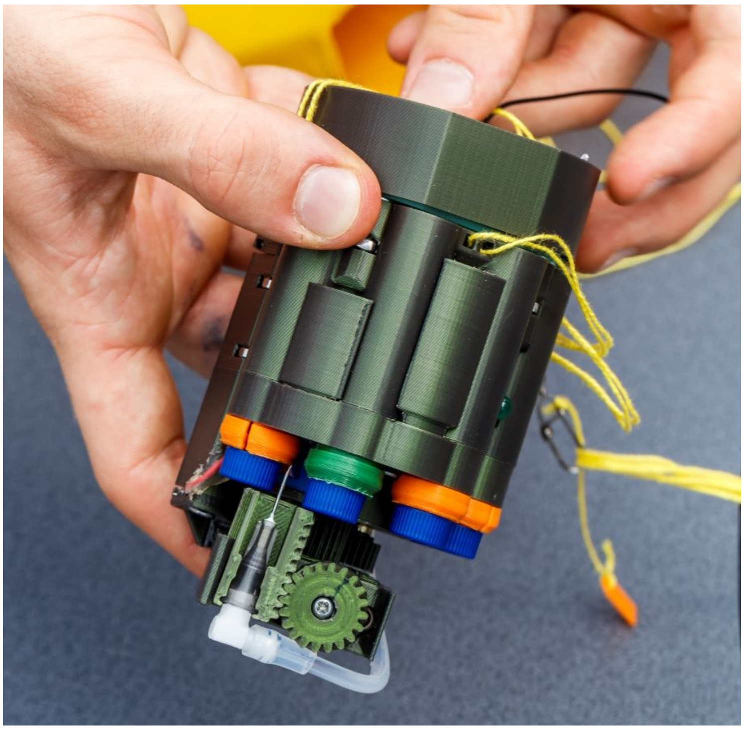
Additional data related to the measurement process itself will be collected at the time of sampling, that is recording initial, final pressure in containers and diagnostic data of the filling mechanism. Data is used to control the filling process. Five atmospheric sample containers are expected to be filled and delivered to the ground.
The radio communication system based on LoRa protocol is designed to send this 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 onboard 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.

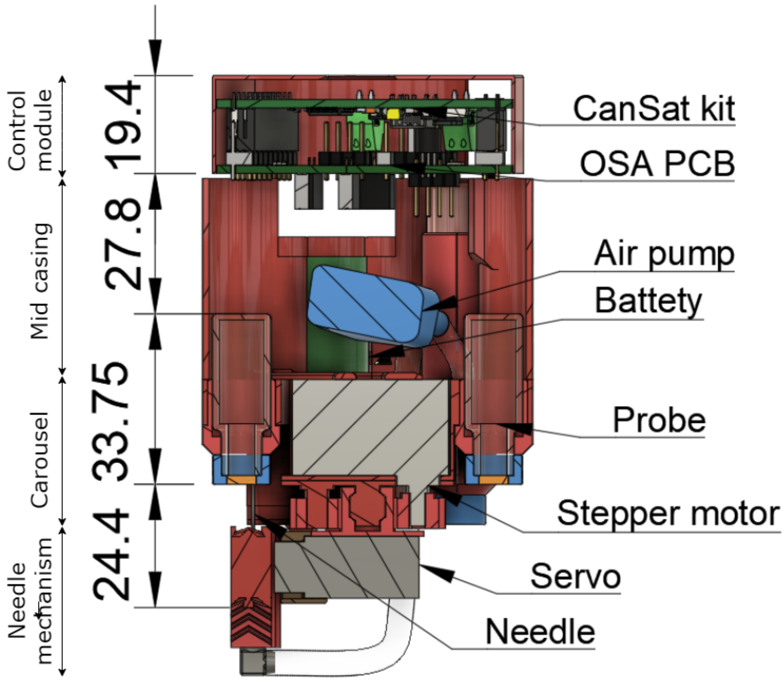
The ***Mechanical Subsystem*** (sampling and probe filling) is a key element of the second mission. A special sting system has been designed to fulfill the purpose of filling. An atmosphere sample at a certain altitude will be sucked from the outside of the CanSat by a gas pump. The gas, compressed to about 1.5 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. The block diagram presents the proposed architecture of the whole system.

2.2 Mechanical

Mechanical design was created in fusion 360. The full project is available here: https://a360.co/3AG3GMY

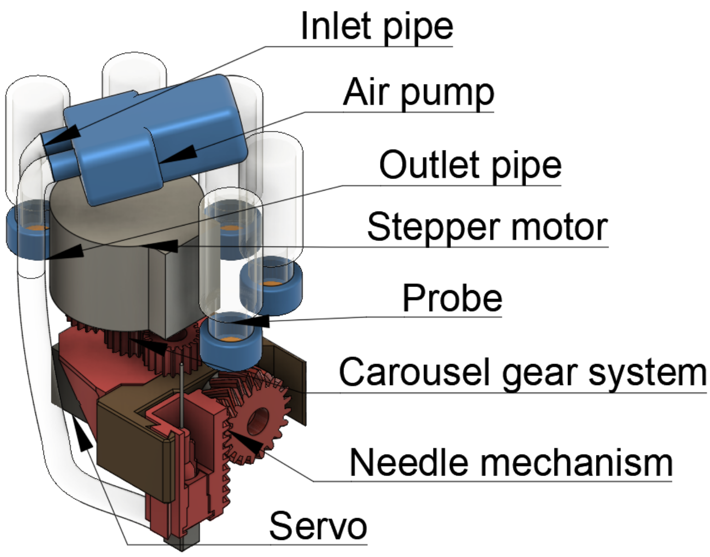




OSA can be divided into four main modules. Starting from the top, the first one is the **Electronics Assembly**. It consists of two PCB-s - the official CanSat kit and a custom shield. All electronics are covered with a thin 3D printed case that slides onto it. The second module is the **Mid-casing**. This part holds everything together and provides mount points for the battery, parachute and diodes. Prevents the stepper from falling out and allows adding external ballast. The third module is the **Carousel**. It holds probes around the stepper motor, and as the same part it is a mechanism that allows it to rotate the needle mechanism. Finally, the **Sting System** is responsible for moving the needle up and down so it can spike the probes.

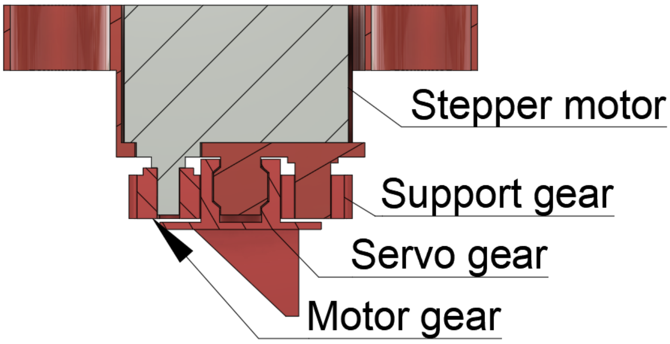
The OSA sting system is designed to collect air samples. After the needle is injected into one of the test tubes, the pump fills the probe with air. Then the needle is ejected and the stepper motor rotates the needle to the next probe. The process is repeated for the next tube. It can be seen in action here:

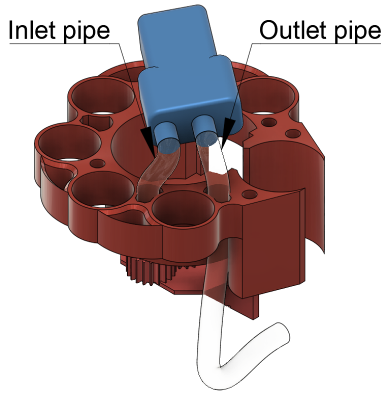
https://www.youtube.com/watch?v=AK9AAYOXLHI



Carousel is designed to hold the test tubes and rotate the needle mechanism between them. It uses a 28BYJ-48 stepper motor. Its shaft is located on the side of the motor so it was necessary to design a custom gear system. It consists of three gears (ratio 1:1:1). The servo is attached to the center one. The motor controls one of the side gears and the last gear is used to reduce the backlash of the mechanism.

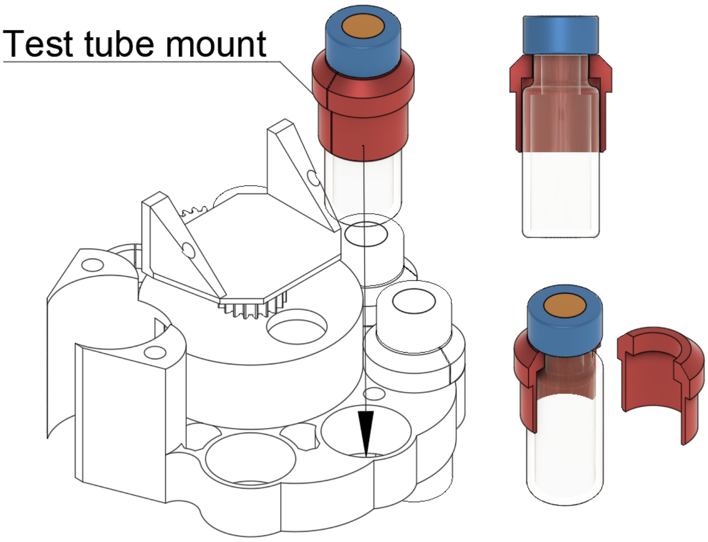
The middle part of the casing prevents the motor from falling out and fixes it in place. The carousel was designed to be easily 3D printed. Servo gear is printed in place with the base of the case (the part that holds the stepper motor and test tubes) as one part. It is

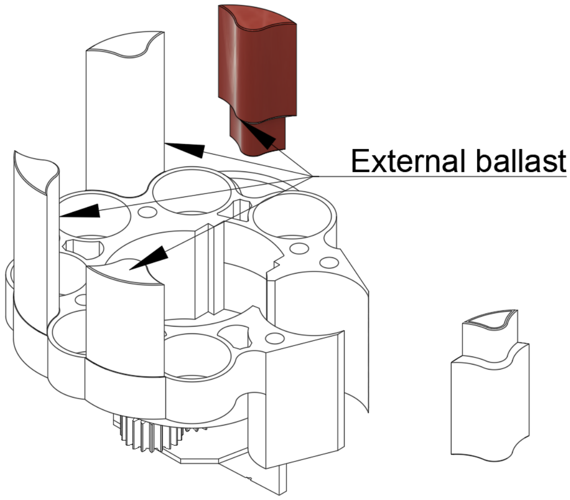




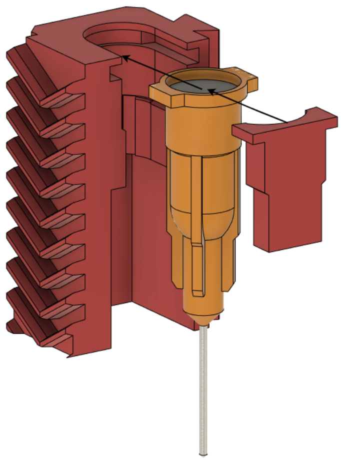
mounted on the round body, so it holds together. Support gear is printed separately. In order to mount it to the base, G-code was modified to pause the print at the right height.

Custom adapters have been designed to allow for easy mounting of the test tubes. They slide into the carousel body and hold the probes strong enough so they don’t fall out during launch, mission and landing but can still be easily removed to take them to analysis or exchange them with new ones. If needed, external ballast can be easily added. It’s made of a 3D-printed body filled with lead balls. The ballast could be mounted as in the picture.





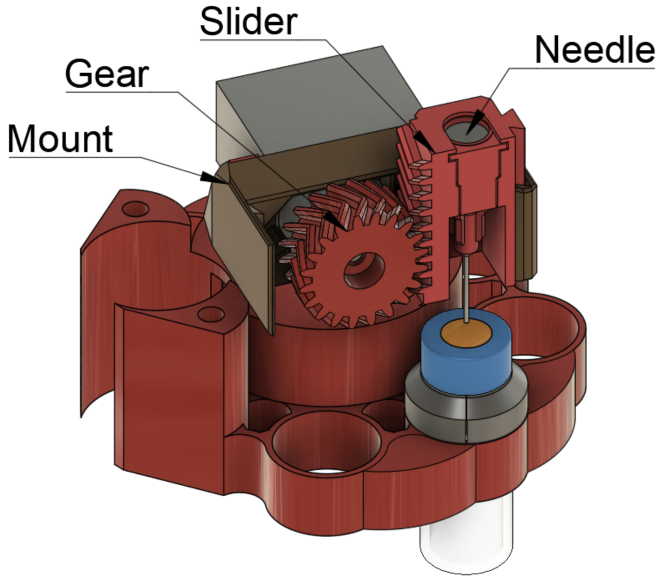
Needle-mechanism



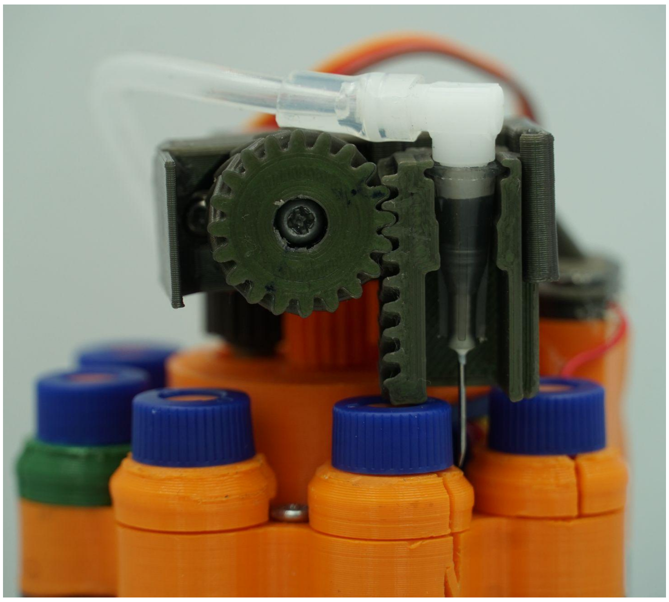
The needle-mechanism is designed to stick the needle into the test tubes. The mechanism translates the circular motion of the MG90s servo to the linear motion of the needle.

The mount part provides a slot for the slider. The gear system was designed to work with as little backlash as possible. Due to the size limit, the mechanism is meant to be small and compact. When OSA

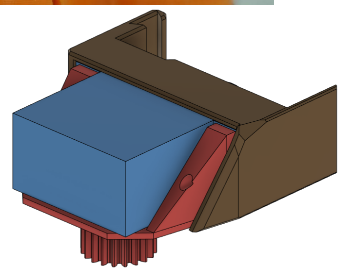
Awaits for launch in the rocket, the mechanism is in the rest position (the needle hides between test tubes) so that it takes less space. After taking all of the samples OSA also goes to the rest position to reduce the chances of damaging the mechanism during landing. To prevent the pipe from spinning into the gear we designed a thin wall on the side of the mount part. The mechanism was tested on rubber up to 6 mm thick so it is more than strong enough to pierce the test tubes chosen in our design.



Rest position

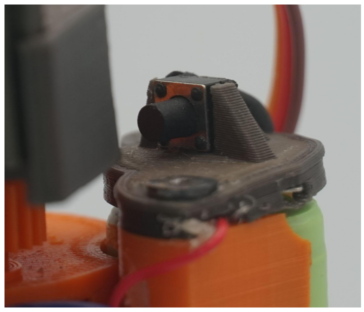


The micro servo is attached to the servo gear (carousel part) by two screws. Needle slides into slots in the linear gear. The blocker slides after the needle to hold it in place, then through a plastic adapter, the needle connects with the pipe. The mechanism is meant to be 3D printed with as little supports as possible (they are needed only for the slider)



Endstop

The end-stop 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 end stop is necessary. For Endstop we chose a simple electronic switch.

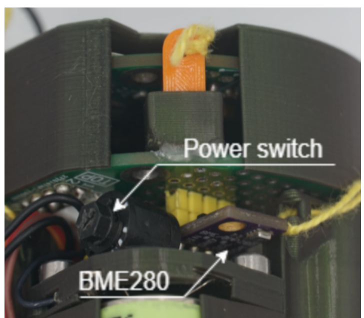


Parachute Deployment Detector

OSA is equipped with a detector that informs whether the parachute is opened or not. It's made of a simple switch and 3D printed box. A little plate that is tied to the parachute goes between the switch and the box wall, so the switch is pushed. When the parachute opens, the plate goes out and releases the switch.

Sensors of Ambient Air Parameters

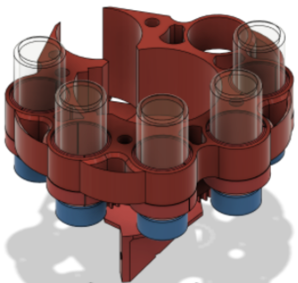
For the primary mission we chose the BME280 sensor that can measure temperature, atmospheric pressure, and humidity. The sensor is located under the detector, and next to the power switch as it is not covered by anything.



Probes

To gather the samples we chose glass probes: and rubber screw caps. Probes were sterile but not vacuum-sealed. We used AGH's (our

Partner, Polish University) equipment to remove air and to fill the probes with argon under pressure. While taking a sample, OSA fills the probe by puncturing the stopper with the needle. After removing the needle, the hole seals itself. When analysing, argon can be easily separated from other gases, so we can know that the sample had not been contaminated before launching with gases from different altitudes.



Probes attachment
to the carousel body

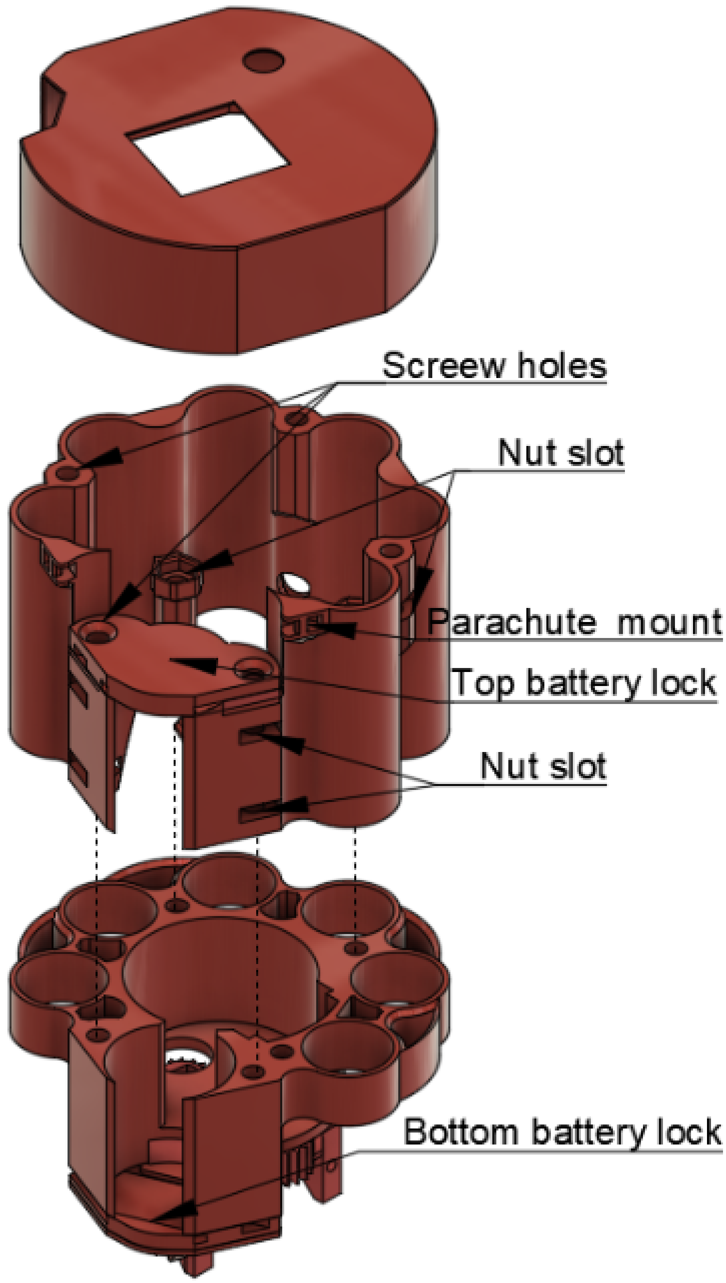
Probes photo

Casing

The main casing (contains mid-casing, carousel, electronic case) and the needle mechanism has been 3D printed. As the material we chose fiberlogy easy pla because it provides high accuracy and is strong enough for our use case. For a mechanism such as a carousel, high print quality is necessary.

The casing is designed to:

- provide the basis for mounting of 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 people who find OSACan after landing from injuring,
- provide quick access to the CanSat power switch, probes, interior including the battery,
- protect the inside of the satellite from outside conditions (temperature, humidity, air momentum when falling),
- be as easy to print as possible



Construction

The mid-casing part is connected with the base by four screws. In the main casing body, there are slots for M3 nuts. The electronic boards are connected with the main casing body by three M3 screws.

Battery mount

The battery is located on the side of the CanSat. The construction allows for easy access to the battery. During overload power supply is continuous since we didn't use any springs.

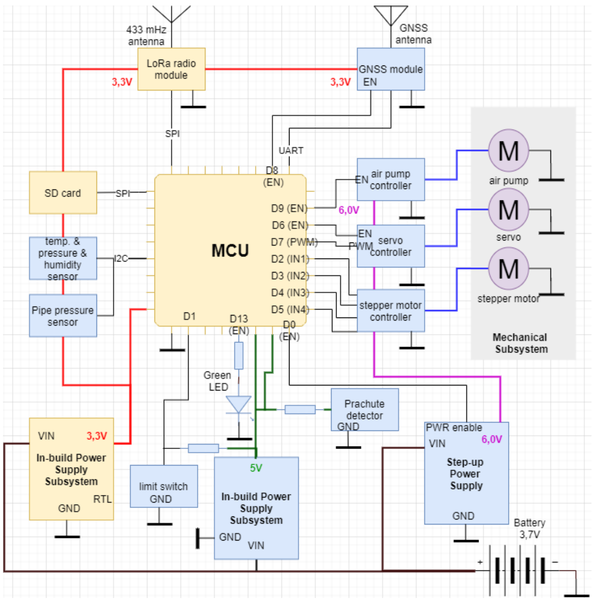
Aerogel samples

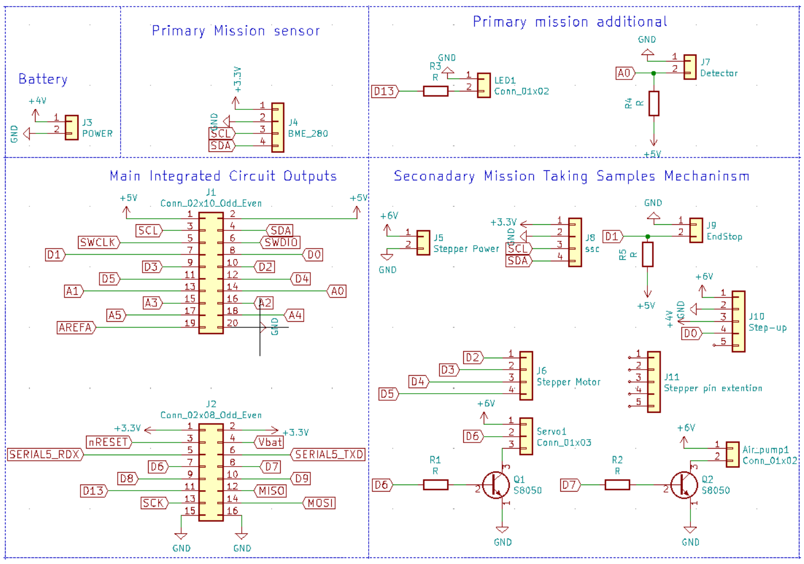
One aerogel sample was located in the place of the sixth probe (which we decided not to use). The other one was between the pump and the stepper motor.

2.3 Electrical design

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. The “Main Integrated Circuit Outputs” section is responsible for connecting our pcba shield with the CanSat integrated circuit. The shield is made from a cansat universal board. On github there is a designed shield that we are working on so it could be manufactured.

Our CanSat uses a BME280 sensor to measure humidity, temperature and atmospheric pressure. After landing stepper motor, air pump and servomechanism can stop taking power to conserve battery. Due to special needs most of the secondary mission components are supplied with 6V voltage which is produced by a step-up.





Bill of Materials (critical):

- *BME280*

  Humidity, temperature and pressure sensor, used for measuring ambient air parameters
- CanSat kit main PCBA
- Honeywell SSCDANV030PASA3

  Very small pressure sensor, used to measure pressure inside the probes to check if probe was filled;
- Adafruit ultimate GPS

  Small GPS module: Model, used for calculating current height of the Can Sat and tracking its position
- Servo MG90s

  Small strong servomechanism used to inject needle into the tube.
- 28BYJ-48 stepper motor

  It is the smallest stepper motor on the market with low voltage supply in a reasonable price range in the shape of a cylinder. Used for moving the carousel mechanism.
- AJK-B03V1405C Air pump

  Small electric air pump, used for pumping air into test tubes.
- S9V11F5S6CMA Step-up

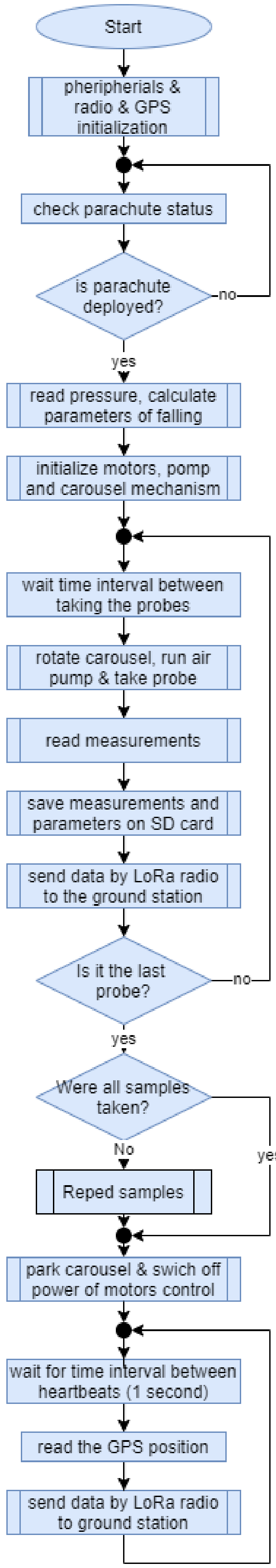
Small Step-Up/Step-Down Voltage Regulator. This component allowed us to supply proper power (6V) to components such as stepper motor, pump, and servo.

- NCR18500A Panasonic Lithium-ion Battery. The capacity of this battery is about 1940mAh - 2040mAh and the voltage: 4.20V.

2.4 Software design

General description

The software covers the support of CanSat Kit Hw v.1.4 and the additional shield with external peripherals. The software was developed in Arduino C, C, and C++. Target binary code is built for the M0 family of microcontrollers. We were using the Arduino toolchain during the initial phase and the Visual Studio toolchain during the final phase of development. To make the code cleaner, we wrote an Arduino library for controlling all OSA systems. The source code is available for download on GitHub.



The way how the developed algorithm works is represented by the block diagram on the right side.

After powering up, the board initializes all its peripherals and runs a self-test procedure. After all the checks are successful, the OSA starts waiting for the parachute deployment, it stays in low-power mode. From that moment OSA sends via radio and saves to SD card all measurements, and mission data every second. It takes measurements regardless of other systems, so there should be no loss of data. When parachute deployment, MCU read the ambient air pressure, calculate the altitude of the satellite. From this maximum altitude and knowing the altitude of the ground (saved before rocket launch), MCU calculates altitude intervals between taking samples. Also, OSA estimates the falling time between taking samples.

We assume that this altitude is the initial point of the falling with velocity 7 m/s. So mcu estimates the falling time. This time divided by the number of probes plus 1, determine the waiting time between taking the probes.

Now one of the most important procedures starts - initialization of motors, pomp, and servo control system. The needle position is also calibrated based on the limit switch. The GPS fix should be found in seconds with a backup battery connected to the GPS module.

After successful initialization, the main loop starts. The software executes the chain of procedures inside the loop. The first is responsible for the carousel manipulation (taking samples at previously calculated altitude). Next gather values of measurements and parameters, serialize data, save on SD card and send by LoRa radio system. The loop is executed until OSA collects all 5 probes. Thanks to the SSC sensor OSA knows whether the probe was taken or not. If for some reason some sample wasn't taken, OSA after taking the last sample will autohome and try to take this sample again, before it hits ground. OSA saves altitude where it started taking a sample and the altitude on which it finished. This data with other information about the secondary mission (parachute status, sample status, etc.) is sent with all measurements.

The last air probe should be filled before landing. The carousel system goes to the rest position to protect the mechanism from damage before it hits the ground. All motor, servo, and pump circuits are turned off to save energy again.

Afterward, MCU starts to execute an infinity loop, where the GPS position and other data are periodically transmitting every one second to the ground station to provide a way of finding OSA. The loop continues until the device will be found and powered off.

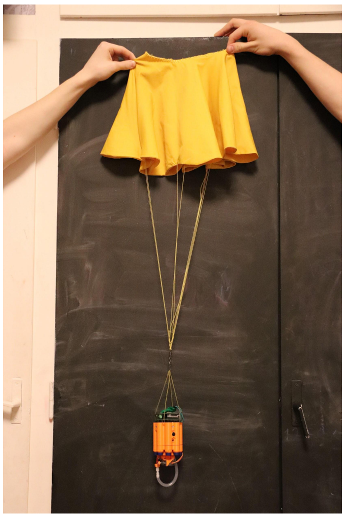
Data before transmitting are serialized using an encoded function to reduce the radio frame size.

Measurements

We are measuring, gathering and transmitting following data:
Timestamp of the moment when turn on the CanSat (milliseconds), ambient air pressure, in-pipe air pressure, ambient air temperature , ambient air humidity, GPS data, Number of probe was taken, Altitude where the probe was taken, In-pipe pressure (should be equal in-probe pressure) after pumping, Time of pumping

2.5 Recovery system

As a recovery system we have decided on using a parachute. The drag force, which was easily calculated, allowed 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 about 6-7 m/s. Using the terminal speed equation we figured 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 is located a spill hole that keeps the chute from tilting sideways. The ratio between spill hole area and canopy area measures 1/20. Furthermore we connected canopy lines to the cansat using a ball bearing swivel that helps to prevent line entanglement. Total descent time was calculated to be around 7 minutes but during the finals it turned out to be a little less making the average velocity equal to 7 m/s.



2.6 Ground support equipment

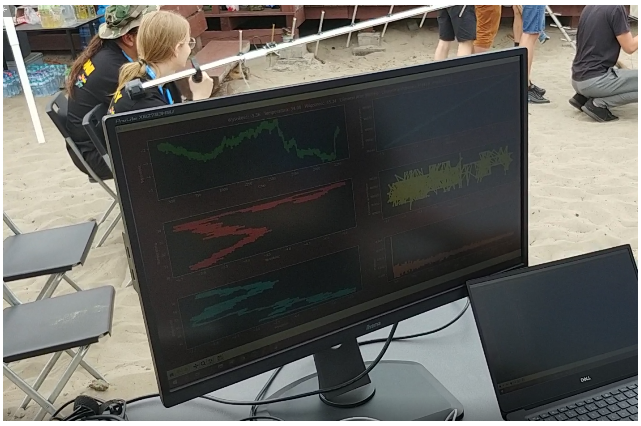
Ground receiving station

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

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]. We calculated parameters with yagi antenna calculator[3].

The most important construction element is the dipole **with balun.** The balun is made of the special plate and transformer JA4220-ALC Coilcraft to strengthen the signal.

Data visualization Front-end



We used PuTTY software to put received data into one log type file. Using simple python programming and matplotlib library we are able to plot graphs reading the log file in “real time”. Using matplotlib’s animate functions we were able to do so in real time. We had three different windows running at the same time. One of them presented six different graphs as well as current values of the collected data. The second one was connected to the GPS location of our probe. The last window displayed important information regarding our second mission. It presented which probes were collected as well as the altitude at which the process started and finished for each probe.

3 Project Planning

3.1 Time schedule of the CanSat preparation

Originally Time Schedule

The originally planned activities were divided into the following groups of tasks represented on the attached Gantt chart (yellow):

- Team Building (activity started before we decided to enter the CanSat competition)
- Ideation (activity started before we sent the application to the competition)
- Looking for Sponsorships
- Design
- Prototyping (we planned two phases: Run A - the first of our prototype, and Run B - construction after needed modification)
- Test campaign
- Content and Outreach
- Competition (we hoped to participate)

[3] https://www.changpuak.ch/electronics/yagi_uda_antenna_DL6WU.php

The plan was prepared in relation to all deadlines resulting from the competition regulations at the national level of CanSat Competition (Esero Poland). We also added deadlines related to the European level of the competition (ESA).

Most of the project tasks were done during lockdown because of the pandemic. This situation forced the team to work mainly online. We had to adapt to the difficult challenge of developing a hardware project remotely.

Completed Activities

Most of the project tasks were done during lockdown because of the pandemic. This situation forced the team to work mainly online. We had to adapt the plan to the difficult challenge of developing a hardware project remotely.

The completed activities section (green) on the Gantt Chart reflects the main changes in approaches:

- Instead of the two phases of prototyping (Run A and B), we changed the approach to a more agile, based on iterative increment.
- Start Campaign was postponed, so we had got more time for development, we did more prototype iterations and tests.
- We carried out an additional start campaign using drone (on our own) to correct the mechanical construction and software
- Unfortunately we ran out of time for Content & Outreach activities, we started this activities after settlement of country competition

Continuation of the project

What is worth emphasizing, we want to continue the project independently of CanSat European Competitions. We have planned further activities until the Christmas season (section Next Planned Activities).

Gantt Chart

For the project schedule, we decided to use the free desktop project scheduling application Gantt Project[4]

3.2 Resource estimation

3.2.1 Cost Budget

5 Probes and nuts - 1.75 € Swivel- 1.99 € canopy fabric - 9.83 € 28BYJ-48 stepper motor : 3.29 € motherboard -95 € SG90s - 5.44 € case - 3€ 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€ switch x2 - 0.02€ Silicon pipe - 0.17€ PCV tee - 0.66 € PCV nipple - 0.33€ Wire - 0.11€

sum: 220.44€

[4] https://www.ganttproject.biz/

3.2.2 *External support*

1. Scientific support
    - 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).
2. Financial support
    - We got 66 EUR from family & friends for a good start.
    - We got 358 EUR from our school Principal

    We were and will be financially supported from following companies, although amounts are confidencial:
    - Fitech Sp. z o.o. (Grupa Fideltronik), ul. Kościelna 5, 34-200 Sucha Beskidzka, Polska
    - Bart serwis Sp. z o.o.: ul. Małobądzka 4A, 41-214 Sosnowiec, Polska
    - Brena Nieruchomości, ul. Jerzego Samuela Bandtkiego 13b, 30-129 Kraków, Polska
    - Prokon Piekarska Katarzyna, ul. Arniki 22, 04-903 Warszawa, Polska
    - Grenton Sp. z o.o, ul. Na Wierzchowinach 3, 30-222 Kraków, Polska
    - Fundacja Nauka. To Lubię!, ul. Jojki 7C, 44-186 Gierałtowice, Polska
    - Estimote Polska Sp. z o.o, ul. Krakusa 11, 30-535 Kraków

    Summing up we were sponsored with almost 1000 euros which were used for testing, designing and marketing campaigns.
3. Which support did we lack during the country phase of CanSat competition?
    In the future we would like to find specialists in marketing since we had big problems with outreach programme.

3.3 Testing

Primary mission

1. Communication
    We put two CanSat boards in protective boxes on the very high place with 7m inbetween (figure 69). We used 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

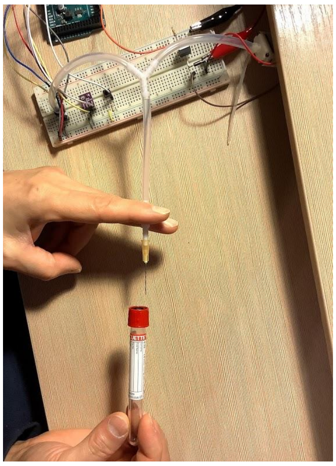
"1" the better.

The final test was made using two different CanSat boards. One was put in OSA, the second connected to the antenna. We decided to use a distance of 7.89 km with no obstacles on its way (two hills). We tested a lot of sets with different parameters and decided to go with: Frequency: 433Mhz, Bandwidth 125000, SpreadingFactor 9, CodingRate 4_8.

2. Recovery system
We went over three different iterations of parachutes. The first parachute test results were a failure. The parachute did open but the drag force did not hold the maximum velocity from reaching 18 m/s. We concluded we selected a wrong value for the drag coefficient. To determine the correct value of the drag coefficient we created four test parachutes with different values of the coefficient(0.5; 0.65; 0.75; 0.9). We also made a strip of coloured tape to help us indicate the scale of the video. 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 6 m/s.Using the newly found coefficient value we created our final parachute. The lines were connected parallel to each other and were connected to the swivel to prevent line entanglement. Drop tests:
    - 1st iteration
    - 2nd iteration
    - 3rd and final iteration
3. Overload

Sampling system

1. Gearing:
We tested many different gears designs, ways of locking them in place and printing tolerances to print in place. The final result put into the main project works well and servo gear is stable connected with the base part while easily spinning.
2. Power:
When the stepper motor was powered directly from the battery (3.7V) the voltage went down and mcu resets. We needed to build an independent power circuit for motors, using a step-up module. By the way, the voltage for motors increases to 6V
3. Injection:
We executed numerous on-desk tests during parameters matchup. We tested different mechanisms and probes. Finally we used a linear injection runner by slider.
4. Pump and needle:
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.
After changing probes we tested filling time again and it reached maximal pressure after 2 seconds. Although it was tested on an already built prototype. When the

mechanism was changed we decided to use a 0.7 mm needle as it is more resistant to damage and since force was no longer a problem.

5. Containers airtightness
   Containers right before finals were tested if they are hermetic. As they were filled with argon underpressure we decided to see if water was sucked when injecting the needle underwater. Probes passed the test.
6. Sampling during falling
   We tested if samples were taken by executing numerous flights from the roof (10m). We measured pressure in the probe during falling.

3.4 Lessons learned from the National Competition

During the competition (11.07.2021) on Pustynia Błędowska (50.33985162679201, 19.53330466640272), OSA was sent at a 2,6 km altitude above ground in a SOLARIS rocket. It was deployed from the 2,5 km altitude and landed safely, due to the parachute, on the tree. It was found after 4h.

Primary mission:

1. Recovery system: After deployment the parachute opened which was detected. CanSat was falling with an average velocity (calculated from altitude and time saved on SD card) of 7 m/s. OSA was safely delivered to the ground with all samples unharmed. ***No problems noted***
2. Communication system: We received all sent data until OSA stopped sending it due to a discharged battery. All the the time signal was strong (RSSI from -41 to -89, during flight). Since the subsystem worked it was possible to find CanSat after landing. ***No problems noted***
3. Electronic system: after flight conditions, during descent electronics worked without any problems. ***No problems noted***
4. Power supply system: must be safe, the energy reserve must be sufficient for the assumed number of working hours.
5. Software: in the post-finals review, we found literal errors in the part of the code responsible for taking measurements. They were made with such short intervals that the buffer stuck. We had lost 37,6% of our measurements data from sensors. Our code missed one safe code line. Probably due to that problem, the battery used more energy and had released more heat. Chamber in the rocket was warmed up from 30.12 to 34.24 Celsius degrees and during falling it needed 82 seconds to cool down. The secondary mission didn't start because we failed to put safe code. Probably the pressure sensor had read very high pressure due to wind blow and calculated several hundred times larger altitude (this amount differs from the ones sent via radio) and calculated sampling altitudes below ground level.

Secondary mission:

1. Mechanical system: didn't start working. However, after landing the mechanism was tested and acceleration did not impact the post-landing sampling process.
2. GPS: correct conversion factor wasn't used, due to buffer overload we were receiving only 1 location after CanSat was put into the rocket chamber.
3. Aerogels: were delivered safely to the ground. Samples were ready to be analysed.

Deployment from the drone:

We decided to repeat the flight right after finals, due to the fact we didn't collect any atmosphere samples and had one shot to give them over for analysis in the

chromatograph. ***All previously found errors were fixed.*** We add some <u>diagnostic data</u> to be sent. CanSat was deployed from 300 meters from the drone.
Primary mission:

1. Recovery system: ***No problems noted***
2. Communication system: ***No problems noted***
3. Electronic system: ***No problems noted***
4. Power supply system: ***No problems noted***
   Software: We collected 100% measurements from sensors. ***No problems noted***

Secondary mission:

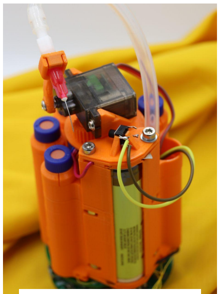
1. Mechanical system: All samples were collected. A sampling of the first one started 1 second after deployment, of the last one, 2 seconds after landing. Samples did not depressurize or unseal. They were safely delivered to the ground for later analysis. ***No problems noted***
2. GPS: worked correctly. ***No problems noted***

Data analysis:

We decided to analyse: data from sensors, samples in terms of composition and atmosphere contamination, and aerogels in terms of overload impact. Since it is not part of our mission we are putting it on [github].

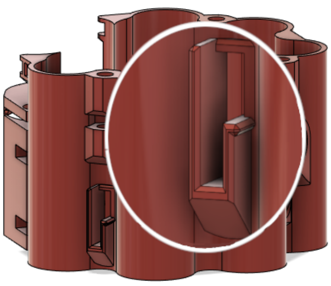
3.5 Troubleshooting

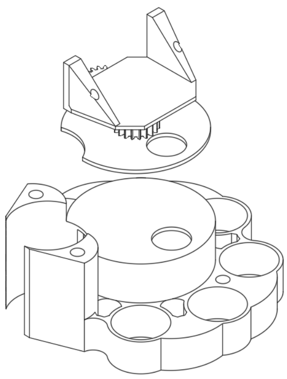
Mechanical


prototype **A**


prototype **B**

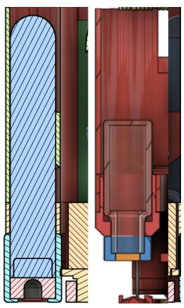
1. We designed two mechanisms. The main problem of thirst was that the needle had been injected at an angle. Needle needed more force to inject the needle. Not only we used more power but also needed to camber the needle. If angle wasn't perfectly measured, needle bended. Solution:
   We fixed it with a changing mechanism that translates circular movement to linear.
2. Heating problem: Chamber in the rocket as it was hermetic was warmed up from 30.12 to 34.24 Celsius degrees and during falling CanSat it needed 183 s seconds to cool down.
   Solution: After finals, we changed the location of the temperature sensor. However, the solution wasn't tested.





3. Printing: While the base is printing the printer stops at the right height so we can manually add support gear. As the mechanism is fragile and after the printing cut was needed to be executed it was easy to damage the mechanism. We decided to split it into two parts and then glue them. If we accidentally damaged a part only 45 minutes of printing is lost (compared to 4,5 hours).

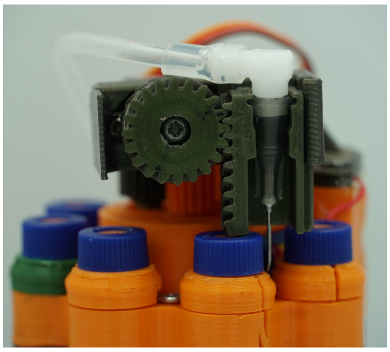
Space and mechanical adjusted:

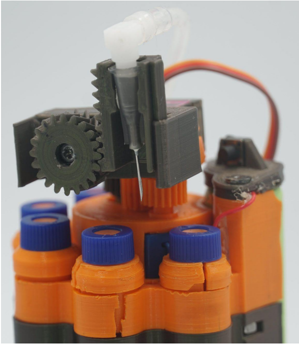


As OSA contains a lot of containers, samples and revolving parts we had problems with fitting in dimensions.
Solutions:

- We decided to use a smaller battery as power was sufficient for working for our missions.

- We changed probes. Firstly we wanted to use blood vessels as they were pre-vacuumed. However, there were no chances of fitting them with electronic parts. This change made us find a laboratory to fill our probes with argon under pressure.
- We added a *rest position* to our mechanism. This means when CanSat is in the rocket it is taking much less space. When the deployment is detected CanSat slider moves and OSA is sampling ready





Too small weight:

1. We added ballasts.

Software:

1. In the post-finals review, we found errors in the part of the code responsible for taking measurements. They were made with such short intervals that the buffer stuck.
   Solutions:
   - We programmed encoding data as it takes less memory
   - we fixed literal errors
2. Probably the pressure sensor had read very high pressure due to wind blow and calculated several hundred times larger altitude (this amount differs from the ones sent via radio) and calculated sampling altitudes below ground level.
   Solution:
   - We added a safe code line. CanSat waits 1 or 2 seconds (dependable on setting) to stabilise after deployment and then it takes interval measurements and calculations.

GPS:

1. During the in-house development we noticed permanent problems with the GPS signal and fix. Unfortunately the GPS signal under the roof is near 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 in-house.

2. the correct conversion factor wasn't used, due to buffer overload we were receiving only 1 location after CanSat was put into the rocket chamber.

4 Outreach Programme

OSATeam is currently socially active on these three media platforms:

- facebook
- website
- instagram

We managed to get 220 facebook and 194 instagram followers. Instagram was established after finals, so we reached this amount within 1,5 month. During the summer period it was hard to find media that would be interested in covering our story. That's why we decided to use paid advertisements to reach more people on social media. We had no trouble reaching out to several companies and managed to get a few helpful sponsors. Using those advertisements gave us a reach of 70 thousand people.

Facebook Page reach	Instagram reach
70,135 ↑ 34.3K%	67,258 ↑ 100%

However we were mentioned on following medias that have much bigger audience:

- Onet article
- lovekrakow article
- Centrum Nauki Kopernik facebook post
- lemkowyna ultra trail facebook post

We established contact with:

- Fundację Nauka. TO Lubię and they offered us publishing an article.
- Estimote which offered us contact with important space companies (such as NASA)
- Grenton which offered us promotion on their Facebook newsfeed
- AVT offered us article

We also shared our project with 3d printing community:

- creality 3d facebook page post

We redesigned our website to make it more clear for people trying to find out about our project.

Due to the fact that most of our project took time during lockdown we had to share our project via the internet. That’s why we made a presentation for people at our school. We presented the CanSat competition, talked about our primary and secondary mission, the process of designing and constructing the ground system and OSACan itself.

We have also started searching for a new generation of people interested in cosmic projects. We wanted to get new people involved in the cansat competition. We placed a few posters at our school with information about a potential science club.

Logo was designed by Piotr and is connected to the name as well as the second mission of our project. Osa can be translated to wasp. It is clearly visible in the design that it is stinging the probe - exactly what our cansat does with its needle.

We also started to make most of our files and code open source and available at Github. We wanted people that would find our solutions helpful to use them.

5 Requirements

Characteristics	Figure (units)
Height of the CanSat	114.4 [mm]
Mass of the CanSat	304g
Diameter of the CanSat	65.6 [mm]
Additional length of external elements (along axial dimension)	40[mm]
Flight time scheduled	167[s]
Calculated descent rate	7 [m/s]
Power consumption	1305 [mAh]

Total cost	219.94€

5.1 Power budget

For the power consumption budget we assumed that:

- OSA satellite is working 5 hours
- The first 1 hour OSA is waiting for parachute deployment (only mcu is working)
- The falling last 10 minutes (all motors consumed energy)
- The last 4 hours OSA is waiting for finding (LoRa radio is working all time, but only 10% of this time is used for transmission)

Component	Voltage (V)	Current (mA)	Power (mW)	Working time (s)	Energy consumed (coulombs)
MCU*	3.3	1.25	4.125	5h = 18000s	74.25
Radio module - standby mode*	3.3	1.6	5.28	1h = 3600s	19.01
Radio module - transmit mode**	3.3	184	607.2	4h * 0.1 = 1440s	874.3
Stepper motor - loaded**	6	410	2460	10m = 600s	1476
Servo motor**	6	400	2400	10m = 600s	1008
Air pump - loaded (1.5 atm)**	6	380	2280	25s	57
BME280 (1 Hz data refresh)*	3.3	0.0036	negligible	10m = 600s	negligible
Honeywell SSC*	3.3	2.1	6.93	10m = 600s	4.16
GPS module*	3.3	20	66	4h = 14400s	950.4
Total power (sum of all)					**4463.12 C**
Efficiency of power converter					95%
Total consumed energy					**4700 C**
Needed battery capacity (1 mAh = 3.6 Coulombs)					**1305 mAh**

*) datasheet
**) real measurement

Battery rated capacity is about **1900 mAh**, so it seems we have a sufficient reserve of energy for 5 hours. But it should be remembered that in freezing temperatures (which occur at high altitudes) the battery capacity rapidly decreases.

Anyway, during the start campaign OSA satellite was working about 3.5 hours without any problems.

On behalf of the team, I confirm that our CanSat complies with all the requirements established for the 2020 European CanSat competition in the official Guidelines,

Signature, place and date: Wyzlinski *(P.Wyżliński, Team Leader), Kraków, 14.09.2021*