cansats in europe

CanSat Final Design Review

Team Name: NERV

Country: POLAND

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1 CHANGELOG

PDR

- We have decided to use different method of measuring air composition

CDR

- We have reverted to original idea of using dedicated sensors for measuring air composition
- Our previous tactics to acquiring funds for project was not as successful as we expectd but we took a different approach and succeeded
- Way of harvesting energy was also changed due to Saul Technologies not responding in any way, and also with that change this system will minimalize the force of impact during the landing
- Source of energy was changed to Li-Pol (the permission was granted from the competition administration)
- Accelerometer and gyroscope was added

FDR

- After further testing the idea of harvesting energy using motor failed, so we went back to using solar cell to collect energy.
- Particulate matter sensor was replaced with more professional one, because the previously used model accurate was not sufficient.
- Filament used to print internal structure was changed along with upgraded hardware.
- Outer carbon fibre shell was upgraded.
- Parachute was modified to meet our requirements.
- Protoboard was replaced with PCB to increase reliability.
- Motor used originally for energy harvesting is used for different purpose.
- Software took necessary modifications to accommodate newly introduced data, more details are available at respective GitHub repos.

2 INTRODUCTION

Team organisation and roles

From left to right:
Paweł Kelm – Supervisor of the project, external support acquisition. Assistant Professor at Institute of Electrical Power Engineering, Lodz University of Technology
Aleksander Ałaszewski - Team leader, mechanical design, mission objectives. My interests are mechanics, automotive, space industry. I spend around 20 hours after school and 1.5 hour at school per week developing our project.
Janek Pawelec - Outreach and graphic design. My interests and hobbies are electric vehicles, electronics, resin moulding and photography. I've joined my friends in the CanSat project thinking that my skills and determination might come in helpful. I spend around 9 hours after school and 1 hour at school per week developing our project.
Jakub Sztuka – Electrical design and software. My hobbies revolve around DIY electronics, 3D printing, radio-controlled aircraft and programming. I'm familiar with micro soldering and PCB design. I spend around 20 hours after school and 1 hour at school per week developing our project.
Dawid Frukacz – Ground support equipment and recovery system. My interests are mainly 3D printing, modelling and space industry. I spend around 8 hours after school and 1 hour at school per week developing our project.

Mission objectives

Our primary mission is to measure air temperature and pressure during the descent of the CanSat, this data will be transmitted in real time (one time per second). Then we would compile, analyse and present the data with graphs showing those variables. On the basis of the gathered data, we will determine altitude and falling speed. We expect pressure and temperature to change in proportion to the height.
We plan to investigate three topics as our secondary mission. First, we want to explore the efficiency and potential of energy harvesting by using a special low light solar cell. During the descent, then after landing the solar cell will be exposed to sunlight and will generate power. A special circuit will regulate voltage and charge supercapacitors that will act as a power source for our on-board real-time clock (RTC). The voltage of the supercapacitors will be constantly monitored, and after mission we will calculate the collected power by equation no 1 also taking into account the power drawn by RTC:

$$E = \frac{CV^2}{2} \tag{1}$$

Also, we want to examine to what extent we can minimise the force of landing impact. During the descend, when the height sensor detects that the cansat is 2 m above the ground the motor will be started. Electronic speed control (ESC) will be used to give the motor full throttle for 3 seconds to minimise the force of touchdown. The accelerometer will be analysed to assess the effectiveness of braking.
The next objective is to put an array of sensors dedicated to measure different air parameters. Used instruments offer the ability to efficiently analyse the air composition (For example: NH_3, CH_4, CO, CO_2, H_2O, PM1.0, PM2.5, PM4, PM10). This gives us an understanding and confirmation of what type of pollution (and its severity) is present at different altitudes. After consultation with one of the biology teachers at our school, Ms. Joanna Durka, she brought our attention to the concentration of water in the air. There are not many studies on the amount of H_2O at lower levels of atmosphere at different altitudes. It is especially important because H_2O droplets at these altitudes act as a very strong greenhouse gas, and proportionally to the condensation, there is a higher probability of sunrays hitting a H_2O droplet and thus being trapped and accumulating thermal energy. Hence, we could see and record the environmental impact of humanity on our planet. Although there are alternative measures to collect air pollution data, in our opinion using CanSat has many advantages. Due to the use of affordable high-tech equipment and rockets as a launch system (the whole concept of CanSat design), the presented system is compact and mobile. Its sensors can be easily replaced (there are many types of sensors compatible with Arduino) to better fit the needs of researchers. In our opinion, as satellites and the whole space industry is a very popular topic, the results and findings, from our mission (regarding human influence on climate) have more potential to bring people attention.
In summary, we will be able to investigate the problem of low air quality, inspect quantities and size of pollution by analysing air composition at different altitudes. On

the basis of the gather results, we will try to locate the sources of this pollution. A possible consumer for that type of tests would be a city government where air pollution is a serious problem or ecological organisations that want to monitor greenhouse effect. During negotiations with one of our sponsors -Foundation for the Development of the Kleszczów Commune (FRGK), we suggested that our system could be used by FRGK to monitor air quality in the town of Kleszczów and the surrounding of Belchatow power plant. Our proposal attracted a lot of interest. Also the ‘rocket - wow effect’ will help to better promote our results and findings.

3 CANSAT DESCRIPTION

Mission overview

Before take-off, it is necessary to check the condition of the parachute, to measure the battery voltage, and replace the battery if needed, to check the voltage of the supercapacitor, and to charge it up to around 2V if needed. Turn on the ground station and the CanSat to make sure the signal is received correctly. Inspect the can for any visible damage or abnormalities.

The CanSat will establish a radio connection with the ground station. Then it will be launched to an altitude of around 500 or 2000 meters (height depends on the launch method: drone or rocket). The satellite will deploy a parachute immediately after being released and maintain a constant velocity of 6,7 m/s. During the descent, it will collect measurements of temperature and air pressure. The on-board sensors array will collect data about the air surrounding the can. Also, an IMU sensor will report linear accelerations and angular velocities that the CanSat is experiencing. All of the data will be timestamped with an RTC clock module, then transmitted in real time, and recorded onto an SD card sitting in the aircraft. The Can should slow down before touching down using an electric motor with a 2-inch propeller.

After the touchdown, it will be recovered from the ground as soon as possible. It will be inspected for damage, powered down, and the onboard SD card will be removed and stored in a safe place. After successfully landing and recovering the can, the mission is considered complete and the collected data is going to be analysed.

After collecting all the data from the onboard SD-card, the readings of atmospheric pressure and temperature will be put together and presented, then the data from the sensor array will be processed to state the amount of air pollution at different altitudes. Lastly, the power delivered by the solar cell circuit throughout the mission will be inspected to decide whether it is a viable solution for this type of aircraft and use.

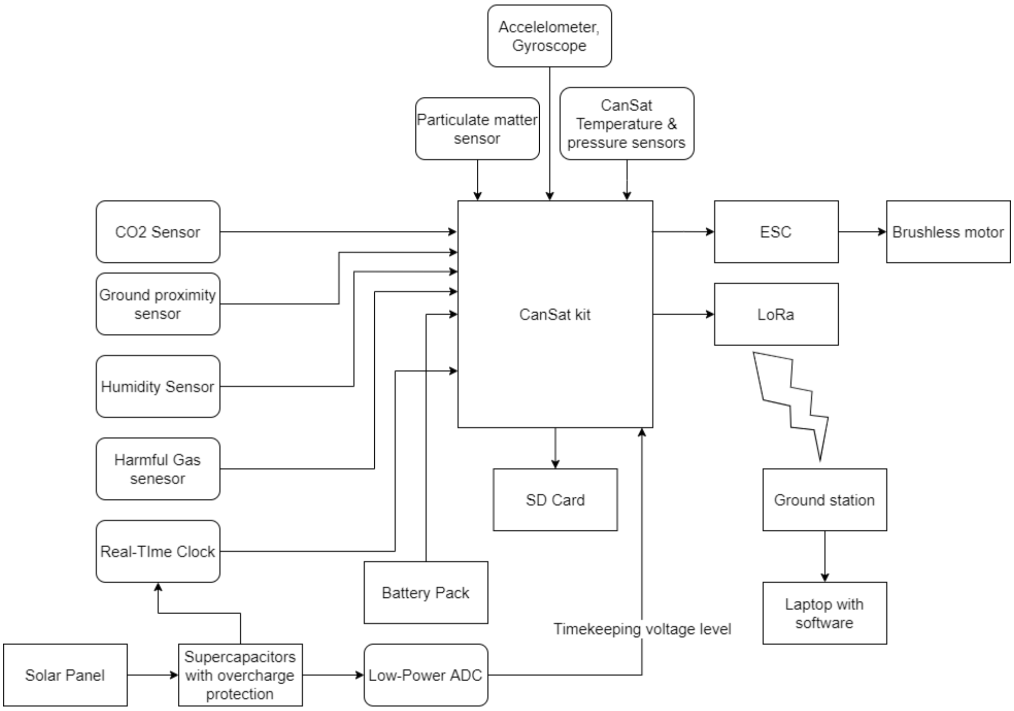


Figure 1. Block diagram

Mechanical/structural design

The main structure of the CanSat is an outer carbon fiber intertwined with red Kevlar and glass fibre composite shell. Carbon gives the structure rigidity, and glass fibre makes it less brittle. Inside there is a 3D-printed cage, in which structural prats are printed from PETG infused with carbon fibre to make it stronger; other parts are printed with regular PETG. The entire structure contains all components required by the mission. The 3D-printed PETG infused with CF structure is attached to the carbon fibre by a four-set screws at the bottom and screwed to the lid. To reduce unnecessary weight, we used titanium hardware for the can.

We firstly started by 3D printing a mould for carbon fibre shell and preparing it by sanding surface flat and painting it with non-stick primer.

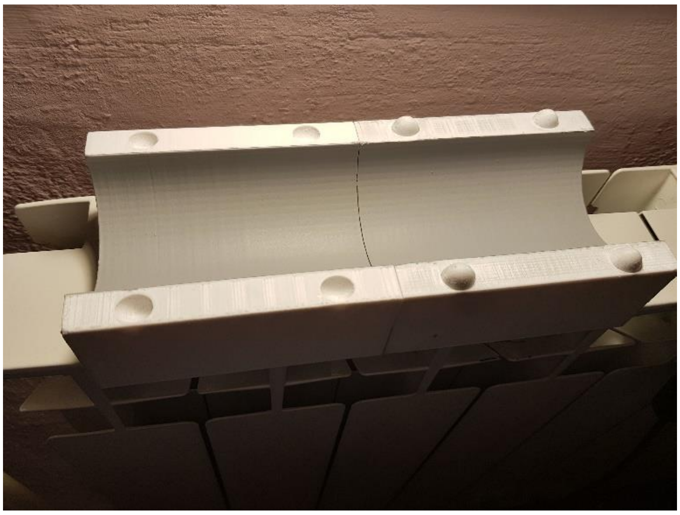


Figure 2. A mould for carbon fibre shell

Then, all materials were prepared and inserted into the mould layer after layer, repeatedly soaking them in resin. First, there were carbon layers, then glass fibre.

Figure 3. A Mould and used materials

The outcome was rough material that needed to be trimmed, painted with UV protectant lacquer, and polished.

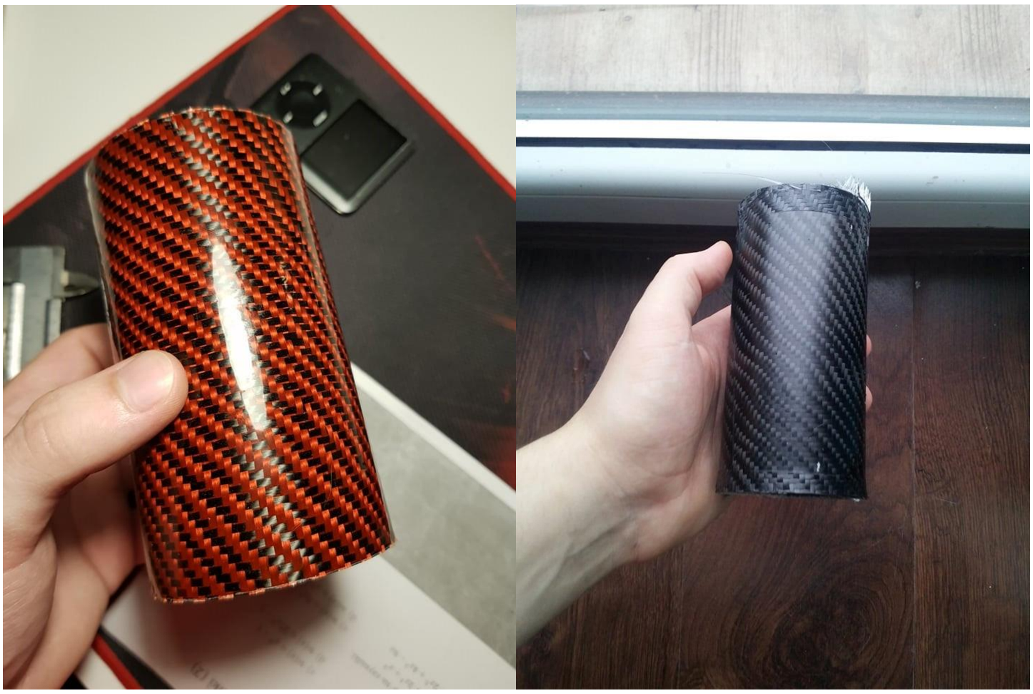


Figure 4. CanSat case (left: final design, right: prototype)

Our first prototype was made using traditional carbon fibre but our second final can was made using carbon fibre intertwined with red Kevlar in exactly the same way. The last step was to drill out air inlets for the motor and the sensor array. We used a Dremel and a 3D printed template for that.

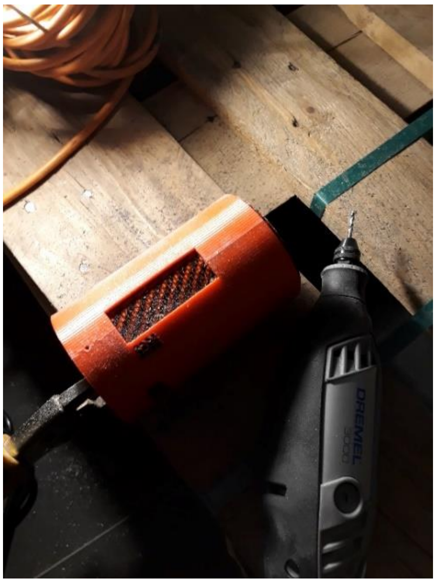


Figure 5. 3D printed template

Then, we had designed the entire inner casing used to hold everything together. There were many failed prints and wrong designs during the prototyping phase, but after a lot of effort, everything fits perfectly together.

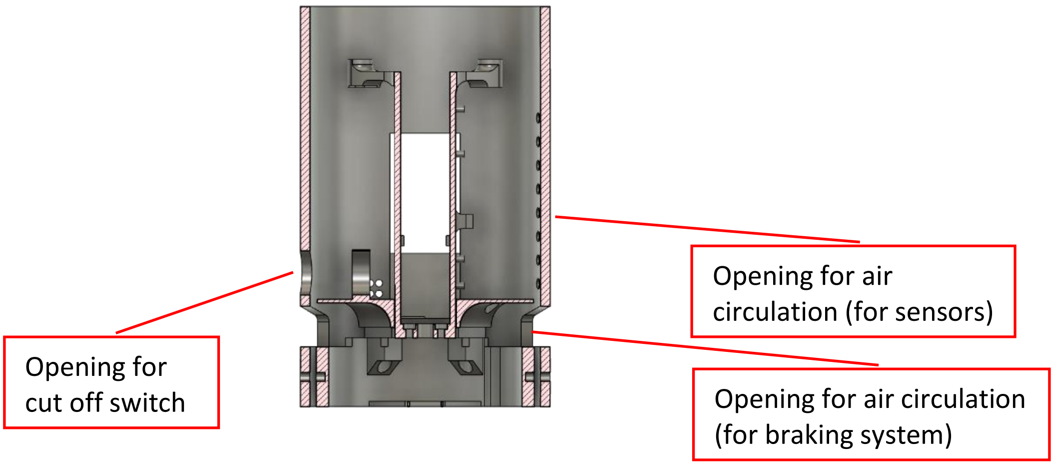


Figure 6. Cross-section of CanSat case

Here are some links to an animation showing how everything comes together and the process of printing the main body (the final design was printed in the exact same way, only with a different filament).

https://drive.google.com/file/d/1axKentsKqzAjW_UZoIHU7bu2uICpRzzg/view?usp=sharing

https://drive.google.com/file/d/1Bwrc0o4Qog-rLC6Xks_1Jq2PYGG3XVBZ/view?usp=sharing

Lastly, there was a 3D printed cap backed by the carbon fibre sheet. After assembly everything fits perfectly.

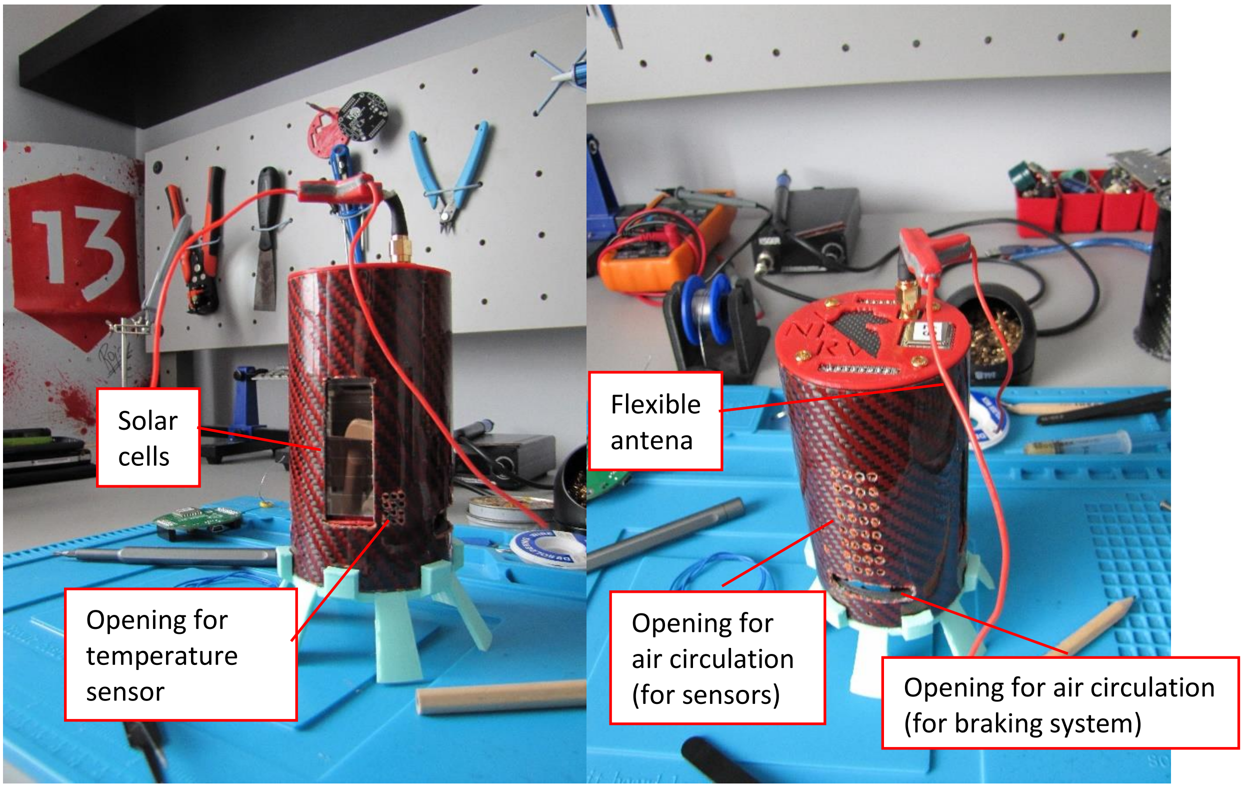


Figure 7. Elements of CanSat

Due to that type of design, we have a lot of space inside for the components and the whole can is much lighter than traditionally built using other solutions (285g) while possessing outstanding durability. To see how tough it really is, our mechanics teacher PhD Jacek Świniarski offered us to perform a professional stress test of that shell. For all of that we went to Lodz University of Technology on 29.01.2022.

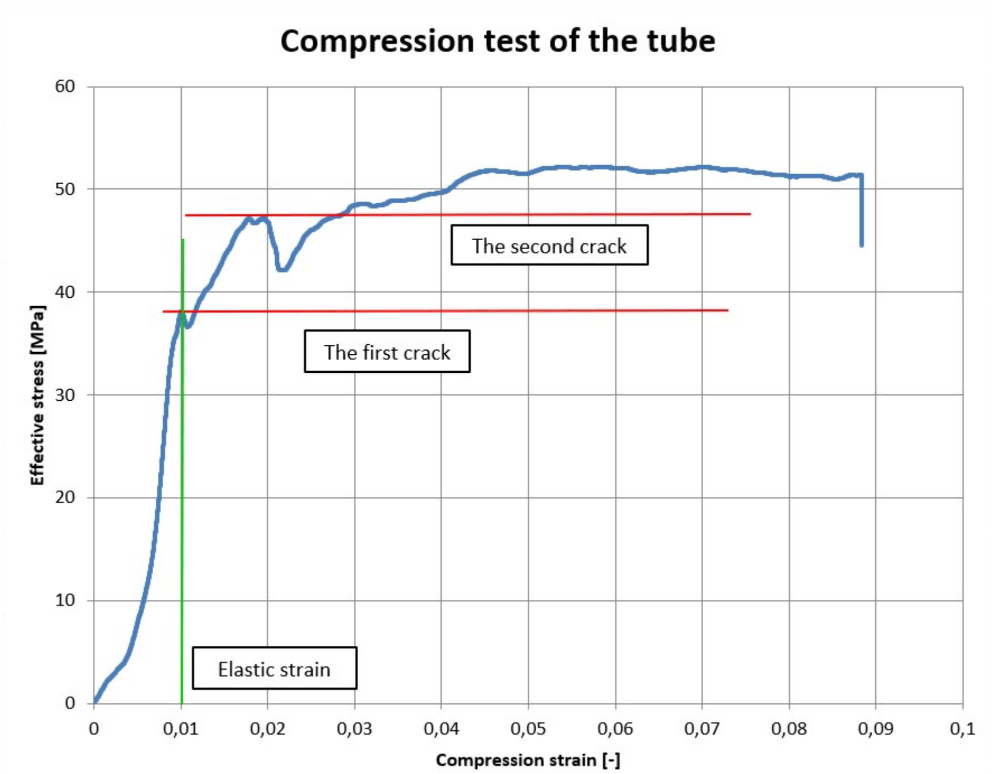


Figure 8. Compression test results

These are the results of the stress test. We can see that the can is able to withstand a load of around 1150 kg without damage, a point where the first crack appeared can be clearly seen on the graph. The maximum load that the can could held was around 1530bkg.

Link to the full analysed excel spreadsheet (should be downloaded and opened in MS Excel to show everything properly) and the video from the stress test:

https://drive.google.com/file/d/1uwwoGfO0U4d1jxMKmTI6PvaM7utjKQ73/view?usp=sharing

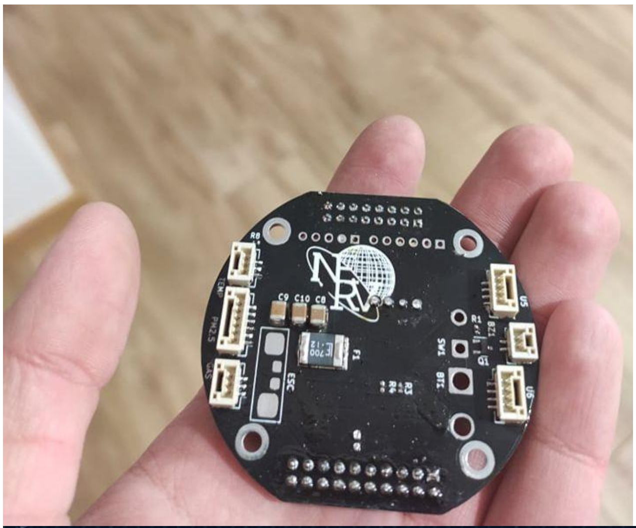
https://docs.google.com/spreadsheets/d/1-9WOhu5GSy6SJMinDcDgTIaIl0kjXPv0/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

For more videos and photos please visit our google drive:

https://drive.google.com/drive/folders/15mEbUV5Q8JfqSBnggYBcRBIoefHuYsY8?usp=sharing

Electrical design

General architecture



The circuit is made onto a custom PCB, with some wires being an in-air connection. The PCB features the same shape, pin, and mounting hole layouts as the protoboard, so it fits perfectly. Sensors are connected via JST-GH connectors. Wires are properly routed and most of them are protected by nylon cable sleeves.

View of top and bottom layer of our PCB.

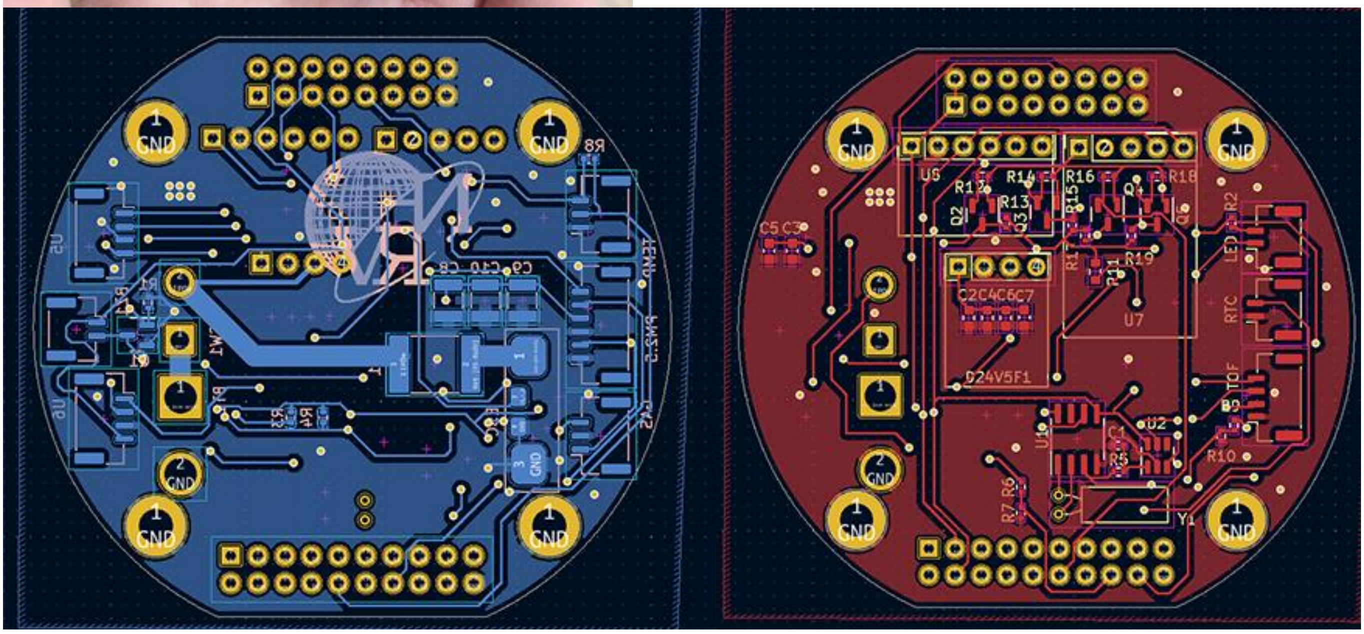


Figure 9. PCB design

The whole schematic is available at this google drive link:
https://drive.google.com/file/d/1NzWlbUIqzKUQ_pxD-vEL8Ejn1xOzbpwK/view?usp=sharing

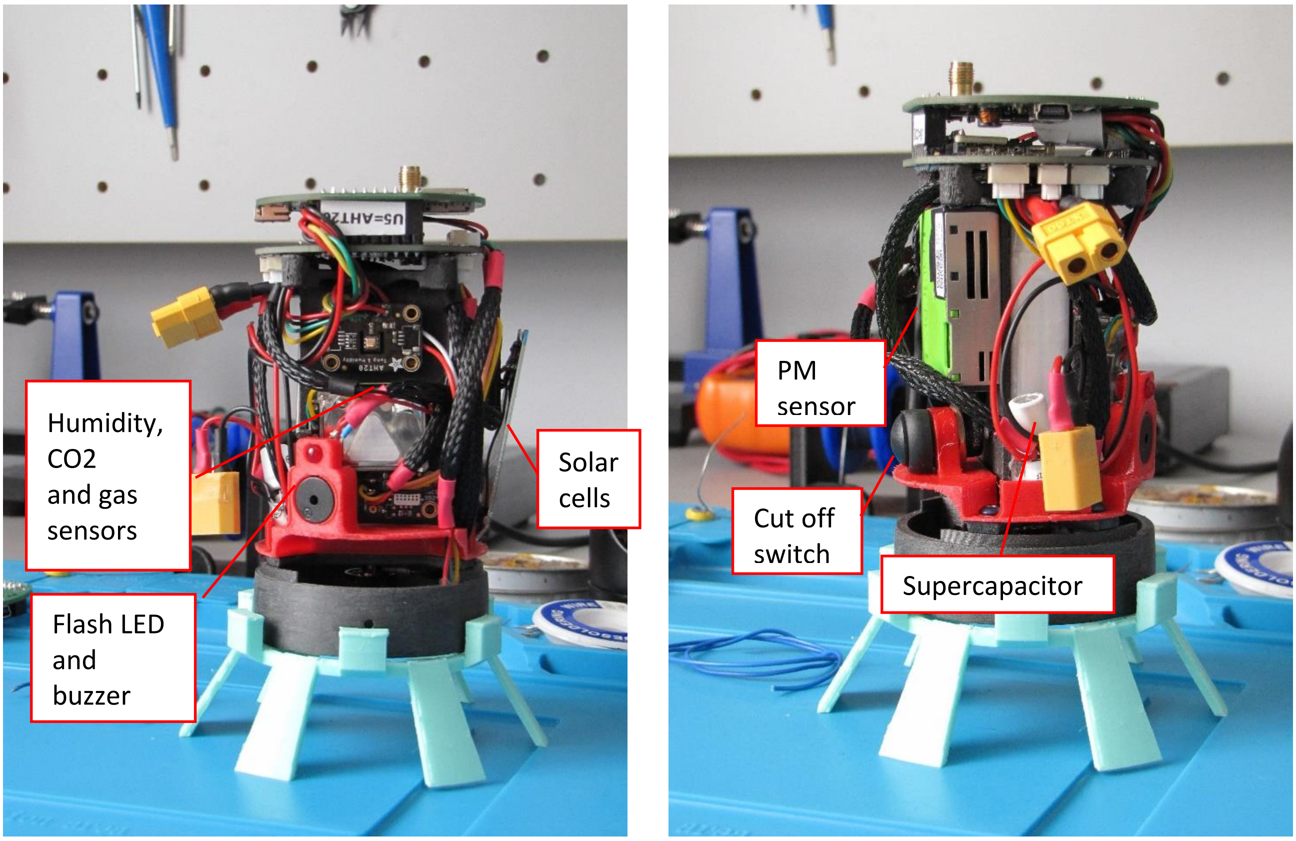


Figure 10. Interior of CanSat

Primary mission devices

The primary mission will be carried out using the included CanSat kit. Default LoRa RF communication will be used. All data are going to be saved onto an SD card and transmitted to the ground station connected to the laptop. The following components will be used:

- DS18B20 temperature sensor
- BMP280 pressure sensor
- CanSat kit's onboard LoRa module
- CanSat kit's onboard SD card module

All components required by the primary mission except the thermometer, that is, on the sidewall, were transferred from protoboard to our new PCB

Secondary mission devices

To accomplish the secondary mission, a variety of sensors and additional equipment is used to collect all the data mentioned in 3.1. Currently, the can is using:

- AHT20 Humidity Sensor
- Honeywell CRIR-E1 CO2 sensor
- Sensirion SPS-30 particulate matter sensor
- MICS-5524 gas sensor
- MinIMU-9 v5 accelerometer & gyroscope combo
- VL53L1X ToF infrared distance sensor
- DS3231 Real-Time-Clock module
- AM-1085CA Solar panel with 2 supercapacitors
- T-Motor F1103 8000KV BLDC motor with a HQprop T2x2.5x3 2” propeller
- HGLRC BS28A ESC
- D24V5F1 step-down 5V regulator

<u>Energy harvesting setup</u>

RTC timekeeping solar charging schematic. D2, D3 are used to set a maximum voltage across the solar cell, the voltage is capped at ~3.1V, as the diodes begin to conduct below their nominal voltage, because the whole schematic being in the microampere range. The D4 schottky diode is used to prevent the accumulated charge from escaping from the supercapacitors. In theory, supercapacitors can be charged up to 2.9V, which leaves headroom with their 3V max voltage rating.

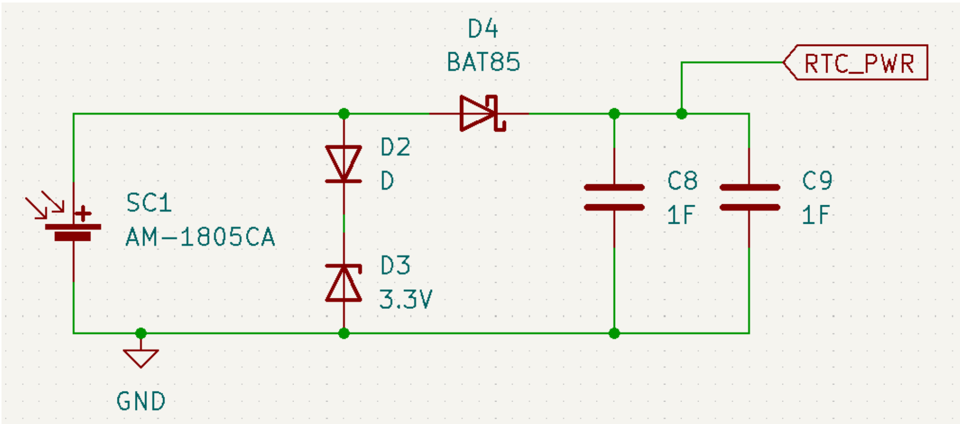


Figure 11. Energy harvesting circuit

Most of the sensors and components are mounted on sides of the main body.

<u>Implementation of braking system</u>

The key elements of the braking system are presented below.

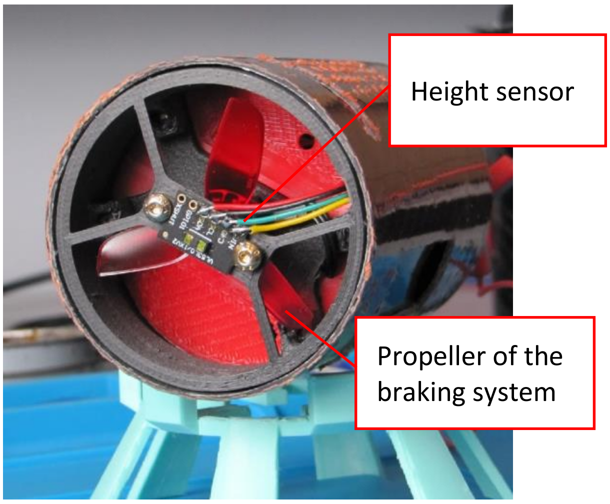


Figure 12. Breaking system

For more photos, please visit our google drive:

https://drive.google.com/drive/folders/1tAH9UjC5KaRfeYqCsfxWlsZwIs20LWfk?usp=sharing

Power supply

The can is powered by a 2S 1300mAh LiPo battery supplied by Gens Ace. This voltage is fed to the voltage sensing pin using a voltage divider. Then it is supplied to an ESC and the 5V regulator. The CanSat board and the rest of the sensors run off this 5V rail, or the internal 3.3V CanSat kit supply. The board freezes when the voltage is below 3.1 per cell that features internal voltage protection.

Power supply section schematic:

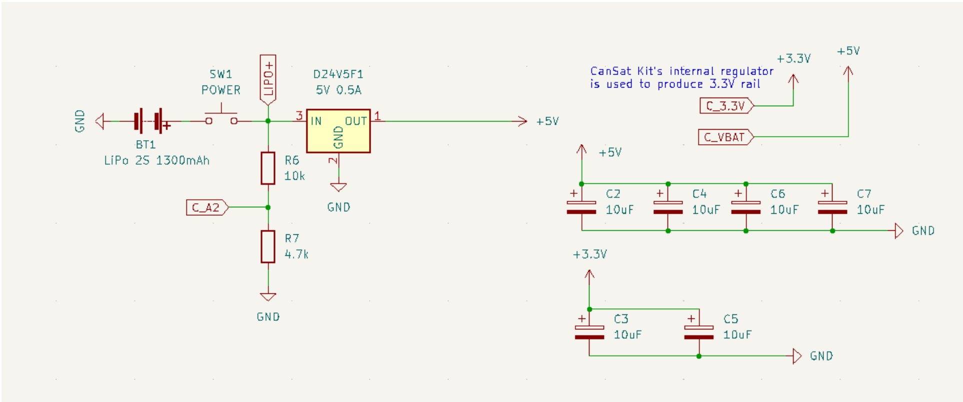


Figure 13. Power supply schematic

The graph below shows the discharge characteristics of a similar LiPo battery (same cells number, same manufacturer and rated current, smaller capacity). The green line corresponds to the current consumption of our satellite.

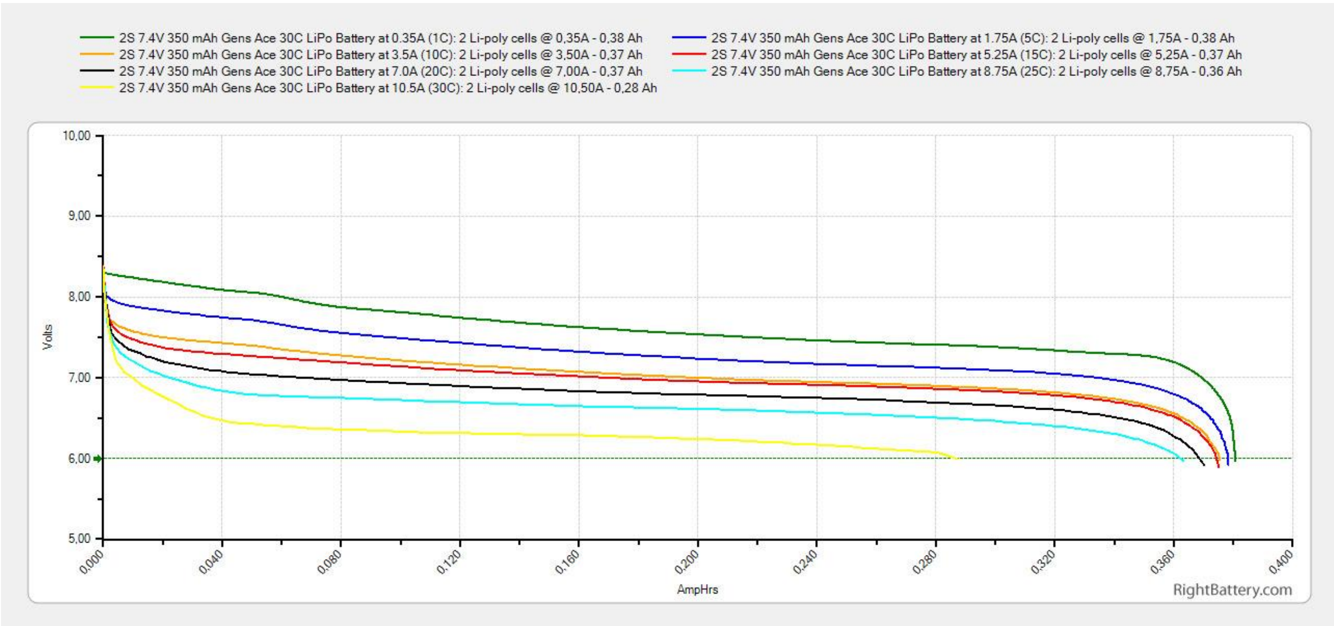


Figure 14. Discharge curves

As shown in the schematic, the tantalum capacitors were added to the step down regulator output, to increase the electronics stability.

Communication system

The CanSat uses one-direction communication, from the can to the ground station. We are using the default supplied LoRa communication. We have chosen a Yagi antenna with a vertical beam width for the ground station. Also, Actuna.pl made us a dipole tuned for 433Mhz that was later modified by us to use a very flexible wire coated in silicone insulation. Thanks to all of that, on this frequency we have calculated a gain of around 10dB.

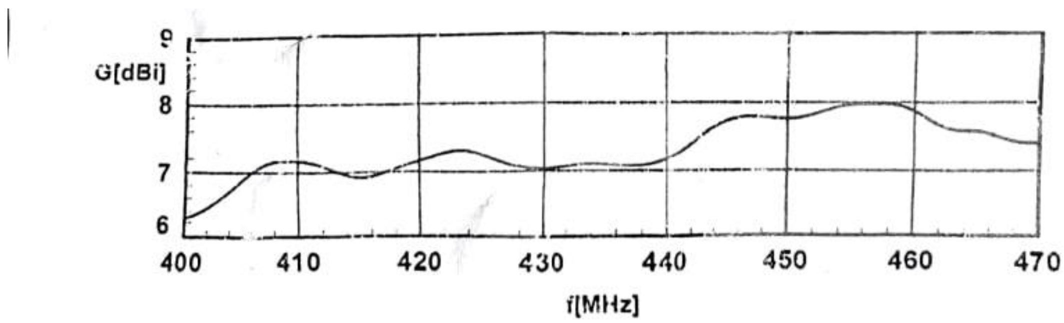


Figure 15. Gain of used Yagi antenna at different frequencies

Software design

Our main GitHub account: https://github.com/nerv-cansat

Our software consists of three components: software running on the CanSat itself, ground station software, and data parsing software.

The CanSat software is written in C using an Arduino framework. The software was developed using an PlatformIO IDE, allowing one to swap boards easily with an Arduino Uno for prototyping and quickly compiling everything on new devices.

This software follows a loop summarized below:

1. Check for voltage
2. Check time from the RTC
3. Check distances from the ground and eventually run the motor
4. Check sensors
5. Parse everything to JSON
6. Send the first radio frame containing data from most sensors
7. Write the first radio frame to the SD card
8. Send the second radio frame containing IMU data
9. Write the second radio frame to the SD card
10. Send the third radio frame containing particulate matter sensor data
11. Write the third radio frame to the SD card

The repository below also contains code running on the second CanSatKit board sitting in the ground station. This software only forwards incoming radio data to a serial port.

Source code: https://github.com/nerv-cansat/cansat

The ground station is using an electron app to display the current values received from the can. This application communicates with the CanSat kit in the ground station and parses the data incoming from the radio signal. It provides real-time graphing and a log system.

Source code: https://github.com/nerv-cansat/cansat_app

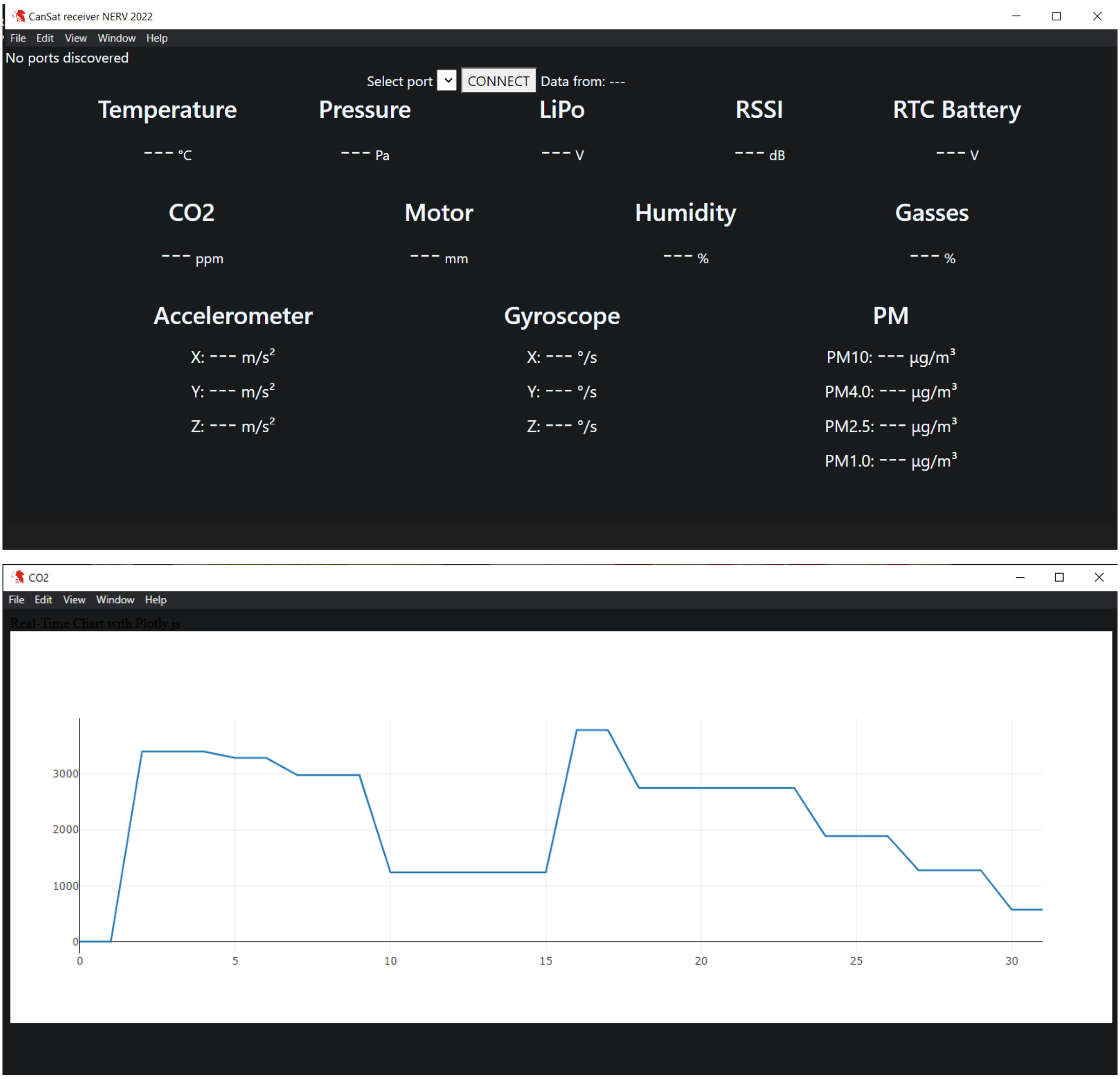
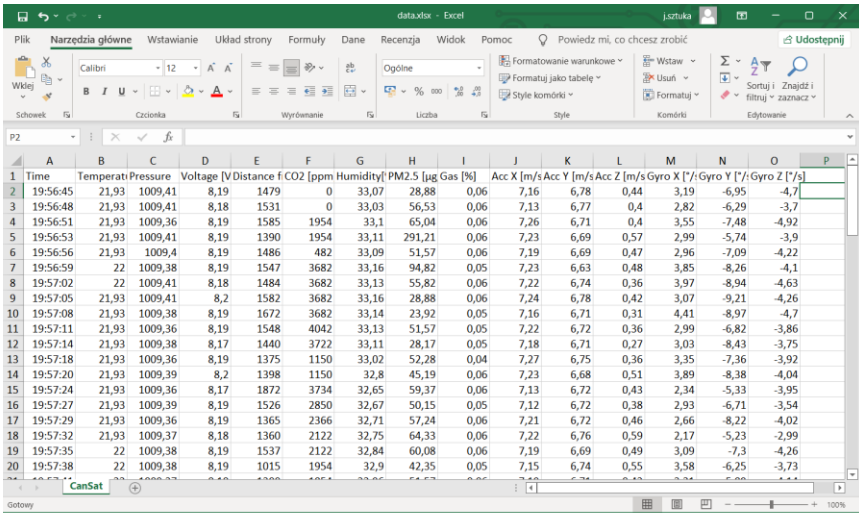


Figure 16. Developed operator's panel of CanSat ground station

The third piece of software used in our project is an SD card data excel parser. It collects data stored in a text file (formatted in JSON, new line is a new record) that is written by CanSat and stored on a SD card.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Time	Temperat	Pressure	Voltage [V	Distance f	CO2 [ppm	Humidity[	PM2.5 [µg	Gas [%]	Acc X [m/s	Acc Y [m/s	Acc Z [m/s	Gyro X [°/	Gyro Y [°/	Gyro Z [°/s]
2	19:56:45	21,93	1009,41	8,19	1479	0	33,07	28,88	0,06	7,16	6,78	0,44	3,19	-6,95	-4,7
3	19:56:48	21,93	1009,41	8,18	1531	0	33,03	56,53	0,06	7,13	6,77	0,4	2,82	-6,29	-3,7
4	19:56:51	21,93	1009,36	8,19	1585	1954	33,1	65,04	0,06	7,26	6,71	0,4	3,55	-7,48	-4,92
5	19:56:53	21,93	1009,41	8,19	1390	1954	33,11	291,21	0,06	7,23	6,69	0,57	2,99	-5,74	-3,9
6	19:56:56	21,93	1009,4	8,19	1486	482	33,09	51,57	0,06	7,19	6,69	0,47	2,96	-7,09	-4,22
7	19:56:59	22	1009,38	8,19	1547	3682	33,16	94,82	0,05	7,23	6,63	0,48	3,85	-8,26	-4,1
8	19:57:02	22	1009,41	8,18	1484	3682	33,13	55,82	0,06	7,22	6,74	0,36	3,97	-8,94	-4,63
9	19:57:05	21,93	1009,41	8,2	1582	3682	33,16	28,88	0,06	7,24	6,78	0,42	3,07	-9,21	-4,26
10	19:57:08	21,93	1009,38	8,19	1672	3682	33,14	23,92	0,05	7,16	6,71	0,31	4,41	-8,97	-4,7
11	19:57:11	21,93	1009,36	8,19	1548	4042	33,13	51,57	0,05	7,22	6,72	0,36	2,99	-6,82	-3,86
12	19:57:14	21,93	1009,38	8,17	1440	3722	33,11	28,17	0,05	7,18	6,71	0,27	3,03	-8,43	-3,75
13	19:57:18	21,93	1009,36	8,19	1375	1150	33,02	52,28	0,04	7,27	6,75	0,36	3,35	-7,36	-3,92
14	19:57:20	21,93	1009,39	8,2	1398	1150	32,8	45,19	0,06	7,23	6,68	0,51	3,89	-8,38	-4,04
15	19:57:24	21,93	1009,36	8,17	1872	3734	32,65	59,37	0,06	7,13	6,72	0,43	2,34	-5,33	-3,95
16	19:57:27	21,93	1009,39	8,19	1526	2850	32,67	50,15	0,05	7,12	6,72	0,38	2,93	-6,71	-3,54
17	19:57:29	21,93	1009,36	8,19	1365	2366	32,71	57,24	0,06	7,21	6,72	0,46	2,66	-8,22	-4,02
18	19:57:32	21,93	1009,37	8,18	1360	2122	32,75	64,33	0,06	7,22	6,76	0,59	2,17	-5,23	-2,99
19	19:57:35	22	1009,38	8,19	1537	2122	32,84	60,08	0,06	7,19	6,69	0,49	3,09	-7,3	-4,26
20	19:57:38	22	1009,38	8,19	1015	1954	32,9	42,35	0,05	7,15	6,74	0,55	3,58	-6,25	-3,73

Figure 17. Raw data from CanSat sensors

Source code: https://github.com/nerv-cansat/data_parser

Recovery system

After reaching 500 or 2000 meters (depending on the launch method), a parachute will be deployed immediately. The parachute is made from ripstop nylon, as it is a durabe and relatively inexpensive material; the standard forward stitch with polyester thread was used. For the shroud lines, we used red twine thread. The diameter is approximately 47 centimeters with a hole at diameter of 4.7 cm. at the apex to provide a more stable descent.

The parachute should provide the descent at rate of around 6.7m/s. A bit slower descend helps us with more accurate air composition measurements at different altitudes.

It is worth noting that 6.7m/s is calculated for air density equal to 1.22kg/m^2 (at the sea level). At higher altitudes the air will be thinner, so descent rate will be higher, up to 7.4m/s at 2000 meters.

These are sketches and calculations done for parachute.

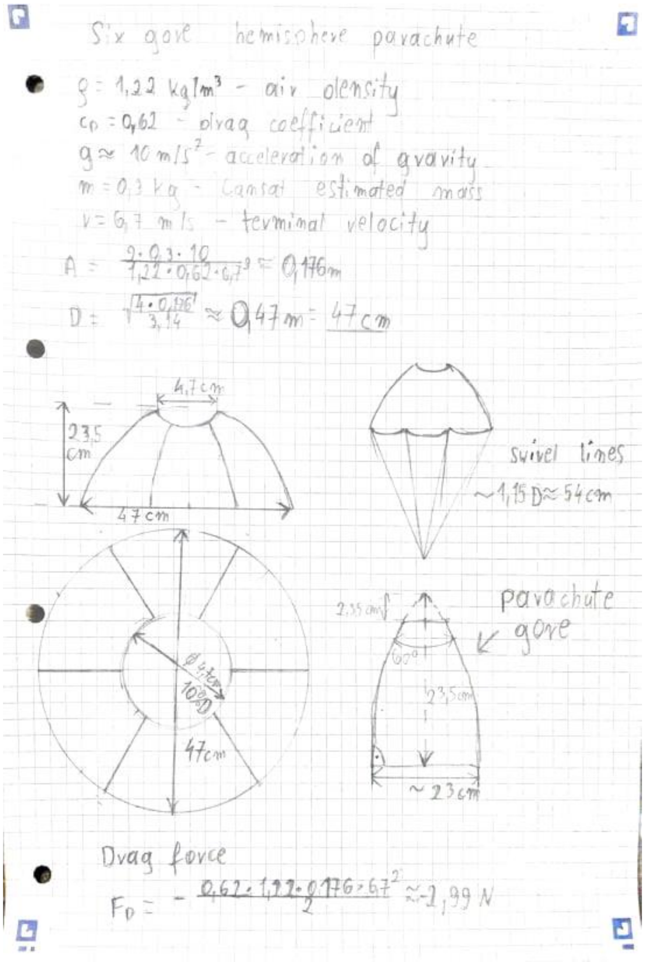


Figure 18. Parachute sketches

And to be sure we also checked our calculations with a computer software.
Link to screenshot of calculation:
https://drive.google.com/file/d/1p4ilcEgOtnbDDE18mxjtR_omMGgaAkO0/view?usp=sharing

We also made a render of how the parachute will look:
https://drive.google.com/file/d/1oa-RO4mzVU1t_YWYIGv1z7IQnErDhNP8/view?usp=sharing
We have created a simulation using the rocket software that shows the speed, height, and acceleration of the can. After the real launch we will compare this graph with one made with the data from an accelerometer onboard.

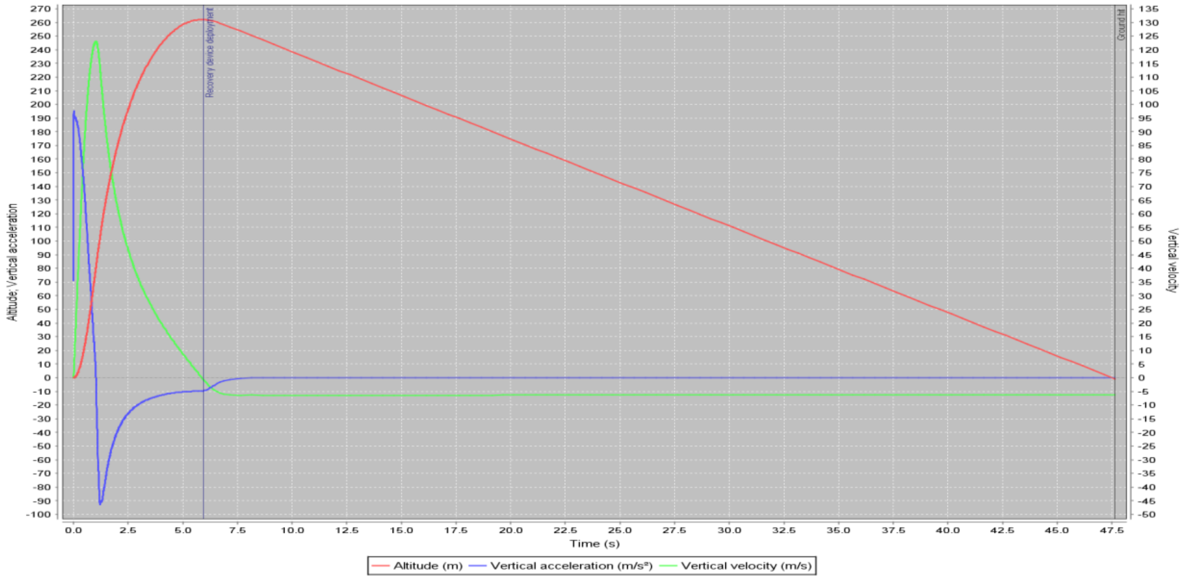


Figure 19. Simulation results of CanSat acceleration

We initially wanted to use off the shelve parachute and modify it but its parameters did not completely match our targets, so we decided to make our own. First, we designed gores and cut out all the elements from ripstop nylon. Then they were sewn together and the shroud lines were attached to four bolts at the top of the can.

Figure 20. Developed parachute

Ground support Equipment

Ground equipment consists of:

-laptop with a dedicated software for data collection and data further analysis,

-radio board module with an integrated antenna to maintain connection with CanSat,

-additional batteries and LiPo charger,

-tool set (Screwdrivers, pliers, tweezers, mustimeter etc.),

-spare parts,

-USB cables for connecting boards to computer,

-aluminium case for safe transport of all elements.

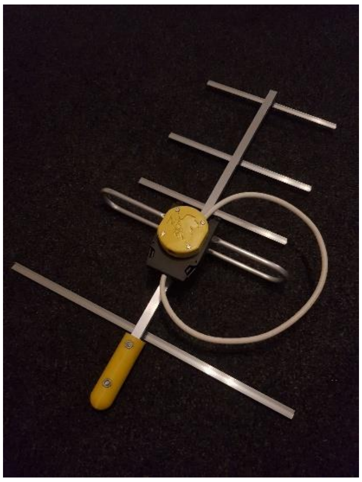


Figure 21. Left: aluminium case, right: ground station antena

Yagi antenna combined with the main board that has a radio receiver. Everything is enclosed in a 3D printed case. The antenna also has a 3D printed handle, allowing for easy pointing in the approximate position of a CanSat. Everything is very compact and easy to use.

4 TEST CAMPAIGN

Primary mission tests

For the primary mission test, we put the whole can in the fridge to see the response of a temperature sensor. During the test we also compared readings out of the pressure sensor with a known good weather station. As you can see the readings from all sensors are sent to the station correctly and the results are excellent.
Link to the video from the test:
https://drive.google.com/file/d/1icN8R_dtOWIhvcTV7CMZKJEPnhC1QP9x/view?usp=sharing

Secondary mission tests

To test our secondary mission devices, we checked if all sensors react as expected. Humidity sensor was tested using steaming water, CO_2 sensor reacted on exhaled air, harmful gas sensor reacted to paper towel soaked in ethanol, gyroscope and accelerometer also behave as they should (accelerometer when placed vertically shows G≈9,81) and PM sensor was tested during a very cold evening when smog levels were high, we recorded the baseline in the room (30µg/m3) then opened the window (reading jumped to around 250µg/m3).
This is a link to video in which harmful harmful gas, humidity sensors are tested:
https://drive.google.com/file/d/1r5ZqIC4sIm7_6U8eSg9n4c0UpQdrJfoK/view?usp=sharing
We also performed a test of the motor. At full speed we had to hold it at the back otherwise it starts moving.
Link to the video:
https://drive.google.com/file/d/1W8fax3AanGVlvv7gFSTKwd6X-xp7UoBT/view?usp=sharing
The circuit that outputs power from solar cells was also tested, in the direct sunlight the voltage doesn’t exceed 3.3V and on a cloudy day it was able to charge completely empty capacitors to 2.7V which is sufficient for powering the RTC module.

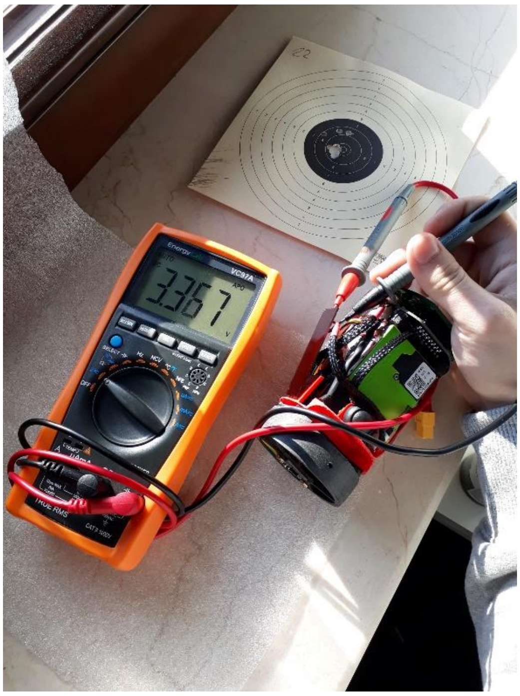


Figure 22. Tests of energy harvesting system

We have tested I2C and RS232 communication with every module on our CanSat, the pictures below show how humidity and CO2 values are decoded from electrical signals. I2C Humidity sensor readout. Data is calculated through formulas provided in the sensor's datasheet. Individual bytes of the I2C transmission are in the bottom part of the picture.

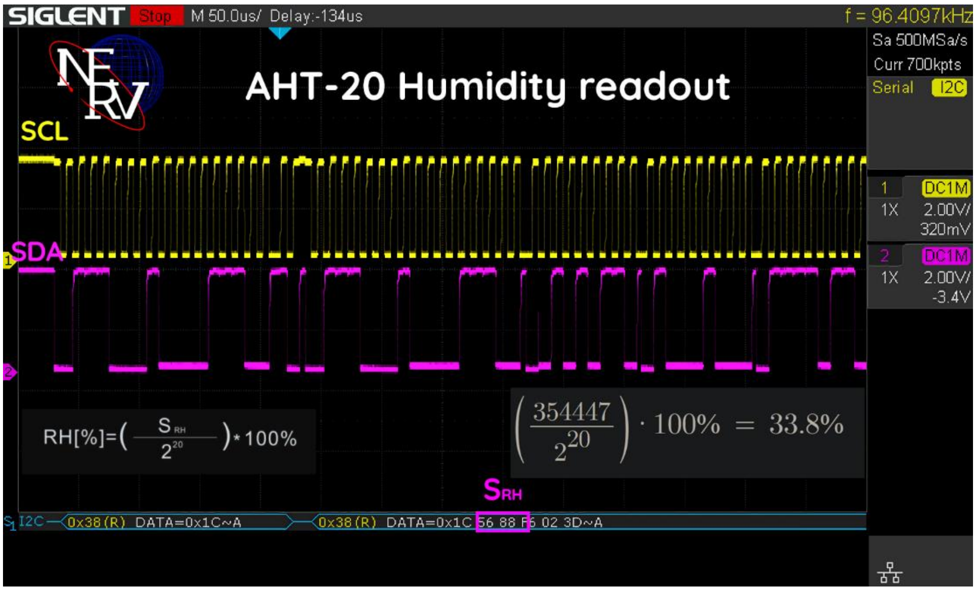


Figure 23. Tests of sensors communication

RS232 CO2 sensor readout. Yellow waveform is data transmitted from the CanSatKit, the pink waveform is data transmitted from the sensor. Decoded bytes can be seen at the bottom of the picture. According to the datasheet of the sensor, bytes 4 and 5, combined together give a CO2 readout. Later on, transmitted data is followed by a CRC-16 MODBUS checksum.

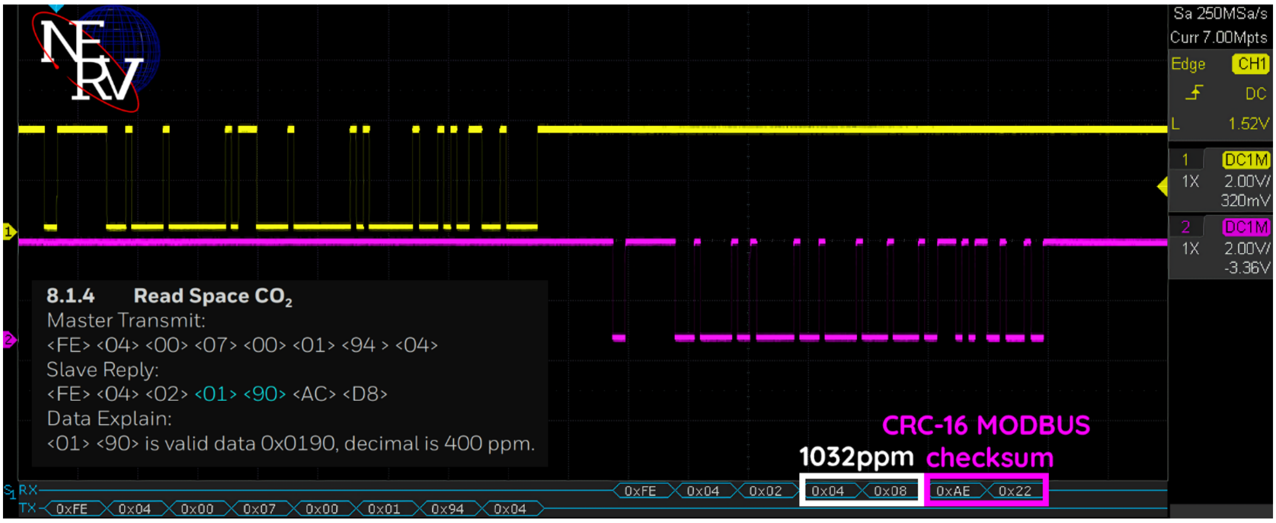


Figure 24. Tests of sensors communication

Tests of recovery system

To test the recovery system, we have created a 'PhantomCan' to do that part of mission without risking damage to the original can. PhantomCan is empty inside, so we can add weight, making it an ideal copy of the real can for this task. The test was successful, the parachute was deployed immediately and slowed the can.
Photo of the PhantomCan with older parachute

Figure 25. Tests of parachute operation

Video from test of falling speed and stability of new parachute:
https://drive.google.com/file/d/10FM68MGv0ZxE2AUzH7LmcGr_Uhk-QOFn/view?usp=sharing
Video of testing how fast parachute deploys, to fully open it took only around 2m:
https://drive.google.com/file/d/1e2TBJxehLQzSGtS4X_ye4XK30ICK1ZxB/view?usp=sharing

Communication system range tests

We have placed the ground station in a safe and distant location with an operator on-site and put the can in a car. The car was driving ahead until the communication was lost. The conditions were very hard because on the path of the signal was a hill, some buildings and a large section of a forest, nonetheless we achieved a range of 3km. The range in the air will be much higher and communication will not be a problem. The communication was tested again after modifying the CanSat antenna, and the results were pretty much identical.

Figure 26. Tests of communication system

Link to the photo of the whole setup:

https://drive.google.com/file/d/1LpxnM3NbphXBrbC8CUH0y9CoXBqwGwvX/view?usp=sharing

Energy budget tests

To see how long our can will be able to operate, we have performed two tests. In the first one, the battery was fully charged, the can was turned on and left idle. In the second test, the motor was additionally turned on for 3 seconds to determine. After each run, we read the data saved on the SD card to see when the battery was drained (we used the real-time clock that is onboard the can). The results were 8.5 and 8.25 hour, respectively. Both results are well above the minimum requirement.

5 PROJECT PLANNING

Time schedule

For planning all our tasks, we used a platform called ClickUp. Additionally, to improve workflow on documentation, we used Office 365 services. To achieve everything, we had to be very strict when it comes to organisation and doing all tasks on time. Thanks to excellent time planning and leading, we succeeded in every task that we wanted to finish until our final report.

Link to a Gantt chart of all tasks:

Phase I - https://sharing.clickup.com/g/h/q67z3-341/168fdf446290fd1

Phase II - https://sharing.clickup.com/g/h/q67z3-361/bf0ff769696c6fb

Phase III - https://sharing.clickup.com/g/h/q67z3-383/935042f26a97a80

Task list

All our main tasks were recorded here:
Phase I - https://sharing.clickup.com/l/h/6-144572592-1/fe6af9e917ebd2b
Phase II - https://sharing.clickup.com/l/h/6-174306242-1/1febb43d29a7ec4
Phase III - https://sharing.clickup.com/l/h/6-175081856-1/c30f1f45caf1a16

There was also enormous number of small tasks to complete during the whole project that we didn't have time to put there also.

Resource estimation

Budget

During our work with sponsors, we had to be very strict when it comes to managing budget. Firstly, we had to create a budget estimation of the whole project for our sponsors:

https://docs.google.com/document/d/1h8l3XPTj7lAxS1ffJf9WECSOVAtVC1IJ/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

Then after buying all of the things from the list, we had to write the whole settlement for sponsors that consist of all invoices and their cost.

https://docs.google.com/document/d/1NhHMXT7Fge5MkKC4M5emgp9wa7b2dIfz/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

https://drive.google.com/file/d/18NDoWTTWY25_vSytbKKHDR6BbqdlwcbK/view?usp=sharing

https://drive.google.com/file/d/1xjj52abV6rtJs0UeSz0cnJMG2A7lWIcB/view?usp=sharing

Statement containing only a CanSat cost which is 433.5€:

https://docs.google.com/document/d/1QA0gDUm8buLVFkVRCWjPuZlwjQ1HNKs4/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

External support

After unsuccessful previous attempts at acquiring sponsors, we changed our tactics and started to contact local companies. To do that, we have written letters to a few companies. In those letters, we have explained the whole situation and asked for support. We also had to create a second document that asks our head teacher to authenticate those letters.

Links to both documents:

https://docs.google.com/document/d/1WKPx0LJf4oJDfsoxWReRe1OXIEpSzRT6/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

https://docs.google.com/document/d/1fuC4dt3iiwEpRn6G7cDGkvOWIWpPkiuq/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

Eventually, three companies to which we had written agreed to be our sponsor: FRGK Foundation, Constantia Flexibles, and EUROPART.

OUTREACH PROGRAMME

We have carried out many actions promoting our activities. First, we will present the created promotional items.

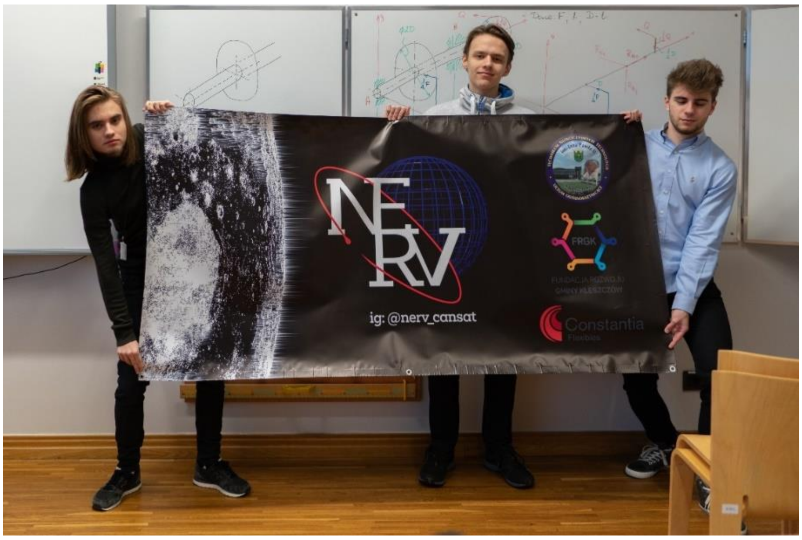


Figure 27. Banner with an interesting design, logos of sponsors, school and our Instagram

T-shirts with streetwear design in the front and all sponsors at the back. They are manufactured by Reflect.pl
Link to the photos of how our T-Shirts look:
https://www.instagram.com/p/CY8yeZ6oJOg/?utm_source=ig_web_button_share_sheet
https://www.instagram.com/p/CY8yh7xoZvI/?utm_source=ig_web_button_share_sheet

Figure 28. Two colour 3D printed keychains with our logo

Thanks to these items we were able to start a giveaway that brought a lot of attention to our Instagram page. That post currently has 80 likes and 32 comments. That action has also raised the amount of people that follow to 155.

https://www.instagram.com/nerv_cansat/p/CYnARVGoitt/

We have also been featured on our school web page:

https://zspkleszczow.pl/2021/12/09/konkurs-cansat/

We have also reached out to our local TV news and they were really happy to make a video and an article about us:

https://www.lokalna.news/wiadomosci/4565,cansat-kosmiczne-projekty-uczniow-z-technikum-w-kleszczowie?fbclid=IwAR1

Links to other posts promoting our project:

ww.facebook.com/permalink.php?story_fbid=1940077046174018&id=674844972697238

https://www.facebook.com/permalink.php?story_fbid=2006559529525769&id=674844972697238

https://www.reddit.com/r/NeonGenesisEvangelion/comments/s0xah8/nerv_irl_shool_project_goes_futher_than_expected/

https://frgk.pl/cansat-kosmiczne-projekty-uczniow-z-zsp-w-kleszczowie/?fbclid=IwAR2u9U4e_w6VIkX8Zm-ZYh09aiCzDlb-jlt1BumjHnrDkliax6GJ2IcOEiU

https://www.facebook.com/permalink.php?story_fbid=2023516534496735&id=674844972697238

https://www.facebook.com/permalink.php?story_fbid=2021620864686302&id=674844972697238

We also had a meeting with Ph.D. Adam Rylski from Lodz University of Technology. We showed him everything we have done to this point and he was very interested. Mr. Rylski also said that if we need anything, he will be happy to help.

Figure 29. Promotional actions

The most important meeting so far was with our sponsor Constantia Flexibles. We have prepared a presentation showing all aspects of our project and the work we have done to this point. We have come to them with our head teacher Ms. Agnieszka Nagoda-Gębicz. They were so impressed that in the future they will use photos taken during the meeting in their newspaper and also put on the screens in reception for promotion.

Presentation: https://docs.google.com/presentation/d/1fTW4NDyGwYYD1kHgfpohR3jQGKoB5Jr-/edit?usp=sharing&ouid=106413308147667590509&rtpof=true&sd=true

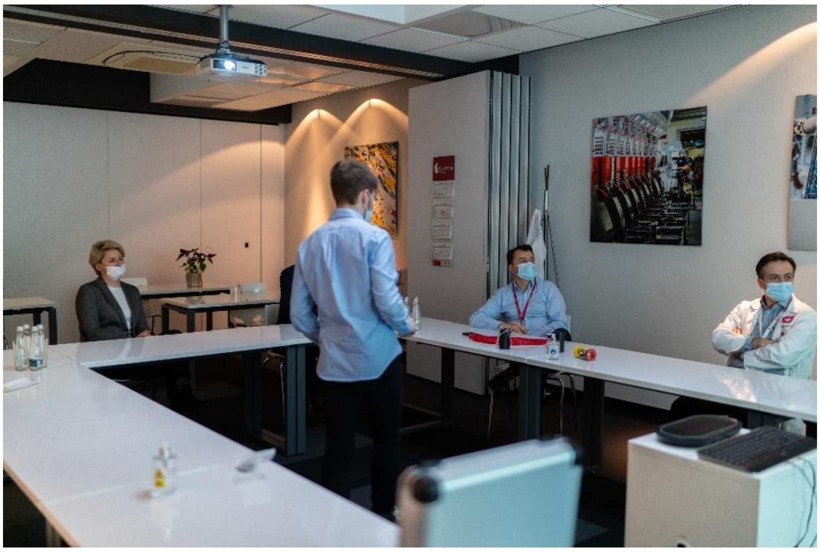


Figure 30. Promotional actions

All photos from the meeting:

https://drive.google.com/drive/folders/1tOoaQoMqkHOVFNRGHeunLcBQfX9zGa-d?usp=sharing

Last thing we did was a school meeting with few technical classes (Around 60 people) and our teacher Phd Jacek Świniarski during long lunchbreak.

Figure 31. Promotional actions

Recently we have started working with EUROPART company and they declared that they will also post articles about us on their social media.

So far, we have reached to over 600 people for sure but that amount in reality is much higher.

For more photos, videos and documents please visit our google drive: https://drive.google.com/drive/folders/1ED8KLq9aUl0YI5bK0ilkV57I5dMKZcap?usp=sharing

6 CANSAT CHARACTERISTICS

Characteristics	**Figure**
Height of the CanSat	115,5mm
Diameter of the CanSat	Ø65mm
Mass of the CanSat	285g+15g of weight
Estimated descent rate	6.7m/s
Radio transmitter model and frequency band	CanSat kit LoRa transmitter
Estimated time on battery (primary mission)	8.25h
Cost of the CanSat	433.5€