TeamVLO Pre-Launch Report

Team Name: TeamVLO

Country: Poland

CONTENTS

INTRODUCTION

ALL ADDITIONAL FILES ARE IN THIS GOOGLE DRIVE FOLDER: https://drive.google.com/drive/folders/1UIVsTSOTziTVPfNlBlMclOxmNskVa1PP?usp=sharing

Team organisation and roles

Our mentor is **Dr Dawid Kotrys**. He is our math's teacher and tutor of our class. He always devotes to all projects proposed by his students. He supports our team computationally and he motivates us to the action.

Emil Kielar is our team leader. He found the information about the competition and created a team. He supervises all the work and sets the tasks individually for every team member. Emil is interested in coding as well as electronics. He is responsible for them during the mission. Using the help of Mr. Kotrys, they will cover the computational site, which will allow us to design and build our CanSat.

Krzysztof Janota is a great lover of aeronautics that's why he engaged into the project. Krzysiek knows the construction of airplanes and their dynamics very well, what will help us greatly in the project. He is responsible for mechanical design and recovery system design.

Natalia Pierkiel oversees planning our tasks, as she is well organized and can find the most effective way of working. She's willing to help whenever it is needed, so her other duties are not strictly determined. For the time being, she writes posts for social media and is responsible for promoting our project.

Julia Zielińska is responsible for reporting and describing our activities. She is endowed with literary skills. Julka is also picking up on small errors and she is an attentive observer what allows her to correct our errors. She is still looking for her interests and she hopes that this competition will help her in it.

We are also members of the Inter-disciplinary Student Research Group "Engineer of XXI Century" at the University of Bielsko-Biała (the certificates of membership are in the Google Drive Folder)

Mission objectives

The objective of our mission is to collect data from the sensors of the primary mission and the secondary mission to determine whether the planet and area where our CanSat is landing is suitable for growth of plants. We will also take photos that will allow us to measure various remote sensing indices as well as to classify land cover of the area where our CanSat is landing. The mission like this one will allow to determine whether the planet on which our CanSat is landing is inhabitable for humans at a low cost. The satellite can also collect data that will allow the preparation of appropriate equipment for interplanetary missions of humans.

Our CanSat can also be used during a mission on Earth consisting of measuring various remote sensing indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Green Normalized Difference Vegetation Index (GNDVI), Greenness Index and other, as well as to classify land cover of places where access is difficult (e.g. rainforests, deserts, high mountains) and other places that are in our area of interest. During the flight and after the landing, the satellite will collect data such as temperature, pressure, sunlight intensity and air humidity. Such a CanSat will allow us to perform field and environmental analysis of the landing area.

We were inspired to select this secondary mission by the mission of Perseverance rover which is looking for signs of life on Mars as well as by missions of Landsat and Sentinel satellites taking photos of Earth’s surface.

CanSat Description

Mission outline

The secondary mission of our CanSat is to determine whether the planet and the landing site is suitable for growth of plants. When our CanSat is launched from the rocket, the parachute will be opened, and the satellite will take photos of the landing site using the near infrared camera (Raspberry Pi NoIR camera) located on the bottom. Every photo will be analyzed, and we will measure various remote sensing indices using a code written by our team. The code will prepare photos with marked remote sensing indices in colors (as on the picture below) and a photo with classification of land cover.

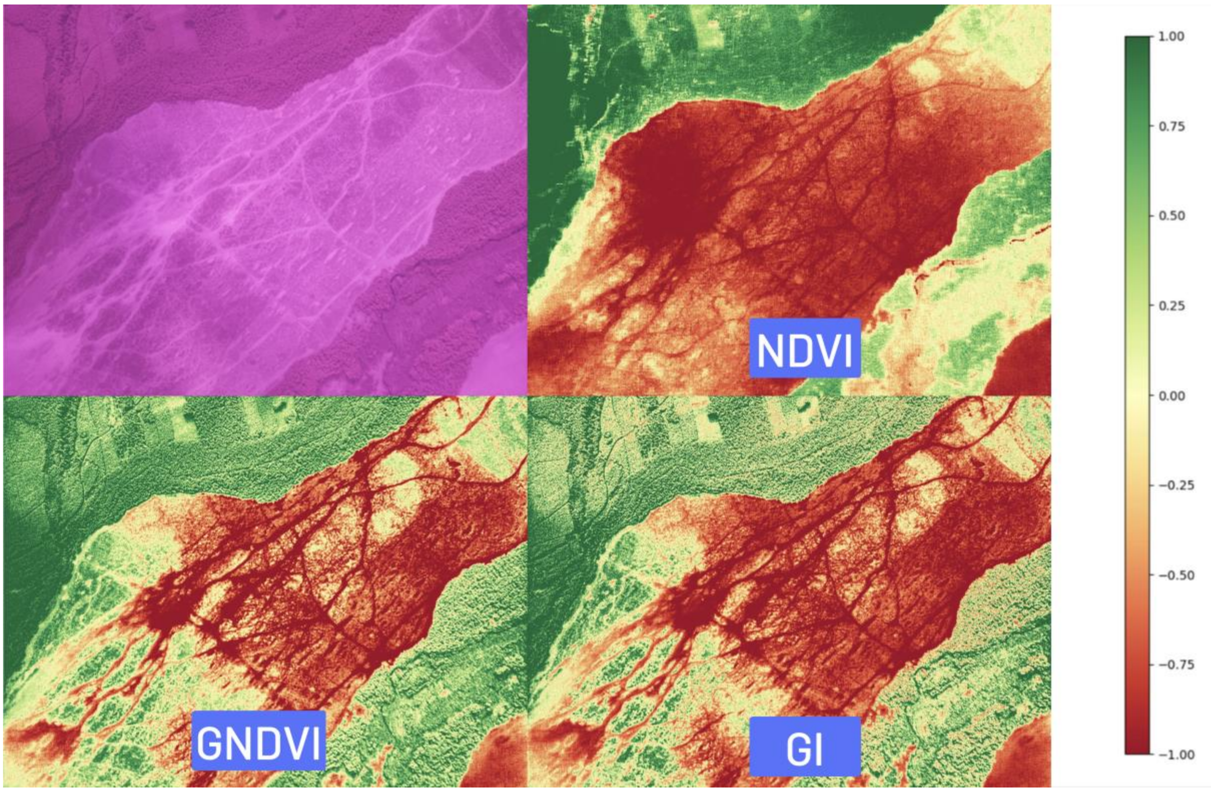

Figure 1: Composition of images

During the flight our satellite will measure temperature, humidity, air pressure, and sunlight intensity. These data will allow us to determine whether conditions in the place of landing are suitable for growth and life of plants (water, temperature and sunlight needed for photosynthesis).

We will analyze all the data after the landing and after an analysis of it, we will determine whether the landing site is suitable for growth of plants and if it’s inhabitable.

The primary mission of our CanSat will be conducted using temperature sensor, air pressure sensor and radio transmitter sending the data from those sensors to our ground station.

We will also use a GPS module, that will send the GPS coordinates to our ground station via radio. The block diagram of our CanSat looks as follows:

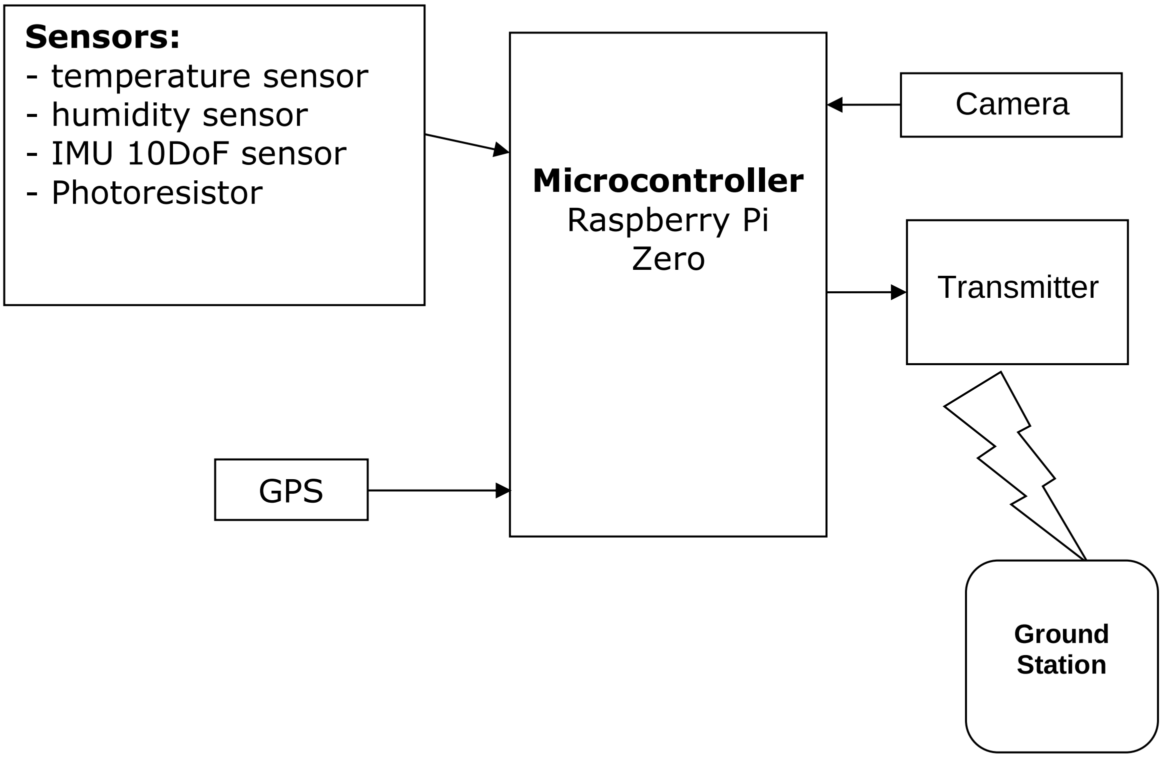

Figure 2: Block diagram of our CanSat

Mechanical/structural design

The main axis of our model are two bolts going through the centre of the CanSat along its entire length. it remained divided into three internal and one external sectors. Because of that we gained a lot of space to work with and to mount all the necessary modules.

Materials used

The main material used to build CanSat is Nylon, of which we printed the casing, as well as most of the internal elements, including sector separation plates. Nylon material is characterized by high mechanical strength, as well as high tolerance to temperature changes, which makes it ideal for the task it's assigned for. The main axis, two screws in the centre of the model, are made of stainless steel. The same applies to any other screws used to attach the modules.

Modules mounting

We used Velcro tape to mount most of the modules inside the CanSat. Where necessary, we placed the modules on special pins, so we could adjust the height of every individual module, and also prevent reduction of durability of our CanSat because of the screws directly screwed into the main structure.

Division of sectors

As mentioned before, our CanSat is divided into 3 interior sectors each of them fulfilling a different task:

- **Sector 1** is the place where most of the sensors and camera is located
- **Sector 2** is the largest section in which the power supply, most of the sensors and the main computer supporting all modules including the radio transmitter is
- **Sector 3** is where we placed a GPS tracker and a parachute mount

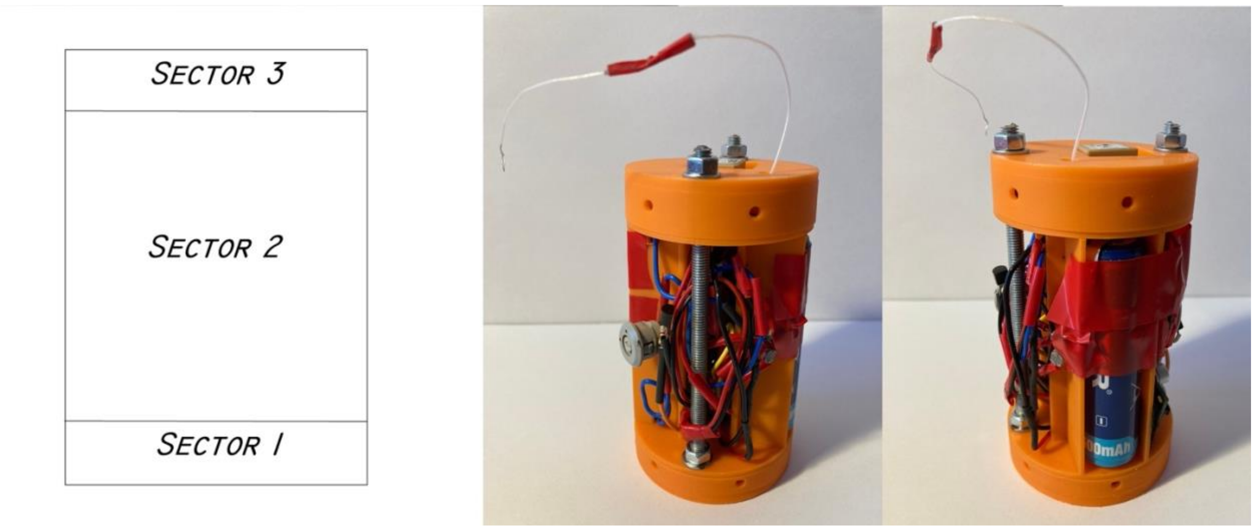

Figure 3: Division of sectors

Casing

Outer casing of our CanSat is divided into 5 individually printed elements, which we put together using fasteners for the "right" and "left" parts, while the "upper", "middle" and "lower" parts, are mounted on two screws which are, as mentioned before, the main axis of our construction. We had to leave some holes in the casing of our CanSat, so that temperature sensors can work properly. Because of that we used hexagonal holes to increase durability of the casing.

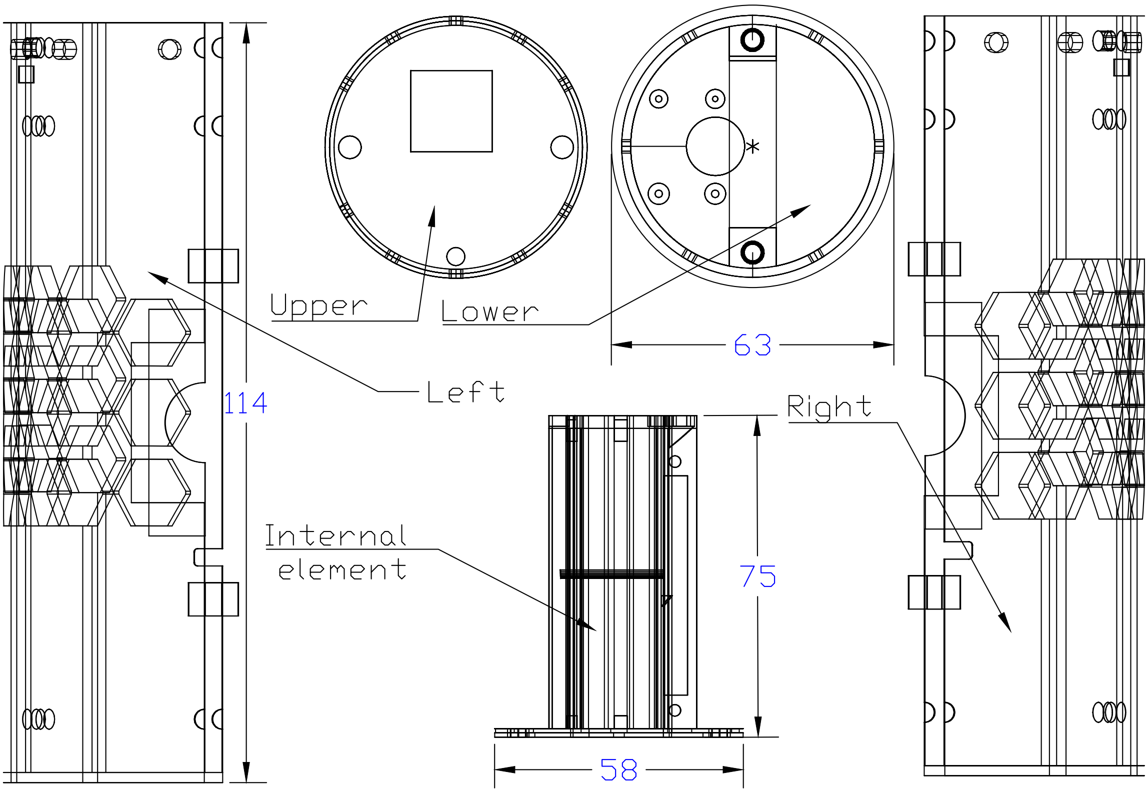

Figure 4: Casing of the CanSat

Electrical design

The system of our CanSat is powered by two 18650 lithium-ion batteries (3.7V; 3500 mAh each). Our main onboard computer is Raspberry Pi Zero W. We also used consecutive sensors: Raspberry Pi NoIR Camera v2, DHT22 temperature and humidity sensor, DS18B20 temperature sensor, Waveshare 10 DoF IMU sensor consisting of air pressure sensor, accelerometer, gyroscope, and temperature sensor; a 50-100 kΩ photoresistor, SX1278 LoRa radio module and Adafruit Ultimate GPS module. Our CanSat will also consist of a 5V 2.5A step-down voltage regulator, a buzzer and a switch-key. An electronic drawing of our CanSat looks as follows:

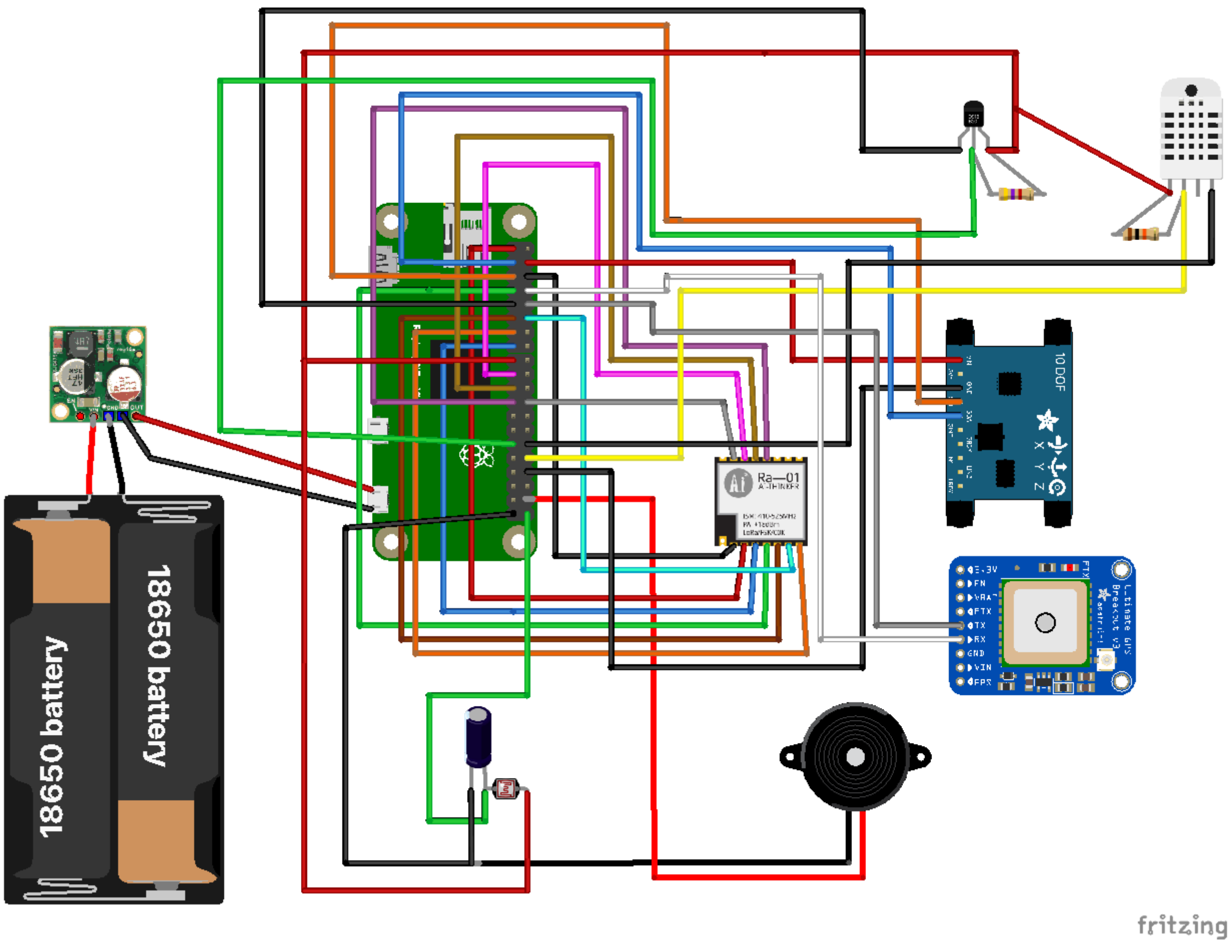

Figure 5: The electronic drawing

The power budget of our CanSat is in the Requirements section. The batteries will allow our CanSat to work for over 12 hours.

Our radio modules (both in the CanSat and ground station) are configured to the frequency of 433.2 MHz and a 125 kHz. The spreading factor is set to 10 and the coding rate to 4/6, what gives the communication speed at about 2600 bps (325 characters per second). The emitting power of the radio is 100 mW. The radio communication will be only used to receive data from the CanSat.

Software design

The code on CanSat is responsible for getting and saving data from sensors, taking images, sending data via radio, and turning different operation modes: preflight mode, flight mode and postlanding mode. We will get data from the sensors every 500 milliseconds. The data gathered from sensors will be saved in a CSV file and images will be saved directly on the SD card in JPG format. All software is going to be written in Python. In order not to create a queue, the CanSat's code is using threading.

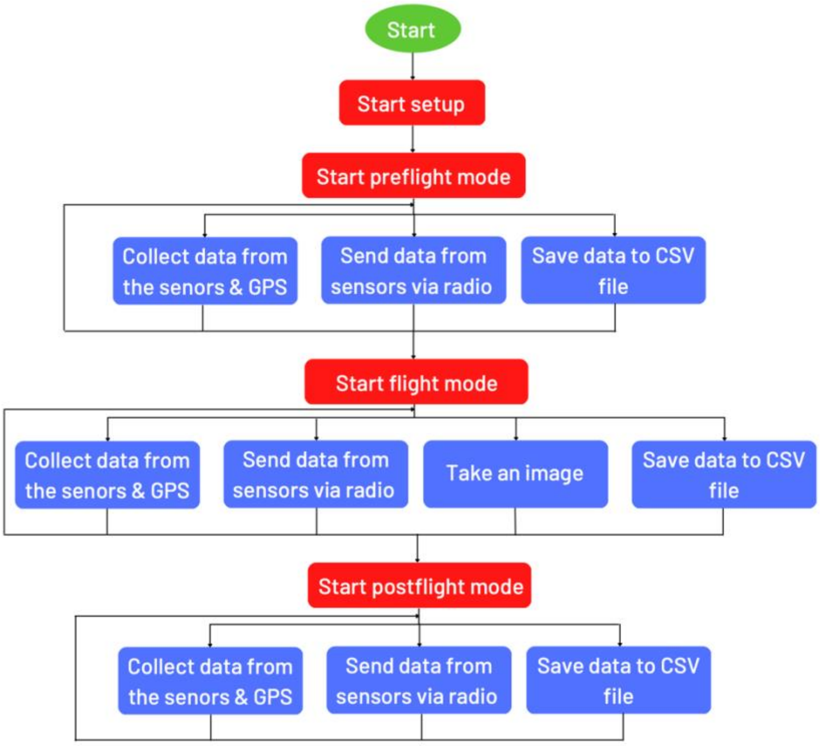

Figure 6: The flow diagram

Preflight mode

This mode will be turned on during the boot of our CanSat. During it, CanSat will only gather data from temperature sensor, pressure sensor and the GPS module as well as send them via radio. Using the readings from GPS and pressure sensor, the code will calculate the altitude of the satellite. If the difference between the initial altitude and current altitude will be bigger than 150 meters for 3 times, our CanSat will switch to the flight mode.

Flight mode

During this mode all the CanSat sensors will be gathering data and the camera will be taking images. The data and images will be gotten once every 500 milliseconds and saved to SD card. Temperature, air pressure, humidity, sunlight intensity, latitude, longitude, and altitude will be sent via radio to our ground station once a second. The photos will be taken in two resolutions: the images in 324x243 pixels resolution that will be sent via radio during the postlanding mode and the images in 2592x1944 pixels resolution that will be stored on the SD card. This mode will be working for 30 minutes and then the postlanding mode will be turned on.

Postflight mode

During the final mode, all the CanSat sensors (except the temperature and pressure sensors) will be turned off. Only the radio module the buzzer and GPS will be working. The radio module will be sending the readings from GPS module, temperature, and humidity as well as images in low resolution to the ground station. The buzzer will be turned on once every 3 seconds for 1 second. This mode will last till the batteries are discharged or until the CanSat is turned off using the switch-key.

Recovery system

We are going to use a hexagonal parachute with an area of 900cm^2 with a parachute vent which will stabilize the flight of our CanSat and reduce the spread of the landing.

The material used to sew our parachute is a polyester-nylon ripstop fabric. It has a high durability and is also waterproof. Its bright blue colour has not been chosen by an accident. It will help us to find our CanSat after its landing. To attach our parachute, we will use 6 nylon lines with a diameter of 3mm. The parachute will give our CanSat a flying speed of 10.6 m/s, what gives the flight time of about 90 seconds.

To attach our parachute, we will use nylon lines inserted into interior of our model through holes in its case. At the end of these lines, we will make knots with a diameter larger than the diameter of the holes, so that the parachute will remain in place. It is a simple solution that doesn't introduce additional elements that could fail during the flight.

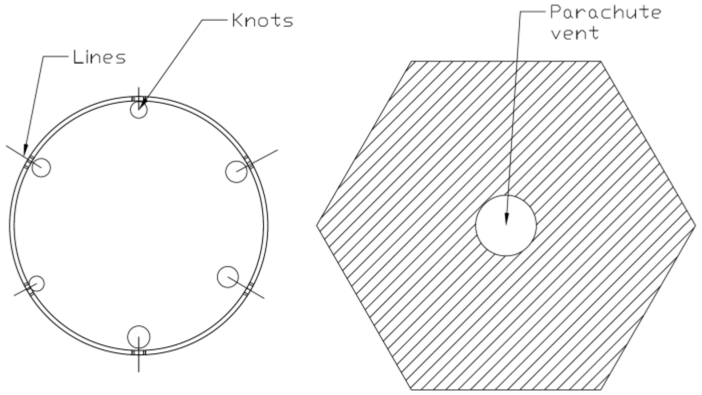

Figure 7: The parachute

Ground support equipment

Our ground station consists of a Raspberry Pi 3B+ set with SX1278 radio module, a Yagi-Uda antenna and a laptop. All the data from the CanSat (except the images) will be sent to Raspberry Pi via radio. The software, written in Python, will receive each second a message, decode it and save the data in the CSV file. Our team is going to use the 433.2 MHz frequency.

Project Planning

Time schedule of the CanSat preparation

HIGH-LEVEL TASK	LOWER-LEWEL TASK	STATUS
Writing CDR	Dividing work	Done
	Submitting CDR	Done
Outreach	Creating Facebook account	Done
	Creating Instagram account	Done
	Establishing new cooperations	Done
	Posting updates	Done
	Giving presentation in school	Done
	Giving presentation in training center for teachers	Done
Planning	Inventing mission's objectives	Done
	Designing electronics	Done
	Designing satellite	Done
	Approximating the budget	Done
	Approximating mass of CanSat	Done
Gathering all necessary things	Choosing materials and modules	Done
	Buying elements	Done
	Eventual changes in budget	Done
Prototypes	Parachute	Done
	Case	Done
	Electronics	Done
Testing	Testing parachute	Done
	Testing GPS module	Done
	Testing case durability	Done
	Testing camera	Done
	Testing battery lifetime	Done
Communication	Choosing antenna and radio module	Done
	Calibrating radio modules	Done
	Writing a script for radio modules	Done
	Testing radio module on short distance (few meters)	Done
	Testing radio module on medium distance (few hundred meters)	Done
	Testing radio module on long distance (3 kilometers)	Done
	Testing radio module	Done
GPS	Choosing GPS module	Done
	Testing GPS module	Done
	Installing GPS module	Done
Software	Writing an algorithm for each sensor	Done
	Writing script for ground station	Done

	Writing script for CanSat	Done
	Writing photo analyzing program	Done
Electronics	Choosing sensors and components	Done
	Making electrical design prototype	Done
	Testing and calibrating sensors and components	Done
	Testing final version of electrical model	Done
Final model	Printing case	Done
	Testing the final model	Done
	Installing electronics, modules, sensors in case	Done
Writing FDR	Dividing work	Done
	Submitting FDR	Done
European finals	Dividing work	Done
	Submitting PLR	Done
	European finals in Bologna	
	Submitting CanSat Final Report	

Resource estimation

Budget

Element	**Cost (€)**
Raspberry Pi Zero W 512 MB	13.00
Raspberry Pi NoIR v2 Camera	32.00
Temperature sensor DS18B20+	2.34
Waveshare IMU 10DoF sensor	14.10
2x 18650 XTAR – 3500mAh battery	21.60
Servo SG-90	4.10
Case (filament)	12.20
GPS module for Raspberry Pi	46.00
SX1278 LoRa RA-02 433 MHz radio module	7.60
DHT-22 Temperature & humidity sensor	6.50
Step-down converter 5V 2.5 A	15.21
Others (switch-key, wires, filament, photoresistors)	15.00
Σ	**189.65**

External support

Since October we managed to get a lot of partners and sponsors for our project. Our partners and sponsors are in succession: University of Bielsko-Biała, WizjaNet - an IT company that provides services to companies in field of IT, programming, and e-marketing; Abel IT – an IT company providing computer services; Botland – an electronic and robotic shop; our school's PTA, the school management, and the V High School Association.

Received support allowed our team to buy all necessary parts to build our CanSat, prepare promotional materials as well as 3D print the casing of our sonde.

Testing

We have tested our sensors by running several tests. We compared the obtained results with measurements from other sensors and weather stations to check if the sensors are accurate. The temperature was measured using three independent sensors: DS18B20 (the main temperature sensor in our CanSat), DHT22 and BMP280. The gathered records are similar with an error of ±1°C.

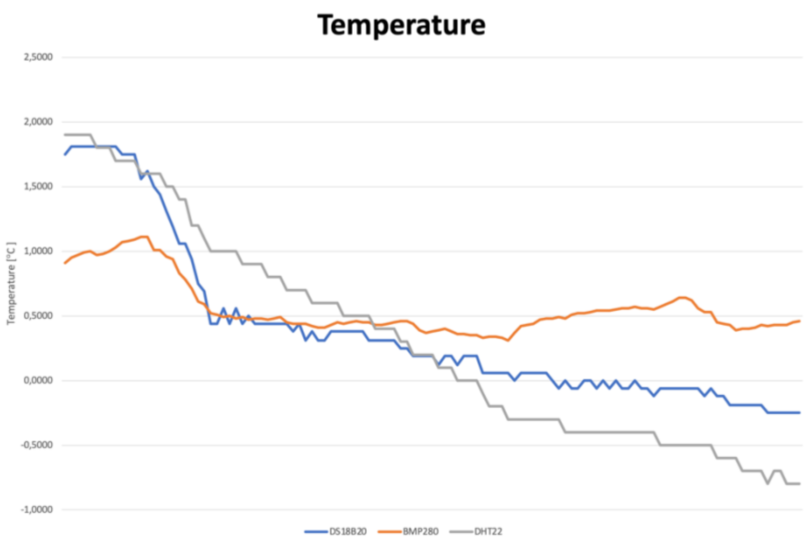

Figure 8: Temperature measurements

The obtained pressure measurements were also accurate compared with the measurements from an independent weather station. The error was ±2 hPa. We also tested a GPS module several times. The obtained results were with an average error of 10 meters in latitude and longitude what is an accurate result, allowing us to easily find our CanSat. We have also tested our camera and the code for photo analysis. We have tested it during different parts of the day and on few different areas. The obtained images are of good quality and indicators are calculated correctly (an example image is in the Mission outline section).

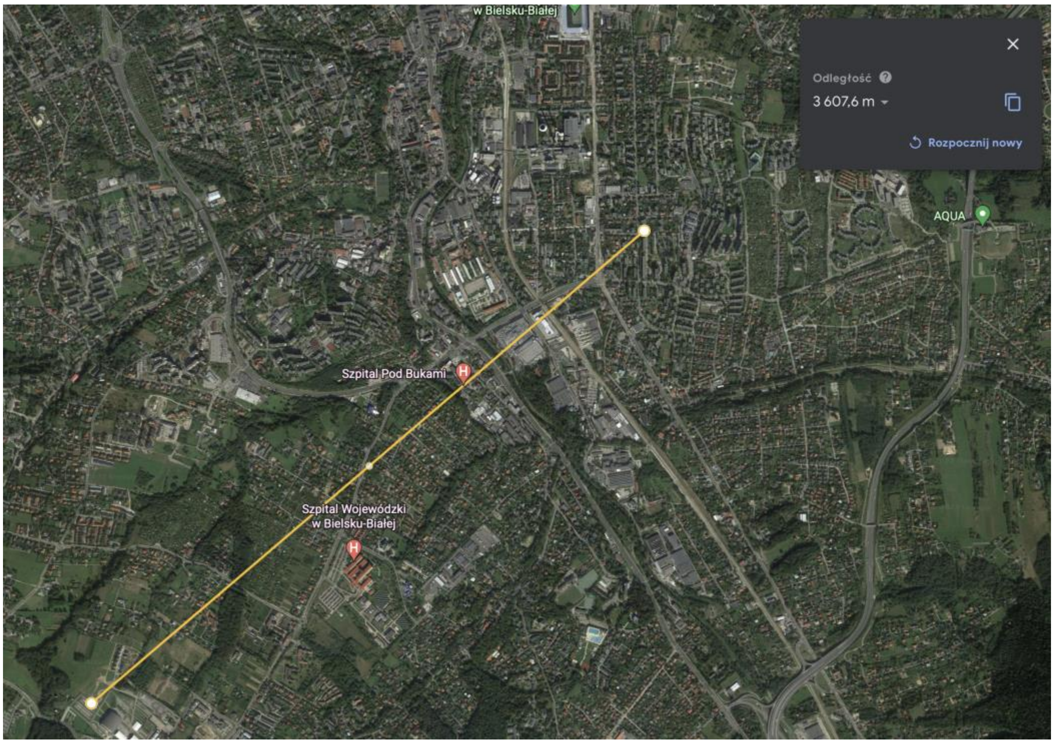

Figure 9: Map showing the place of radio range tests

We also tested the recovery system by dropping a weight model from buildings of different heights. As the models fell, we measured the time and recorded the moment of flight. The footages from the tests can be seen in our Google Drive Folder.

We also have performed several radio communications tests at the distance of 3.6 km. In each test we sent a line consisting of 50 characters. The tests proved that our CanSat is able to freely transfer data on this distance without interferences.

The last test conducted was energy budget test which proved that our CanSat is able to work on batteries for over 12 hours: 5 hours on the preflight mode, 30 minutes on the flight mode and the postflight mode for about 7 hours.

Lessons learnt from the National Competition

During the launch campaign we have learned that:

- The CanSat must be flight-ready before arriving at the campaign. One of the teams was building a CanSat few hours before the flight and this CanSat failed to accomplish its mission.
- During the launch campaign there was a very strong wind. Due to this fact we needed to change our parachute for a smaller one, that will result in our CanSat falling much faster, but it allowed us to find our CanSat easily. For the European finals we are also going to bring 2 parachutes.

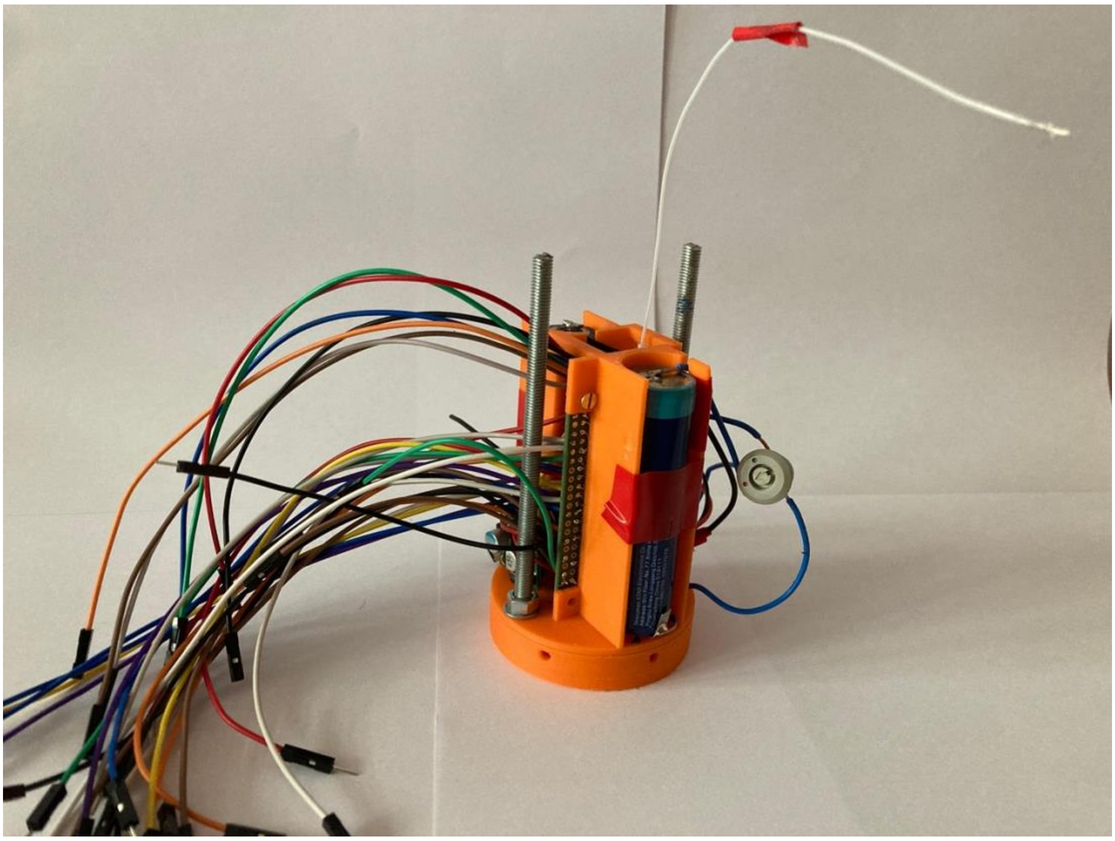

Figure 10: Assembly of the electronic circuit

Outreach programme

All links to our outreach activities are here: https://taplink.cc/teamvlo.cansat

Social media

For our Outreach Programme we set up Facebook and Instagram pages in October. Since then, we are regularly gaining new followers. Currently, Facebook page is a place, where almost all information that a common observer needs can be found.

We still publish updates about the project, our partners, and sponsors as well as about our team. Our posts reach more than a few hundreds. recipients. Our Facebook page has 213 followers and 203 likes, while our Instagram page has 131 followers.

Figure 11: An example Facebook post

Scientific paper

The leader of our team – Emil Kielar with the help of our mentor - Dr Dawid Kotrys published a research paper on the XI Inter University Conference of Students, PhD students and Young Scientists held at the University of Bielsko-Biala (ATH) in Bielsko-Biała. Emil's paper is about a program, written in Python, which analyzes images using the OpenCV function library. The code determines the Normalized Differential Vegetation Index, what is a main stage in our secondary mission

Logotype of our team

To promote our team, we created our own logotype that is being used in all promotional materials of our team (the logotype at the beginning of the report).

Media coverage

We have gotten a lot of attention from local media: there have been written 5 internet news articles about our team as well as a newspaper article. In near future we are also going to give a radio interview to a local radio station.

Presentations and exhibitions of experiment

Our team has already given four presentations about our CanSat: one for the teachers at Bielsko-Biala's Teacher Training Centre, one for the students from our school, one during open day in our school and one at the University of Bielsko-Biala for the university authorities, the mayor of the city of Bielsko-Biala, the authorities of our school, tutors from the university as well as the students from the University and high schools from our city. On 12th of June we are going to present our CanSat at a science festival which is organised by our city.

Figure 12: Presentation at the University of Bielsko-Biała

We also recorded a 13-minute-long video presenting our project and the CanSat competition. It can be found in our Google Drive folder (in Polish only).

REQUIREMENTS

Characteristics	Figure (units)
Height of the CanSat	114 mm
Mass of the CanSat	301 g
Diameter of the CanSat	63.5 mm
Additional length of external elements (along axial dimension)	40 mm
Flight time scheduled	90 s
Calculated descent rate	10.6 m/s
Radio frequency used	433.2 MHz
Power consumption	3.3 W
Total cost	€190

Power budget

Device	Voltage (V)	Current (mA)	Power (mW)
Raspberry Pi Zero W	5	~200	1500
Camera	-	-	1000
Temperature sensor	3.3	1	3.3
IMU 10DoF sensor	5	4	20
GPS module	5	20	100
Radio module	3.3	130	430
Humidity sensor	5	0.2	1
Photoresitor	3.3	4	13.2
Buzzer	5	30	150
Total power (sum of all)	**-**	**~400**	**~3300**

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

Emil Kielar

Bielsko-Biała; 9.06.2022