Starliner

Preliminary Design Review

Team Name: Starliner
Country: Poland

Content

1.Changelog
None

2.Introduction
2.1 Team organisation and roles
The team's work was divided proportionally among all team members. Each element of the project will have its lead member, who will be responsible for their part of CanSat, where each of the 5-person group will have part in each element, so that in case of illness or temporary indisposition of one of the people the project won't stop. Mr Michał Żurawski is our supervisor. He is a physics teacher at our school. Tasks of individual group members:
Kacper Grobelny - team captain; deals with programming the controller and connecting sensors to the main system.
Mikołaj Koralewski - deals with the communication between Cansat and the station on the ground and the construction of the receiving antenna, CanSat prototype constructor
Mikołaj Krzyżostaniak – 3D printing, translations, transport
Piotr Skoracki - deals with the frame, cover design and construction and is responsible for the website, social media management and photography
Dawid Betka - deals with the construction of the parachute and electrical design.

2.2 Mission objectives
The general assumption of our mission is the search of water and favorable conditions for life on foreign planets or moons. We want to focus on finding single places on the planet where it will be possible to set up a base or a colony in the future. The device is to be dropped into an area where, based on remote sensing from the orbit, there is a probability of water presence. The probe will measure the presence of water in the soil and will take photos around the probe. The photos will be analyzed in order to know the topography. If the batteries in the probe are discharged, the device will go into sleep mode until it charges the battery from the solar panel.

3.CanSat description
3.1 Mission overview
We are going to build a rover that will fit the cylinder size of 115x66mm. It will be launched from a rocket to a height of about 3 km. After it is released from the container, it will fall at a speed 10m/s. During the descent, the rover will unfold its wheels. It will also measure the temperature, pressure and air humidity as it descends. The height at which the rover is located will be measured on the basis of pressure

changes. All data will be sent to the ground and analyzed by the program which will be creating graphs in real time. Based on GPS coordinates and altitude, the antenna will direct itself to the falling CanSat. After landing, the probe will detach its parachute. It will travel a few meters and take measurements of the temperature, pressure, air and soil humidity and location, as well as take pictures of the surroundings. The probe will be equipped with an algorithm that will try to follow to the lowest point, because there is the highest probability of finding water there. The travel and measurement process will be repeated many times.

3.2 Mechanical/structural design

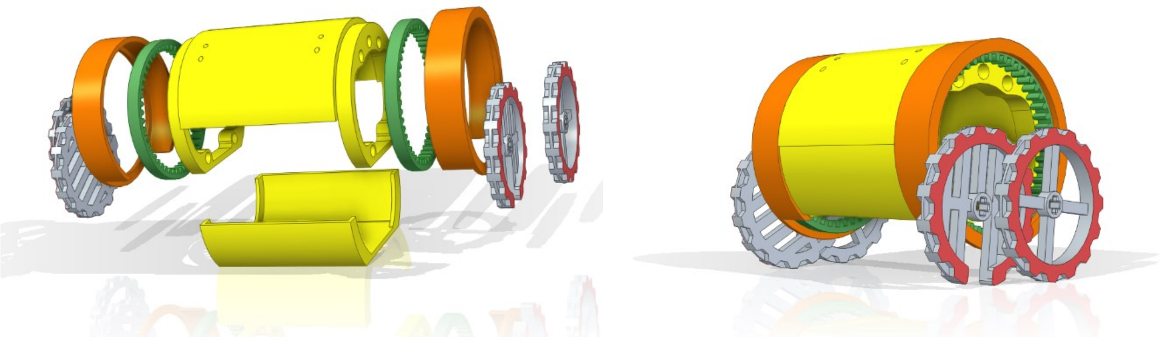


Photo 1: Every single part od CanSat and assemble

CanSat cover was designed in Solid Edge 2020 to print it on a 3D printer. The box consists of a middle segment and two gears with internal toothing, fixed by a cover. The middle segment consists of two parts for easy access to the components inside. All folded elements have clearances (0.4- 0.8 mm) so we can easily put them together and the gears rotate without any problems.

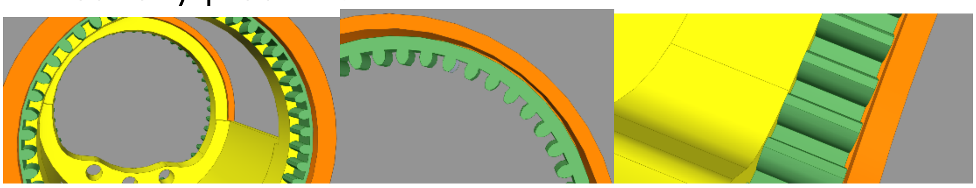


Photo 2: Loose fitting

The CanSat, both in flight and on the ground, will move horizontally, which will make it more stable while driving. The battery will be placed in the bottom of the box to move the weight as close to the ground as possible. At the beginning we wanted to use tracks, but we came to the conclusion that it is too complicated and heavy mechanism, so we gave it up in favour of the wheels. The wheels have been designed so that their diameter is as large as possible. This diameter is 46mm. One of the wheels has a cut-out so that the wheels could be folded while in the container. The CanSat will be equipped with a wheel unfolding system.

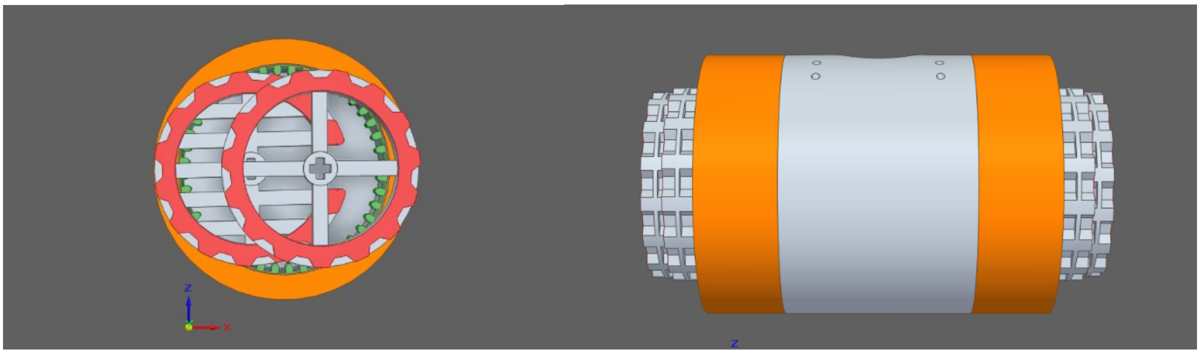
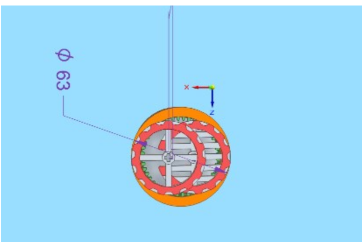


Photo 3: CanSat state in the rocket container

When mounting the wheels and the drive rack, we used Lego axles, to which we adjusted the through holes in the design. We also used Lego for the drive, from which we used small gear wheels, characterized by high strength and low weight at the same time. For these gears, we have created large ones with internal teeth while maintaining the parameters of the teeth.
Looking from the side, you can see that the CanSat is cut from the bottom, which allows it to overcome more uneven terrain. The ground clearance of the rover is 20mm.

Photo 4: Cut bottom

In the upper part of the main segment there are 8 holes for attaching the parachute. The overall dimensions of the CanSat are designed with a margin of 3mm to the maximum possible. After assembling the frame first prototype and applying corrections to reduce the weight, we gained 1.72 times more usable space and reduced the weight of the printed elements themselves from 90g to 75g. We also gained space by removing the side walls.



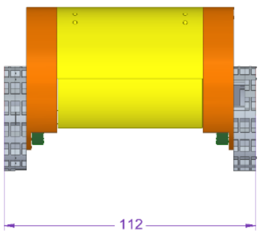


Photo 5: CanSat size

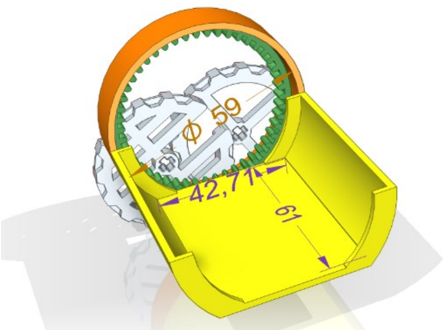
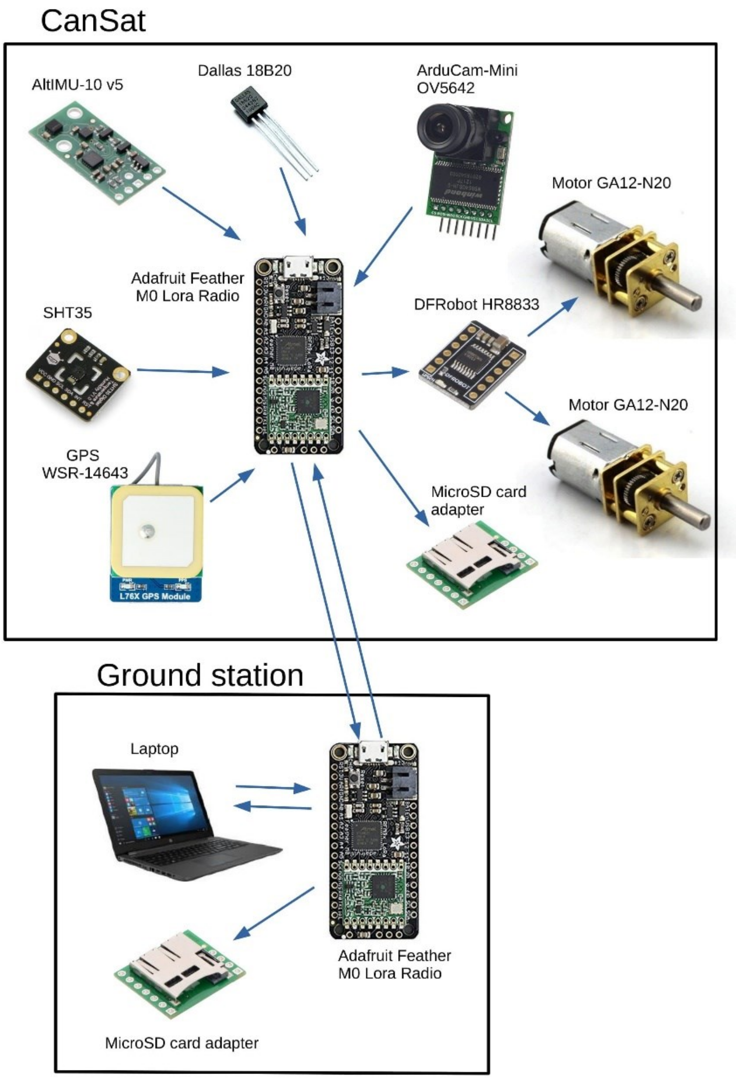


Photo 6: Dummy-mass for parachute tests

We also printed a test can for the parachute test. It is simply a weight with the same shape and weight as the finished CanSat.
The CanSat cover and frame will be printed on a 3D printer. The materials we will use are mainly PET-G and ASA as well as PLA. We will decide on the exact printing parameters such as filling or the type of material for a given part after strength tests.

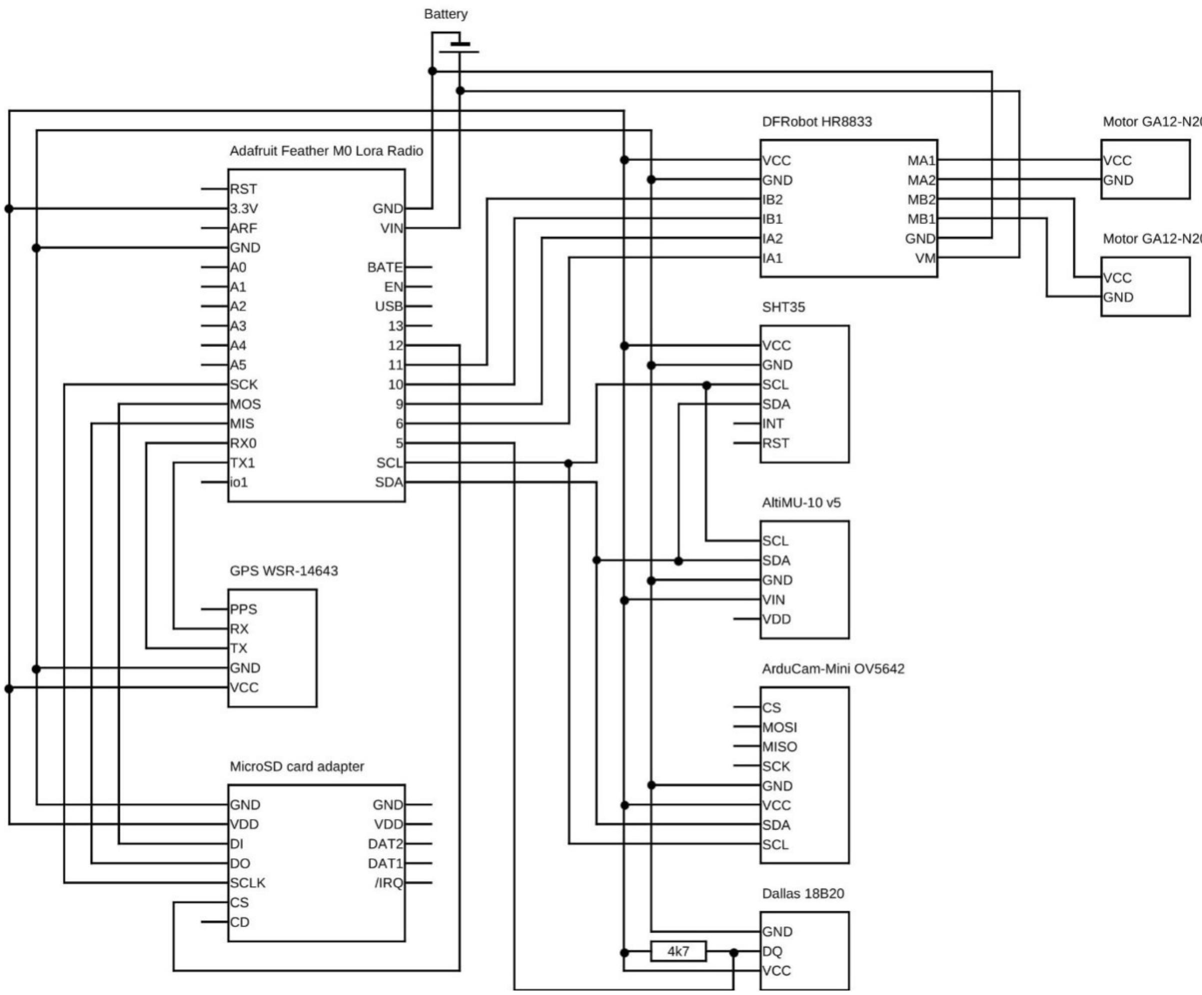
3.3 Electrical design

3.3.1 General architecture



Scheme 1: Overall mission plan

The modules presented in this report are connected on the "Adafruit Feather M0 433mhz RFM96 LoRa radio". The built-in LoRa radio module communicates with the Adafruit Feather M0 via the SPI bus. Characteristics:
-input: 3,3V
-radio frequency: 433Mhz
-mass: 6g
-size:51x23x8[mm]
-pins:20 GPIO, 8PWM, 10 inputs and 1 analog output.



Scheme 2: Detailed electronics connections

3.3.2 Primary mission devices

Dallas 18B20- to outside temperature measurement. Connected with 4,7kΩ resistor. It connects to the Adafruit Feather M0 with the 1-wire bus.
-measuring range from -55°C to 125°C
-accuracy ± 0,5°C in -10°C to 85°C range
AltiMU-10v5- with barometer LPS25H module connected to the Adafruit Feather M0 via I2C bus
-measuring range from 26kPa do 126kPa
-accuracy ±0,02kPa
MicroSD Card Adapter: It communicates with the Adafruit Feather M0 via SPI bus and is saving all collected data.

3.3.3 Secondary mission devices

SHT35- digital sensor connected to Adafruit Feather M0 via the I2C bus able to measure:
1)Temperature:
-measuring range: from -40°C to 125°C
-accuracy ± 0,2℃
2)Humidity:
-measuring range from 0% to 100% RH
-accuracy ± 1,5% RH

AltiMU-10v5-all-in-one accelerometer and gyroscope (LSM6DS33),magnetometer(LIS3MDL). It is connected to the Adafruit Feather M0 via the I2C bus.
Measuring ranges (configurable):
Accelerometer: ± 2, ± 4, ± 8, ± 16 g
Gyroscope: ± 125, ± 245, ± 500, ± 1000, ± 2000 °/s
Magnetometer: ± 4, ± 8, ± 12, ± 16 gauss

L76X Multi-GNSS GPS / BDS / QZSS - Waveshare 16332-gps module that allows us to check the position of our CanSat, communication with Adafruit Feather M0 via UART
-update rate 1 Hz (default) to 10 Hz (maximum)
-baud rate 4800 to 115200 bps (default 9600 bps)
-working temperature From -40 ℃ to 85 ℃

DFRobot HR8833 - a two-channel driver for DC motors controlled by PWM signal
-maximum current per channel 1.5 A
-working temperature from -20 ° C to 85 ° C

2x GA12-N20 motors - DC brush motors with mounted gear connected to DFRobot HR883 controllers
-voltages from 1V to 6V
-torque 3Nm
-50 revolutions per minute

Soil moisture sensor connected to Adafrutit Feather M0 which will be made by us and we will compare its accuracy to other sensors. In case of failure to construct our own sensor, we will use ready-made elements.

ArduCam-Mini OV5642-a module with a camera that will allow us to take photos in real time and send them to the receiving station, and to make short videos that will be saved on the SD card, it will communicate with Adafruit Feather M0 using I2C.

3.3.4 Power supply

In our CanSat we used a Li-ion 18650 3.7V 2.5 Ah battery. The estimated battery life, in which we took into account the operating time of the sensors and motors on full power is 4,4 hours under ideal conditions. This value depends on the ambient temperature affecting the battery and the load on the motors, this time may be shortened or elongated.

Device name	Current electricity consumption [mA]	Supply voltage [V]	Efficiency	Battery power consumed [W]
Adafruit Feather M0 RFM 96 LoRa radio	180	3,3	0.5	0,6
GPS module	11	3,3	0.5	0,36
AltiMU10v5	6	5	0.5	0,03
Temperature sensor Dallas 18B20	1,5	3,3	0.5	0,05
Two engines	120x2	5	0,7	0,6x2
Engine control unit	1,5	3,3	0,5	0,5

3.3.5 Communication system

We will use a Yagi antenna consisting of 12 elements, which will give us a gain of 14.9 dBd. The "yagi" antenna will be supported by a bi-quad antenna, and a "jotka" antenna which is omni-directional one. We will test these three antennas which pair will perform best in different conditions, thanks to which we will make the appropriate selection. A wave antenna with dimensions of approx. 34.6 cm in the form of a cable will be installed in the probe, it may be changed into a screw antenna.

3.4 Software design

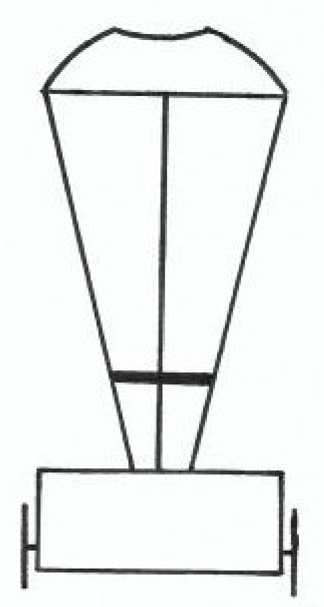
The program will be written in C ++ in the IDE. The on-board computer will be Adafruit Feather M0 433mhz RFM96 LoRa radio. We plan to write it so that it is reliable in all conditions. In case of failure of any of the sensors or modules, the program will do not hang. Data from sensors during the flight will be downloaded every 1s. They will be saved on the SD card and sent to the ground via the radio module. The flight will take approximately 5 minutes (approximately 300 measurements). After landing on the ground, the program starts the engines responsible for turning the wheels. The on-board computer will interpret data from various sensors in order to increase the chance of finding water on another planet - e.g. it will look for depressions in the area where water can accumulate. Data collected on the ground will also be saved on the SD card and sent to the ground. We plan to make a two-way communication with CanSat for possible manual control or fixing any errors.

3.5 Recovery system

During the recovering the most important thing are geographical locations of CanSat. Our current equipment is GPS WSR 14643 module with antenna. GPS gives different coordinates according to the record NMEA. The record was successfully converted into more readable form. The module gives geographical coordinates, altitude, number of satellites in range, speed, and correctness of reading. In addition to geographical coordinates, measurements are burdened with an error due to the accuracy of the antenna and the number of satellites nearby. The minimum number of satellites should be at least four. To recovery system we can also include falling inhibitory system. For this purpose we apply the parachute. After our calculations, in which we considered the maximum CanSat weight (350 grams), the falling speed, which is on average 10 m / s, air density, resistance coefficient equal to 0.5. The pattern itself looks like this:

$$S = \frac{2Q}{cWg}$$

When:
s-parachute surface
Q-weight
c-drag coefficient
v-falling speed
q- air density
After an in-depth analysis and proper calculation, the satellite at constant drag and stable flight , the flight time is ideally at the assumption of a maximum altitude of three kilometers, (it will be five minutes) it needs to include additional drag and a larger distance when the satellite will endure, the time can be up to seven minutes.



Scheme 3: Parachute

3.6 Ground support equipment

To receive data sent by CanSat, we will use either a "Yagi" or "bi-quad" antenna, whichever is better when it hits the ground. The antenna will work with the Adafruit Feather M0 433mhz RFM96 LoRa radio. The received data will be sent to a computer, where it will be saved. We plan to write a program that will display the received measurements in the form of graphs, thanks to which we will have a current preview of how the mission is going.

4. Test campaign

4.1 Primary mission test

After building the first prototype, we will start it up and compare its results (temperature, humidity, pressure) with the results of certified sensors.
We will test the strength and descent speed by dropping the finished prototype with a parachute from the observation tower in Sieków (30m) and from drone as high as possible.

4.2 Secondary mission test

We will check whether our selected soil moisture sensor works and what its real accuracy is compared to certified sensors. We will test the running properties of the finished prototype in various conditions like dirt, sand, grass, etc. We will check what we are able to find out from the photos taken from such a low height. On a slope, we will test the algorithm that is to search of the lowest point in the field.

4.3 Test of recovery system

The parachute mounting will be tested for its resistance to sudden jerks and gusts of wind, and its consistency of the falling speed will be checked. We plan to find the CanSat using GPS coordinates. As soon as the first prototype is assembled, we will test the accuracy of the location of our GPS module. We know from our experience that the deviation is really small and we can easily find the device.

4.4.Communication system range test

We are currently using a Yagi type directional antenna with a range (at a height of 2m above the ground) of 6.7 km. Ultimately, we want to get a range of 12km.

4.5 Energy budget test

We have not conducted such a test, because we don't have a fully functional prototype yet. After its construction, we will test how long it can work on the battery and check the possibility of adapting to a solar charging system.

5. Project planning

5.1 Time schedule

Done:

Date	Activity
10.09.2020-27.09.2020	Choosing the elements
31.09.2020-09.10.2020	Design CanSat project in Solid Edge
05.10.2020-10.10.2020	Create connection schemes
10.10.2020-13.10.2020	Print first elements
12.10.2020-26.10.2020	Creating PDR
14.10.2020	Meeting with a specialist of motion system
15.10.2020-16.10.2020	Antennas design

To do:

Date	Activity
22.09.2020-15.11.2020 (in progress)	Graphing program
28.09.2020-16.12.2020 (in progress)	Write a running program
31.09.2020-16.12.2020 (in progress)	Layout of CanSat construction
01.10.2020-08.11.2020 (in progress)	Find sponsors
10.10.2020-16.12.2020 (in progress)	Design and implementation of the power system in CanSat
18.10.2020-28.10.2020 (in progress)	Parachute design
18.10.2020-07.12.2020 (in progress)	Create ground station
26.10.2020-29.10.2020 (in progress)	Build of antennas
02.11.2020-22.12.2020	Some marketing activities
04.11.2020-13.01.2021	Create CDR
05.11.2020-12.11.2020	Range tests of antennas
09.11.2020-25.11.2020	Selfmade ground moisture sensor
25.11.2020-10.01.2021	Test our ground moisture sensor
01.12.2020-16.12.2020	Wheel unfolding system
01.12.2020-16.12.2020	Returning to on wheel position of CanSat
18.12.2020-20.12.2020	Parachute tests
18.12.2020-20.12.2020	Drop tests
23.01.2021-26.02.2021	Create FDR

5.2 Task list

Done	In Progress	To do
Choosing the elements	Graphing program	Some marketing activities
Design CanSat project in Solid Edge	Write a running program	Create CDR
Create connection schemes	Layout of CanSat construction	Range tests of antennas
Print first elements	Finding sponsors	Selfmade ground moisture sensor
Creating PDR	Design and implementation the power system in CanSat	Test our ground moisture sensor
Meeting with specialist of motion system	Parachute design	Wheel unfolding system
Antennas design	Create ground station	Returning to on wheel position of CanSat
	Build of antennas	Parachute tests
		Drop tests
		Create FDR

5.3 Resource estimation

5.3.1 Budget

Element	Cost (PLN)
Adafruit Feather M0 with RFM96 LoRa Radio	200
GPS	70
AltiMU-10v5	90
Dallas 18b20 sensor	5
MicroSD Card Adapter	3
MicroSD Card	40
Parachute	70
Filament	20
Battery	30
SHT35	75
Camera	220
2X motor	37
DFRobot HR8833	22
Lego elements	10
Soil moisture sensor	15
Together	907

5.3.2 External support

Currently, we have not obtained new funds for the project yet, we use our own resources and savings from the previous edition of the competition. We talked with local entrepreneurs who confirmed that if we qualify to the next stage of the competition, they will help us with finances, equipment and their own knowledge.

6. Outreach programme

During the search of sponsors and donors, we disseminated information about our activities among our schoolmates. On our facebook we got over 100 followers. In our school there are TVs presenting announcements and current events from our school life. The GIF promoting our Facebook was also presented there.

Photo 7: Photos showing our GIF

Our website: https://starlinergostyn.wixsite.com/2021
Our facebook: https://bit.ly/2TlAMhM
Our school website: https://zsz-gostyn.com.pl
Our school facebook: https://bit.ly/32cwHP1
Our Youtube channel, where you will be able to see our future videos of our work: https://bit.ly/37G8Sp9

7. CanSat characteristics

Characteristics	Figure
Height of the CanSat	112mm
Diameter of the CanSat	63mm
Mass of the CanSat	340g
Estimated descent rate	10m/s
Radio transmitter model and frequency band	Adafruit Feather M0 RFM96 Lora with radio module 433Mhz
Working time on battery	4,4h with engines on full power, 30h without engines
Cost of the CanSat	907PLN

8. Register