OnionSAT

Prelaunch Report

Berzsenyi Dániel Secondary School, Budapest

25 March 2024

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1. Introduction

1.1 Team members and roles

Tamás Pécsi: Programming the microcontroller of the satellite, developing and maintaining the IT infrastructure of the OnionSAT project. *(cca. 250 working hours)*

Máté Barnabás Dernovics: Designing the landing mechanisms of the CanSat, designing the electrical circuit of the satellite. *(cca. 250 working hours)*

Róbert Mihályffy: Designing the 3D model of the CanSat, responsible for the physical implementation of the satellite. *(cca. 250 working hours)*

Áron Kolláth: Managing outreach and sponsorship-related tasks, documenting the workflow. *(cca. 220 working hours)*

Miklós Gergely Virág (mentor): Verification of satellite related calculations, technical issues, answering technical questions.

1.2 Mission objectives

Our primary mission is to monitor the status of the CanSat and its surroundings, (the temperature, humidity, and pressure) while it's lowering altitude.

Our secondary mission is to measure the magnitude and direction of near-surface jet streams (fast currents near the surface) and thermals (warm updrafts) using a 3-axis accelerometer.

Our measurements will be compared with aeronautical meteorological forecasts to test their accuracy. We will also share our experiences with them, to help make forecasts more accurate in the future.

2. CanSat Description

2.1 Mission outlines

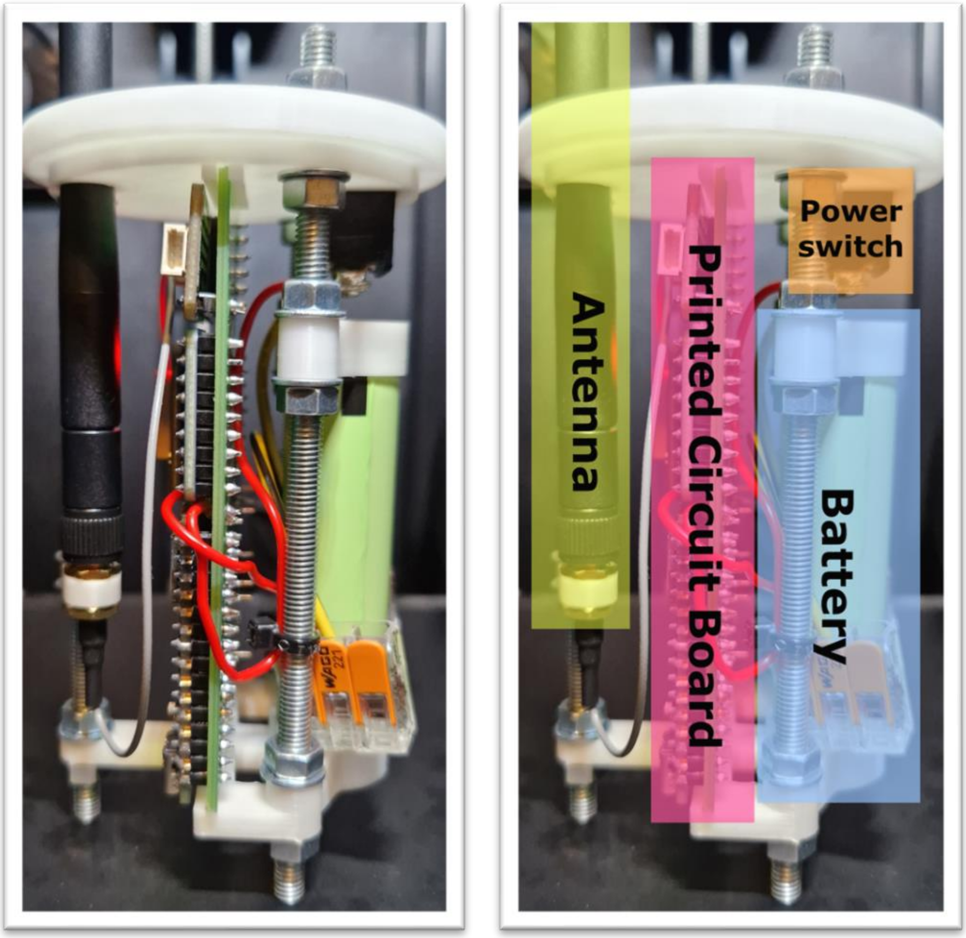
The mission is considered successful if the satellite is able to send the measured data from all sensors (temperature, humidity, atmospheric pressure, 3-axis acceleration, GPS) to the ground station in real time via radio communication and at the same time save them to its own storage (SD card).

For the exact type of sensors, please refer to section 6.2.

From the acceleration values obtained, we can infer the direction and magnitude of the streams/currents, and we also measure thermals in the vertical acceleration direction. We expect to encounter predominantly unidirectional currents during the CanSat expedition.

2.2 Mechanical design

The CanSat's frame is 3D printed from **ABS (acrylonitrile butadiene styrene)**, one of the most durable thermoplastics available.



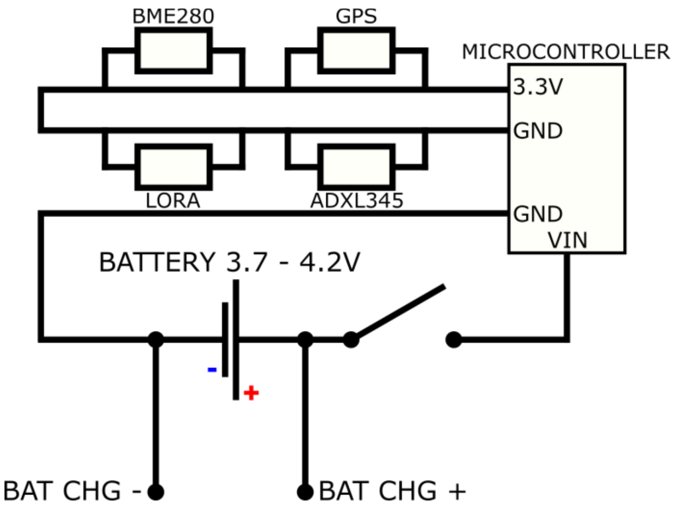
The CanSat frame consists of 3 threaded stems mounted to the roof. All the components connect to these threaded stems. As the picture shows the battery is fixed with two 3D printed parts, from the top and bottom. These parts are fixed to the main frame with nuts.

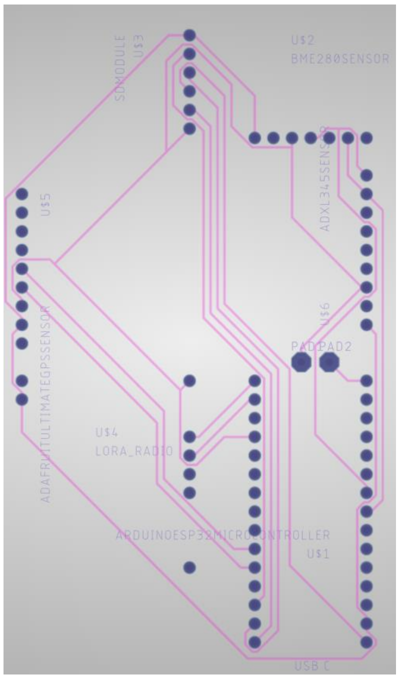
2.3 Electrical design

In the CanSat, the microcontroller and the various sensors are soldered onto a printed circuit board.

A diagram of the layers of the printed circuit board is illustrated below.
The satellite is powered by a 18650 Li-Ion cell with a capacity of 3400 mAh. With this capacity, CanSat can operate continuously **for more than 24 hours**. For a description of the battery test, please refer to section 4.4. For the power budget, please see section 6.2.

The diagram below details the CanSat circuitry. The *"BAT CHG +"* and *"BAT CHG -"* outputs refer to the positive and negative battery charge outputs, where the charge controller will be connected. The microcontroller has a built-in voltage regulator that converts the fluctuating voltage to 3.3V DC.

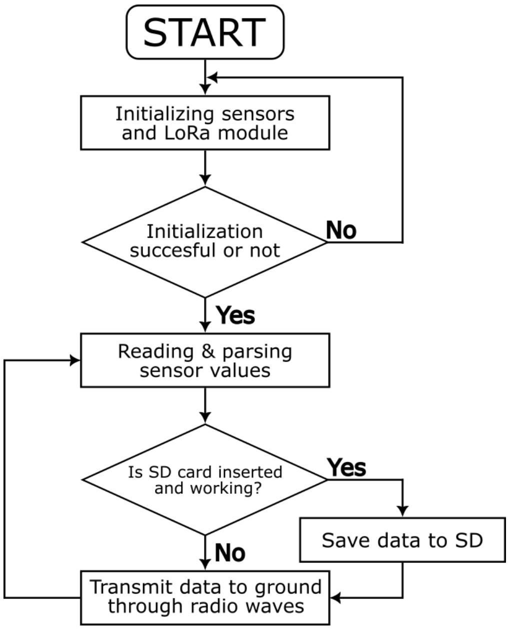




2.4 Software design

The following diagram shows the program flow of the satellite microcontroller.

The microcontroller code is written in C++ using the Arduino IDE development environment. The source code can be viewed on our Github page (https://github.com/onionsat/cansat)



In the initialization stage, CanSat starts the sensors and sets the frequency of the radio communication module, which has to be uploaded to the configuration file on the SD card and/or to the microcontroller code via Arduino IDE.
There is an 8 GB SD card inserted into the CanSat, which could hold an incalculable amount of data. **In about 120 seconds of**

descent, 600 data measurements would be taken (5/second). The data would be transmitted via radio communication (LoRa technology).

2.5 Recovery system

The falling speed of our CanSat will be reduced and maintained by a round-shaped (hemispherical) parachute (Figure 1).

The materials used for the parachute are (i) *rip-stop nylon* (for the canopy part), (ii) the genuine cords of an unused safety parachute, and finally (iii) a special type of hem used when sewing the round edge of the parachute.

The three main cords of the parachute are attached to the CanSat by three uniquely welded and painted eye nuts (M5 Ø mm), made from **stainless steel and copper.** These are screwed onto the three zinc rods that hold the CanSat together.

Based on our calculations with a falling speed of 8.4 m/s, the estimated flight time of our CanSat will be about 2-3 minutes (1.98 min - 2.97 min), depending on the height of the fall.

For easy retrieval after landing, we have built a GPS module into the CanSat and made the satellite and parachute in a striking (yellow) colour.

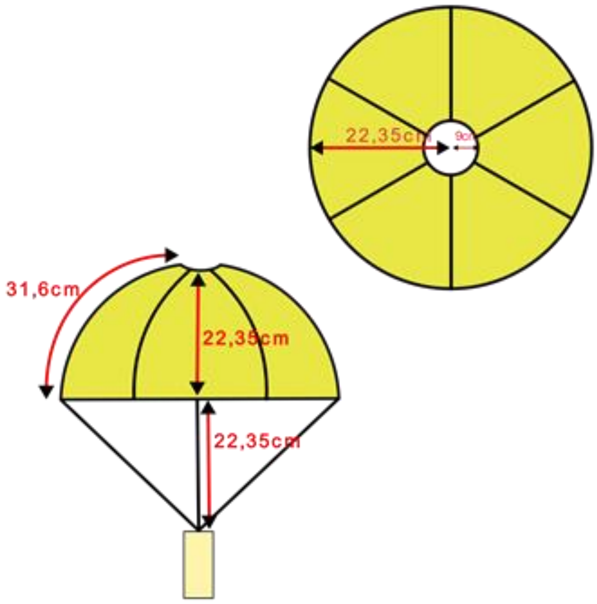


Figure 1. Parachute design

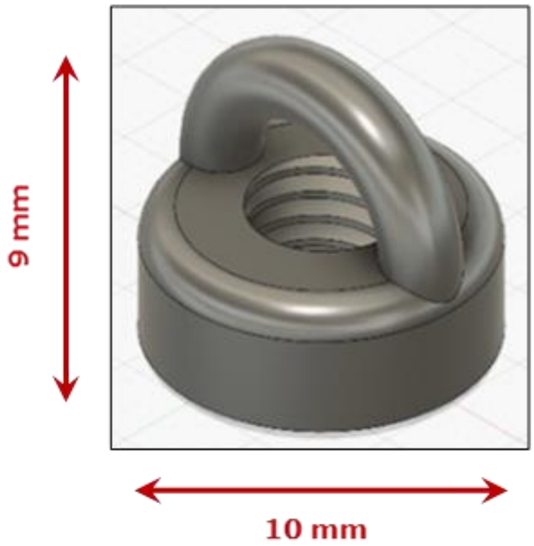


Figure 2. Eye nut design

2.6 Ground support equipment

The **868 MHz** frequency band licensed for ISM purposes is intended to be used in accordance with **European Commission Decisions 2006/771/EC** and

2008/432/EC and **National Media and Communications Authority Decree 7/2015** for satellite-to-ground transmission using LoRa modulation.

We would like to use the **868 200 000 hertz (868.2 MHz) frequency** during the mission if possible.

The ground unit consists of a single computer running a Windows operating system (of which we will have several spares on site in case of failure) and a ground receiver connected to the computer via USB.

Our proprietary software runs on the computer and displays the data in real time in the form of graphs and maps. For an idea of how the software works, please visit: https://onionsat.com/2024/03/14/beszamolo-a-vegso-munkafolyamatokrol

3. Project planning

3.1 Time schedule of the CanSat preparation

For a more detailed schedule please refer to our website or CDR document. (www.onionsat.com)

Time span	**Approximated working hours**	**Description**
October 2023	cca. 25 hours (finished)	Prototyping
November 2023 - December 2023	cca. 150 hours (finished)	Developing/preparing the sensors, radio communication modules
15 November 2023	**Submission deadline of the PDR document**	
January 2024	cca. 100 hours (finished)	Mechanical/electrical design
February 2024	cca. 150 hours (finished)	Constructing landing/recovery system, assembly of the CanSat
17 February 2024	**Submission deadline of the CDR document**	
March 2024	cca. 70 hours	Testing
25 March 2024	**Submission deadline of the PLR document**	

3.2 Budget

The table below shows the budget for one of our CanSat satellites. The greyed out rows show the sponsored items given to us.

Name of asset/object	**Article No**	**Price per piece**	**Quantity**	**Gross price in EUR**
Adafruit ADXL345 Triple-Axis Accelerometer	1231	22.82 €	1 pcs	22.82 €
Adafruit PA1616S Ultimate GPS Breakout	746	41.00 €	1 pcs	41.00 €
Adafruit BME280 Temperature, Humidity, Pressure Sensor	2652	19.21 €	1 pcs	19.21 €
Panasonic NCR18650BL Li-ion Battery 3,7V 3400 mAh	NCR18650BL	13.31 €	1 pcs	13.31 €
Arduino ESP32 WITH HEADERS	ABX00083	25.62 €	1 pcs	25.62 €
Voltcraft VC-13083780	VC13083780	1.47 €	1 pcs	1.47 €
Custom Printed Circuit Board	–	16.67 €	1 pcs	16.66 €
Arduino MICROSD-MODULE	10042087	0.93 €	1 pcs	0.93 €
LoRa modules sponsored by ChipCad Ltd.	–	40.00 €	1 pcs	40.00 €
Hikvision 8GB microSD CL10	10040913	6.34 €	1 pcs	6.34 €
Ripstop nylon	–	7.44 €	0,14 m^2	1.05 €
Hemmer	–	0.64 €	2 m	1.28 €
Zn rod	–	8.04 € (per 1000 mm)	372 mm	2.99 €

Acrylonitrile-butadiene-styrene (3D printing material)	–	21.25 € (per kg)	84.43 g	1.79 €
Washers, nuts	–	–	–	3 €
Sum	–	–	–	197.47 €

3.3 External support

We would like to thank our sponsors for supporting our project:

- **Magyar Telekom Nyrt.**
  - For their outstanding professional and financial support.
- **NN Biztosító Zrt.**
  - For their technical, financial and outreach support.
- Rackforest Zrt.
  - For providing us with the IT environment in their data centre to run our website and the Cloud Station application.
- ChipCAD Kft.
  - For providing us with LoRa radio communication modules.
- PNL-Systems Kft.
  - For providing us with some of our sensors.
- Major Bt.
  - For supporting our project with 20 square metres of Ripstop nylon.
- FreeDee Kft.
  - For their help in printing 3D prototypes.

Special thanks to **Magyar Telekom Nyrt.** and **NN Biztosító Zrt.** for their special assistance.

We would like to thank the following people for providing technical support for our project:

- Dr. Gyula Honyek
  - An ex-professor of Eötvös Loránd University for helping us professionally assemble the electrical circuit of the satellite.
- Zsuzsa Szabó
  - For her help in sewing the parachute.
- Károly Dobos
  - For his help in welding the parachute connection point and other metals.

4. Testing

A video documentation of the CanSat tests has been recorded and can be viewed at the following URL: https://onionsat.com/mediatar/

4.1 Gravitational force test

To comply with the regulations, the CanSat must be able to withstand a force equal to twenty times the Earth's gravitational acceleration (hereafter: 20g).

The most efficient way to test this is to simulate 20g using centrifugal force. The test was carried out in two different ways. In the first test, we spun the CanSat using an electric motor. In the second test, we used a rope to spin the satellite in a slingshot.

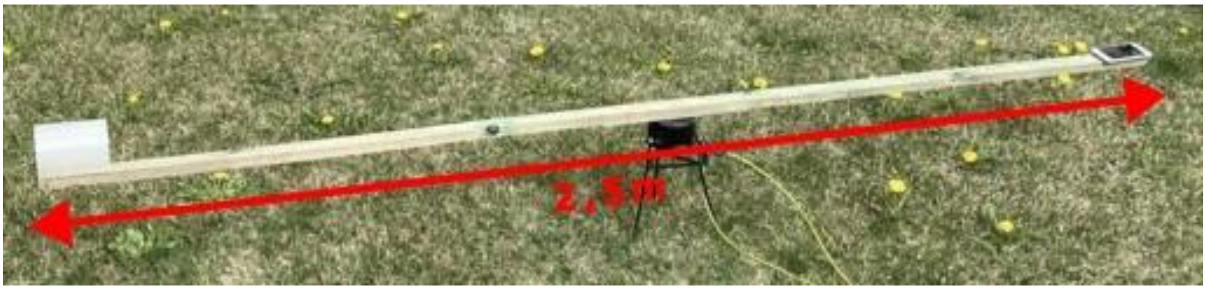
In each case, the required speeds were calculated using the following formula, where "g" refers to the gravitational acceleration of the earth (which is approx. 9.81 m/s²) and "r" refers to the length of the rope/rod **relative to the centre**.

$$n = \frac{\sqrt{20 \cdot g}}{2 \cdot \pi \cdot \sqrt{r}}$$

4.1.1 Test by machine

In order to experimentally validate that the structure of our CanSat design can withstand an acceleration of 20g, a 2.5 metre (**the distance from the centre was 1.25 metres**) long wooden rod was attached to an electric engine.

The electric motor had to rotate the CanSat at ~1.9935 revolutions per second, according to the equation shown in section 4.1.
The engine was fastened to an iron stand that was secured to the ground with its three sharpened legs, and the CanSat was attached to the end of the rod in a 3D-printed case. The final experimental setup is shown in the figure below.



To estimate the period time and to confirm that the CanSat could achieve a centripetal acceleration of 20 g, the CanSat’s motion was recorded with a high-speed camera. Although the 3-axis accelerometer built into our CanSat could measure up to only 16 g, a constant acceleration of 160.59 m/s^2 (16.37 g) was read from the sensor on one axis, **which suggests that the CanSat**

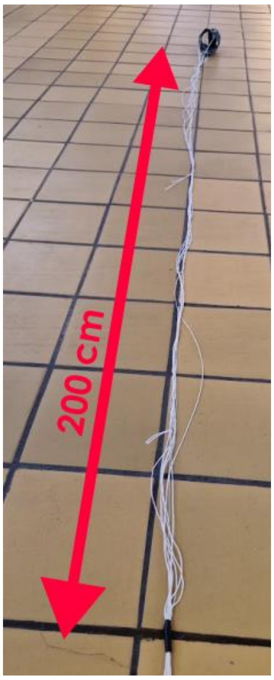
actually exceeded the 16.37 g acceleration on that axis, but the sensor was no longer able to read it.

By examining the video, we concluded that the engine was turning the rod at an **average speed of 2.23 revolutions per second,** which **exceeds** the minimum speed of 1.99 revolutions per second required to simulate a force of 20 g.

The satellite **did not encounter any problems during the test**, saving the data to an SD card and transmitting it via radio communication without any issues.

<u>The test is therefore considered successful.</u>

4.1.2 Manual test



The satellite's acceleration durability was also tested manually, by attaching the satellite to the end of a **rope about 2 metres (+/- 10 cm)** long and rotating it at an average of 1.7 revolutions per second.

It is very difficult to keep the rope exactly 2 metres long when using the slingshot method, so the rope length may have been 190 cm or 210 cm. In the worst case (190 cm), the satellite **would have to be rotated at 1.61 revolutions per second** based on the equation in section 4.1, **which has been exceeded by the average speed of 1.7 revolutions per second calculated from the video analysis.**

You can watch a video of the test in the media library on our website. To access the media library, please refer to section 4.

The 3-axis accelerometer sensor behaved similarly to the machine test described in section 4.1.1, with a constant acceleration of 160.59 m/s^2 (16.37 g) on one axis, **which leads to the conclusion that the real acceleration on that axis exceeded 16.37 g.**

The x|y|z axes of the data read out from the accelerometer sensor during the test (in m/s^2).

```
160.59|-41.03|54.72
160.59|-38.05|34.01
160.59|-55.51|41.31
160.59|-60.49|48.17
160.59|-53.74|63.55
160.59|-43.15|51.39
160.59|-38.36|37.34
160.59|-37.81|48.09
160.59|-51.82|60.88
160.59|-58.41|45.19
160.59|-50.17|50.84
160.59|-25.54|38.80
160.59|-24.24|24.40
```

The CanSat did not have any problems during the test, the data was retrievable from the built-in SD card and the radio communication worked without any errors.

The test is therefore considered successful.

4.2 Parachute connection point test

According to the regulations, the connection points of the parachute must be able to withstand a total load of at least 50 Newtons.

$$F_{rope} = F_{gravity} = m \cdot g = 50\ N$$
$$F_{rope} = F_{gravity} = m \cdot 9.81\ \frac{m}{s^2} = 50\ N$$
$$m \approx 5.1\ kg$$

In the equation above, "g" corresponds to the gravitational acceleration of the earth, "m" refers to the weight of the body which has to be tied to the point of attachment.

According to the above equation, about 5.1 kilograms should be loaded on the connection points. The test was carried out with ~5.5 kilograms (which, converted to newtons, exceeds 50), **which the parachute connection point successfully withstood**.

You can watch a video of the test in the media library on our website. To access the media library, please refer to section 4.

The test is therefore considered successful.

4.3 Parachute/drop test

To make sure that the recovery system is as safe as possible, we wanted to simulate what would happen if the satellite was dropped from the top of a tall building.

The satellite was dropped twice from the roof of a five storey building, about 15 metres high.

During the first test, the satellite landed successfully, matching our calculated speed. The satellite's frame was not damaged at all, except for a small amount of mud that was smeared on the satellite due to the rainy weather.

During the second test, the CanSat's parachute deployed successfully, but a sudden gust of wind blew it into a nearby tree. There was a long period of hurling and other external loads on the CanSat while we were trying to get it off the tree. After an hour, the satellite was successfully removed from the tree and continued to operate without failure. There was no damage to the chassis or the internal electronics.

You can watch a video of the test in the media library on our website. To access the media library, please refer to section 4.

<u>The test is therefore considered successful.</u>

5. Outreach programme

On our website, you can read detailed reports about our workflow, events and general information about our CanSat. From our website, you can access an online interface called the “cloud station”, which shows the CanSat's measurements in real time. Our website is accessible through the following URL: https://onionsat.com

Our primary social media platform is Instagram where we share pictures and short, easy-to-read reports about our work with people who are interested in it. Our Instagram page is accessible through the following URL: https://instagram.com/onionsat

We will continue to keep people updated on our website and on our Instagram page with our reports and documentation of our progress. In the near future, we would like to upload videos to our own YouTube channel to promote space exploration, electronics and programming as a hobby.

Exhibitions and events where our team got or will get represented:

"CanSat viewing" organised by Hungarian Astronautical Society	20 January 2024
"NN Gala" organised by NN Biztosító Zrt. held at the Budapest Congress Center with more than 1000 participants.	12 April 2024[1]
"2024 Physics Conference" organised by Berzsenyi Dániel Secondary School, which is one of the largest events in the school's Faculty of Science and Technology.	17 April 2024 - 20 April 2024

A list of our media appearances:

Article posted on the official website of the Berzsenyi Dániel Gimnázium with the news of our finalist	https://tinyurl.com/cs24berzsenyi
Official facebook page of the CanSat competition	https://tinyurl.com/cs24fb
Publication in the official school magazine of Berzsenyi Dániel Secondary School	will be released in late March

[1] We are aware that in the event of bad weather on the day of the final (5 April), the gala will be held on the same day as the final. In this case, a pre-prepared video will be shown to the participants.

6. Requirements

6.1 Characteristics of the CanSat

Characteristics	**Measurement (unit)**
Height of the CanSat	115 mm
Mass of the CanSat	311 g
Diameter of the CanSat	65.1 mm
Length of external elements	45 mm
Flight time scheduled	119 s
Calculated descent rate	8.4 m/s
Radio frequency used	868.2 MHz, can be changed to any ISM frequency.
Power consumption	452.1 mW (137 mA * 3.3 V)
Total cost	197.47 €

6.2 Power budget

Device	**Voltage (V)**	**Current (mA)**	**Power (mW)**
Arduino Nano ESP32	3.3 V operating voltage (3.7-4.2 V supplied)	60 mA	198 mW
ADXL345 (Accelerometer) sensor	3.3 V	14 mA	46.2 mW
BME280 (Temperature/Humidity /Pressure) sensor	3.3 V	13 mA	42.9 mW
Adafruit Ultimate GPS module	3.3 V	20 mA	66 mW
MicroSD module	3.3 V	17 mA	56.1 mW
WLR089U0 (LoRa) module	3.3 V	13 mA	42.9 mW
Sum	**3.3 V**	**137 mA**	**452.1 mW**

7. Statement

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

Budapest, 25. 03. 2024.
