Critical Design Review

(CDR)

Team: **ÁrpádSat**

School Name & City:

Óbudai Árpád Gimnázium, Budapest

Date: **17th February 2024**

Video link: https://youtu.be/qk9Nb_YrgpE

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1. INTRODUCTION

1.1 Introduction of the team

Our team is called ÁrpádSat. We are all students of Óbudai Árpád Gimnázium's 9.b class. The tasks are done collectively, and we help each other, but there are some main topics that an individual covers.

Team members:

Bognár Gábor: I write, and translate the CDR document, and I plan the parts of the project that involves hardware. Work time: 30h

Debreczeni Huba: I carry out the team's outreach duties, and the 3D renders. I am also responsible for the website and social media channels. Work time: 50h

Jamniczky Márton: I manage the return system, the planning and the production of our CanSat's parachute. Work time: 30h

Mihály Zsolt: I code the CanSat's and the ground station's software.
Work time: 40h

MikIósi-Kovács Dániel: I coordinate our team, help with the assembling of the hardware and lead the overlays in the project. Work time: 60h

Our mentor is Neumayerné Manger Viktória Zsuzsanna, who assists the team in checking the physical formulas that we use.

1.2 Mission objectives

Our team's chosen secondary mission is strongly bonded to the obligatory measurements. Our CanSat functions similarly to a weather balloon, since it will measure meteorological data with the help of a variety of sensors. With the measured information we will hopefully be able to tell the quantity of wind shear and can make a weather forecast. The main instrument is a vane anemometer, which was a challenge to create.

In every homogeneous medium, hence in air, there are layers with different properties, with borderlines. Our team is trying to locate these breakpoints. If the preponderance of data suddenly changes, than we believe that we detected a breakpoint. This is the reason that we are not particularly interested in exact data, but rather sudden changes. It is also important to note that if we do not find any breakpoints, it is still valuable information and we can draw conclusions from it.

We chose this mission, since all of us are interested in the ways of forecasting weather and we can connect to the primary objective as well.

We expect that with this experiment, we will be able to create an accurate short-term weather forecast. Also with the experience, that we acquire will give us a little insight on meteorology.

2. CANSAT DESCRIPTION

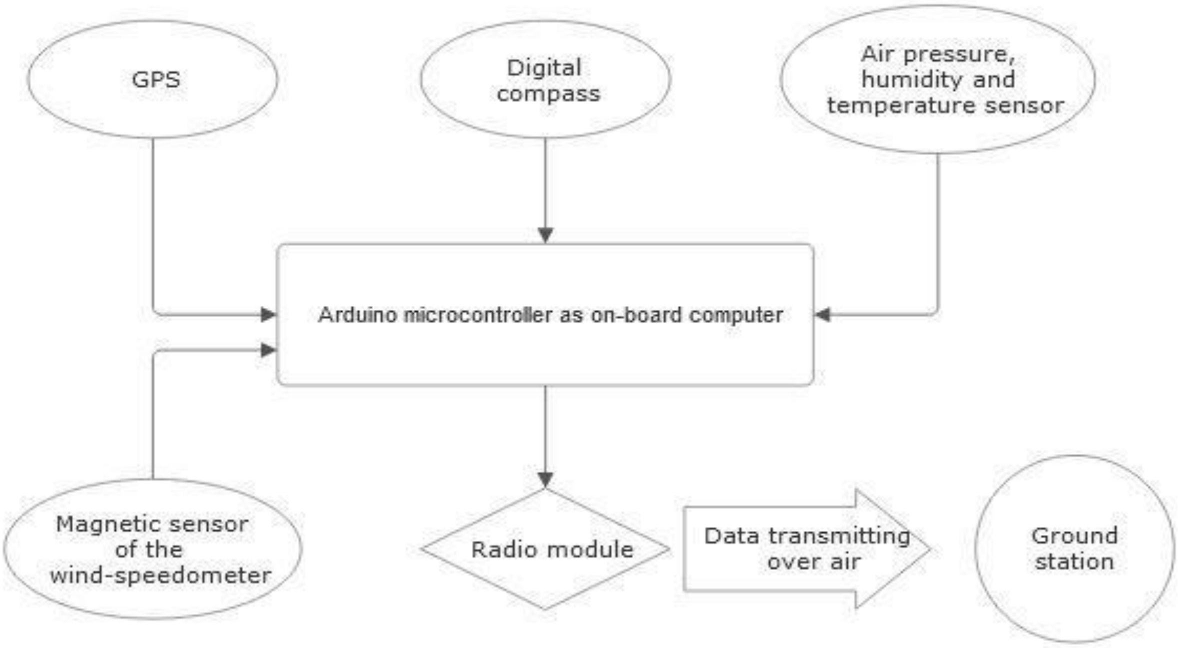
2.1 Overview of the mission

The CanSat created by our team will be launched on a model rocket, to an altitude of about 1 km, where after the ejection from the rocket it will begin it's real mission: a regulated descent with a parachute, meanwhile it measures data related to weather, which is transited through radio to the ground station.

To achieve success it is compulsory that the following components function:

- onboard computer
- radio system
- sensors (anemometer, GPS, compass, humidity-, temperature- and air pressure sensor)

The task of the ground station is to analyse that information and visualise it. From the given data we will be able to create a weather forecast and tell the quantity of wind shear.



1st diagram: Block diagram of our CanSat

2.2 Mechanical/structural design

A majority of components are made of PETG material and are 3D printed. If possible, we printed the component in one piece. But if that was not a possibility, then we printed in multiple pieces and glued them together with superglue. By minimising the number of parts, we also reduced the possibility of errors.

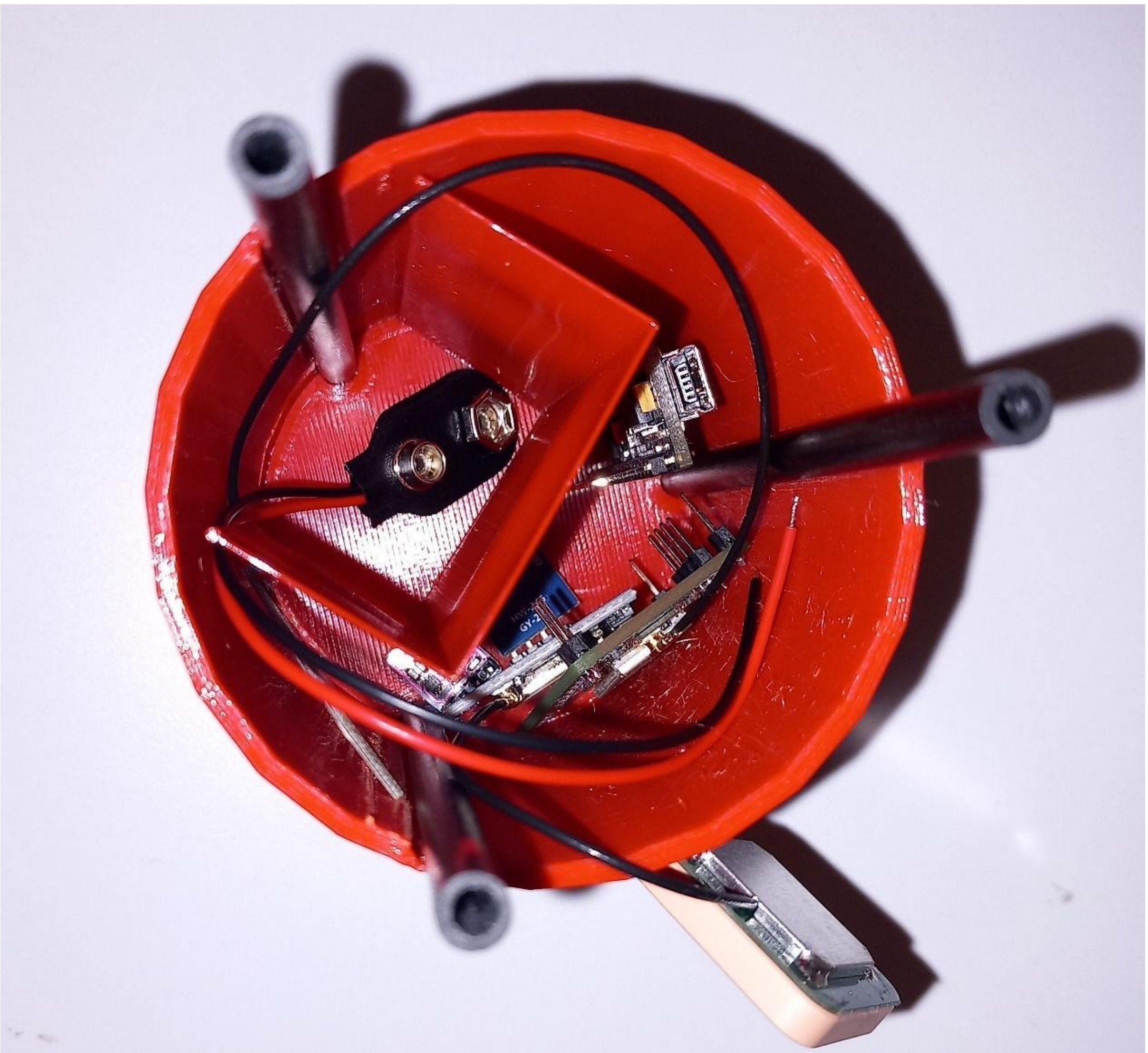
The frame of the CanSat can be structurally divided into two main parts: the lower, cylindrical part, which contains the electronic systems; and the upper part containing the anemometer, which can be removed from the lower part so that we can access the electronics at the bottom. The upper part can be pulled onto the carbon tubes glued to the lower part, it holds it in place, and we also fasten it.

2nd diagram: The CanSat’s 1st structural prototype’s main frame, put together and apart.

The wall of the lower part that stores the electronics is made of 2mm thick plastic, and the bottom is made of 5mm plastic to withstand the forces that occur during take-off and landing. The upper part consists of thinner elements, because it does not have to be impact-resistant, but due to its lightness, it can withstand the forces of a rocket launch.

The part that secures the internal arrangement, which holds the electronics in place, can be removed from the lower frame. This is also 3D printed, but consists of relatively thin elements.

The internal layout of our CanSat isn't quite finished yet, but we have plenty of room to fit items since we don't have a lot of instruments. We plan to place the sensors on the bottom of the CanSat, in an upright position. For this, we plan to use support walls to help with the internal layout, to which we attach the modules with rubber bands and duct tape. We plan to bundle the wiring with duct tape and fasten it to the internal support walls of the CanSat to prevent possible tangling.



3rd diagram: All electronics (except the UART-SPI adapter) without wiring. As visible there is a considerable amount of space unused.

We do not plan to build a complete second spare prototype next to the flying part, but according to our plans, spare parts will be made from the 3D printed elements, so that we can quickly replace the damaged parts in case of possible damage. In addition, there are two batteries so that they can be replaced in case of discharge or malfunction.

2.3 Electrical design

The electronics of our CanSat were assembled from prefabricated, assembled panel modules, we did not design our own printed circuit. The electronic components are:

- Arduino Nano – The CanSat's onboard computer.
- 9V, 1000mAh accumulator – The power source of the onboard computer.
- WLR089U0 LoRa module – The radio used by our CanSat.
- HMC5883L digital compass – We know the direction of the CanSat relative to the north and from it we can deduce the direction of the wind.
- BME280 humidity-, air pressure- and temperature sensor – This instrument measures the mandatory data and humidity.
- GY-NE06MV2 GPS module – Other than simplifying the search after landing, it is also used to measure the wind drift. From that information we can conclude the direction of the wind.
- SS49E linear hall sensor – It is located near the spinning part of the anemometer, and can detect the passing of the magnets, from which we can calculate the strength of the wind.
- UART communication and SPI communication translator

HMC5883L and BME280 have I2c communication with Arduino Nano. Since both the radio and the GPS module would carry out UART communication, and the Arduino only has one such port, we transfer the GPS signal to SPI communication through a converter (which we have not received yet). Thus, the radio can communicate with the onboard computer via UART. The anemometer's hall sensor provides an analog value to the Arduino.

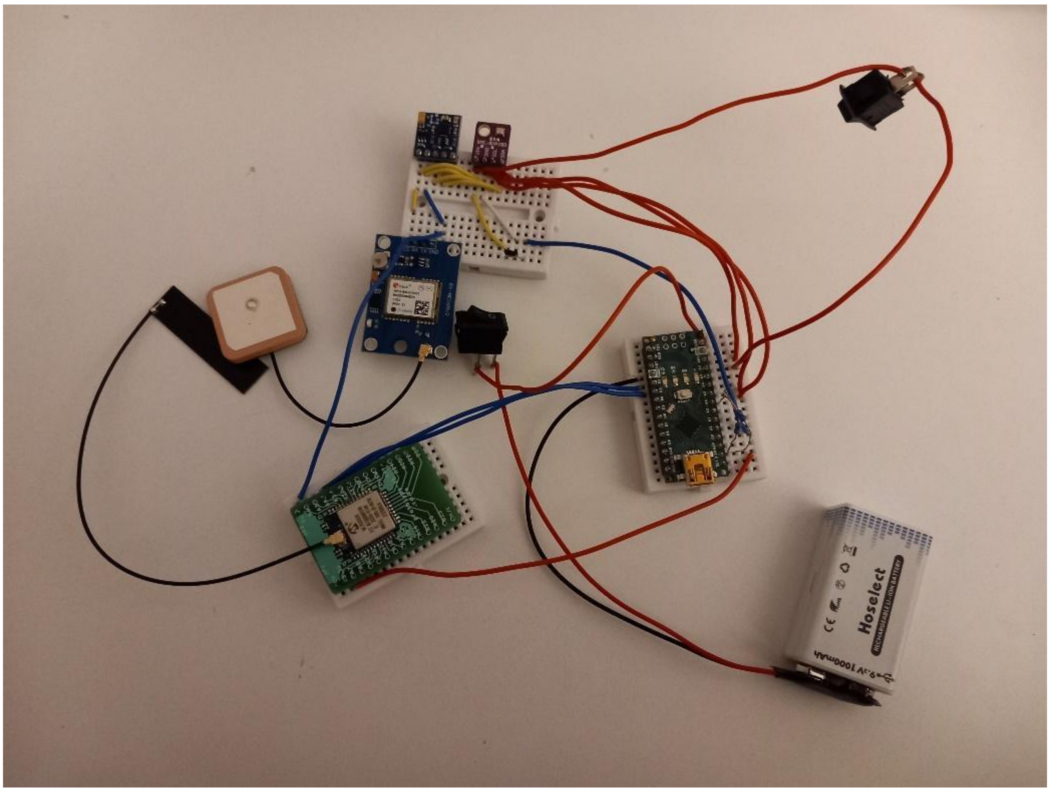
Since LoRa modules are used for communication between CanSat and the ground station, the signals are transmitted using lora modulation. The operating parameters of the radio were determined on the basis of the proposal given during the radio training. We plan to transmit and receive data on a spreading factor of 7, 250 kHz bandwidth, and one of the following frequencies: 867.1 MHz, 867.3 MHz, 867.5 MHz, 867.7 MHz, 867.9 MHz We can set the sync byte of the LoRa radio to anything between 1 and 99. We can modify the data mentioned above by software, via updating our CanSat's software.

We designed the radio communication to be one-way, only the CanSat can send data to the ground station and not the other way around. We plan to transfer data every second.

The accumulator provides power for the on-board computer. The other sensors get 3.3 or 5 volts from the corresponding pin of the arduino depending on the voltage used. The consumption data of the devices placed on CanSat available on the Internet are as follows:

- Arduino Nano: 19 mA
- Humidity-, temperature- and air pressure sensor: 0,0036 mA
- GPS module: 10 mA
- Compass: 0.1 mA
- LoRa radio module: 100 mA
- Hall-effect sensor used for the anemometer: 8 mA

We calculate an extra 20% individually and to the summary and with that, we get 197mA. Since our CanSat needs to be operational for 4-5 hours, we decided on a 1000mAh battery. The accumulator we use is a 9V, 1000mAh, USB-chargeable 6F22 Li-ion accumulator.



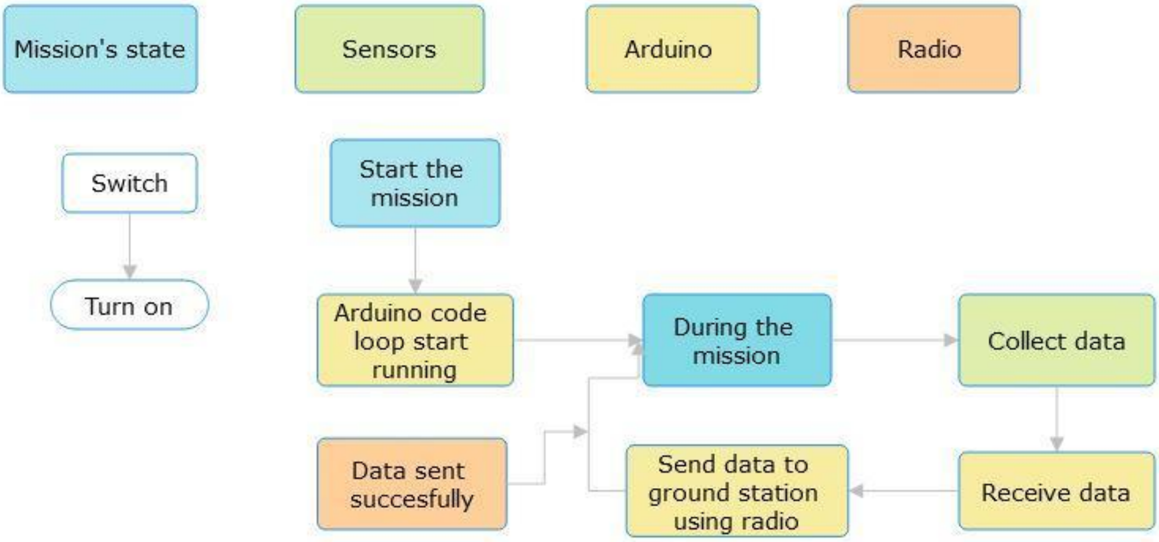
4th diagram: Our CanSat’s electrical system, with the exception of the UART-SPI adapter (and potentially our camera).

If we still have time after assembling all the parts of the CanSat until the final, we plan to install a second Arduino Nano, which would be operated from another accumulator with the same type as the current one. The task of the second Arduino would be to control an OV7670-M camera and save its images to an sd card. The calculations in this document were made without this optional system.

2.4 Software design

CanSat's on-board software was written in the Arduino IDE, the Arduino development environment, in C++ language, using Arduino's built-in functions. The software collects the data from the sensors one by one, and then compresses the measured data into a data packet and sends it over the radio. We do not plan to store the measured data on board - contrary to preliminary plans - due to the lack of storage capacity. The software has one mode -the flight mode- when it operates all sensors and sends data over the radio once per second.

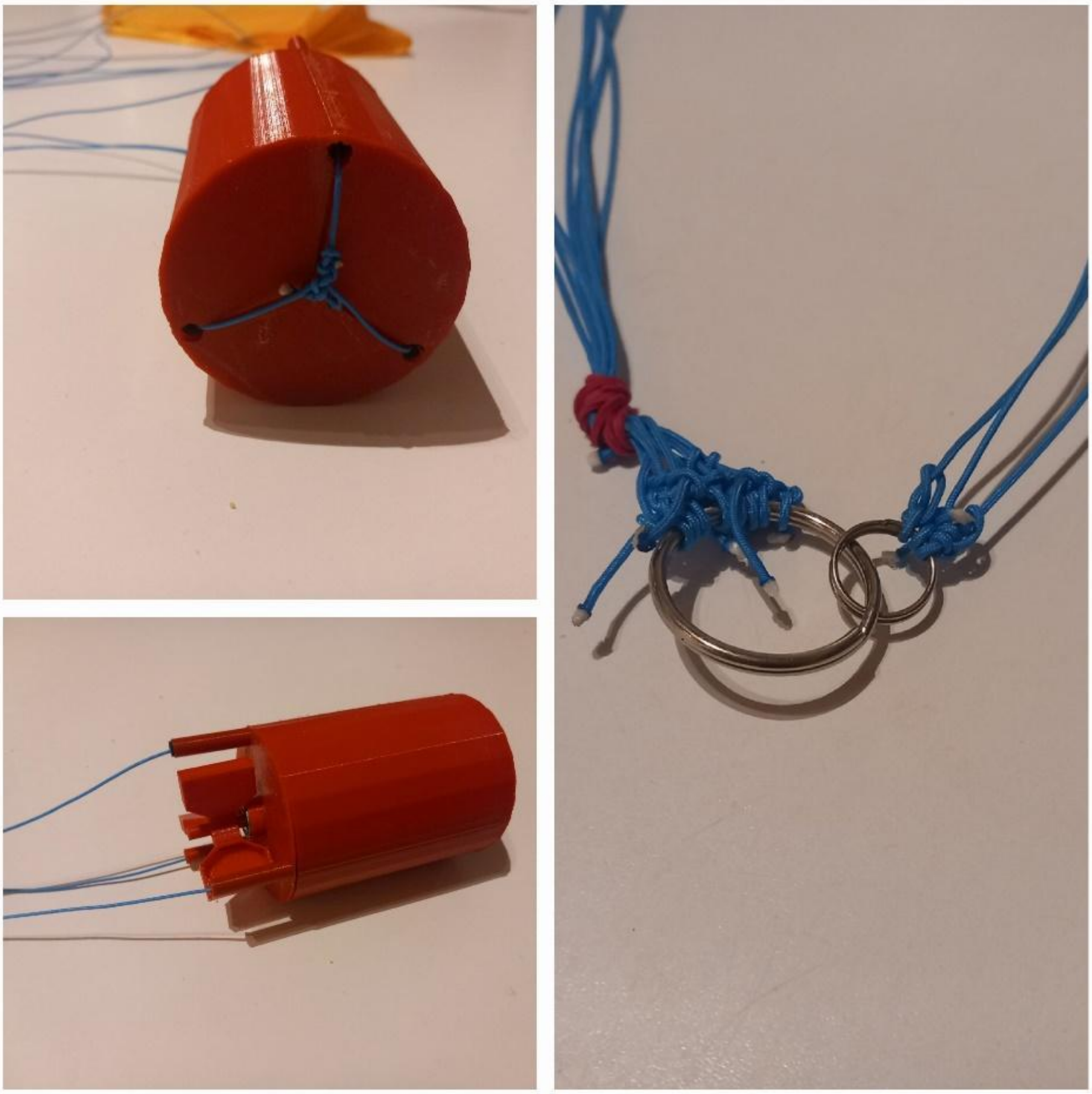
By our estimates, we collect 0,1296 mb of data every hour, so during the 4 hours, we plan on collecting a total of 0,5184 mb of data.



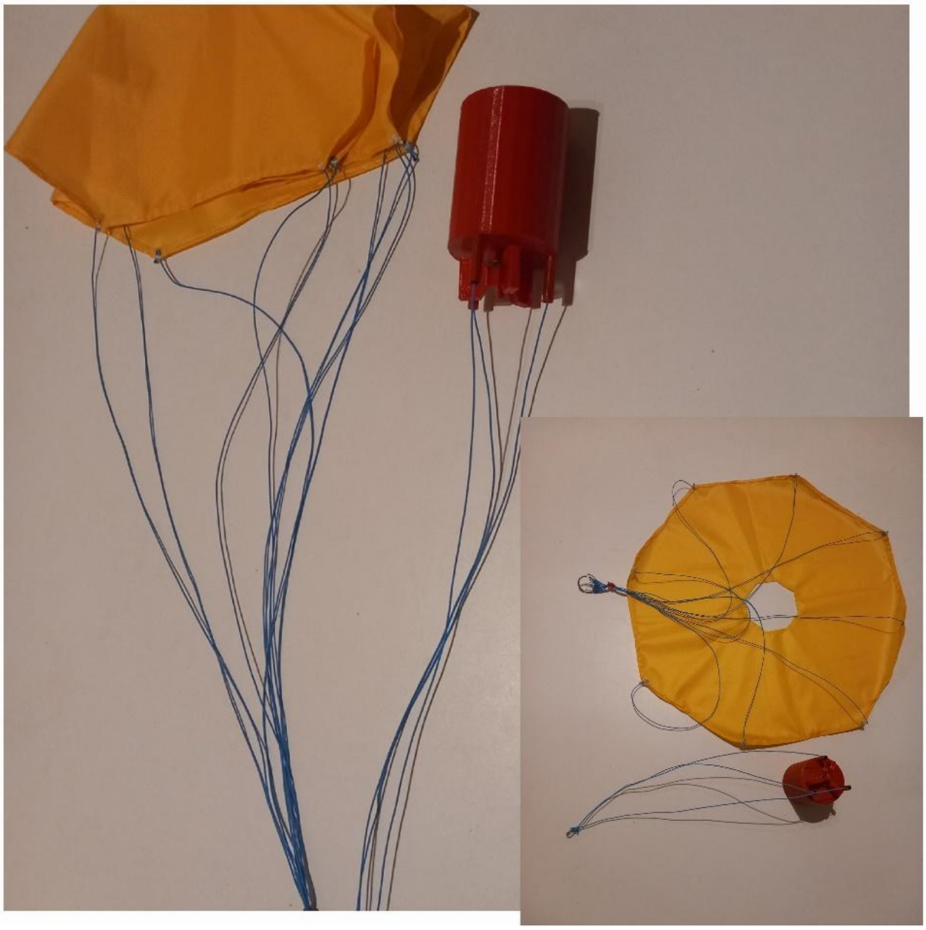
5th diagram: Our CanSat's software's flow diagram

2.5 Recovery system

The safe return of the CanSat is ensured by an octagonal parachute with a hole in the middle. The umbrella is made of a durable material, which is not going to tear apart. A rope is attached to each of the eight corners of the umbrella, which are led into a key ring. In addition to strengthening the structure, the 3 carbon tubes running through the frame of the CanSat also serve the purpose of running a rope through them, which are tied into a strong knot at the bottom of the CanSat and fixed with superglue. At the upper end of the tubes, the 3 ropes run together in a key ring. By assembling or disassembling the two key rings, the parachute can be quickly removed or added to the CanSat.



6th diagram: The parachute's attachments. The final frame will have grooves on the bottom where the ropes and the knot will be located, so that they will not exceed the size limitations.



7th diagram: Our CanSat's parachute

We performed drop tests with mass simulation. The further planned tests are mentioned in 3.2.3.

2.6 Ground station

When planning the ground station we were aiming for simplicity, the hardware is the following:

- radio receiving unit: A LoRa module, which connects to a computer and receives the data sent by the flying unit
- laptop
- accumulator (for the laptop)

The task of the ground station is to receive the data package, appraise it, process it and save it. The data is saved into a file, which can be downloaded later for more detailed elaboration. The software also draws a real time graph with a fixed size, and can compress the content according to the data. The more detailed elaboration and analysis will take place later and will take place later after the landing. For the sake of understanding the presentation will contain graphical segments (ex.: diagrams, charts). The ground software was written in C++, with the help of the SDL2 graphical module.

The operating parameters of the radio were determined on the basis of the proposal given during the radio training. We plan to transmit and receive data on a spreading factor of 7, bandwidth of 250 kHz, and one of the following frequencies: 867.1 MHz, 867.3 MHz, 867.5 MHz, 867.7 MHz, 867.9 MHz We can set the sync byte of the LoRa radio to anything between 1 and 99. We can modify the data mentioned above via software, by updating CanSat's software. With the radio, we plan to send data once per second.

3. PROJECT PLANNING

3.1 Time schedule of CanSat preparation

Our plan was the following:

2023.11.25.	Complete planning.
2023.11.25-30.	Purchase the necessary parts, and materials.
2023.12.01-20.	Assembling the first prototype and testing basic systems.
2024.01.07-20.	First round of assembling of the hardware required for flight.
2024.01.20-02.01.	Test of flight hardware and parachute.
2024.02.01-07.	Final installation of flight hardware.
2024.02.07-17.	Final testing and assembling. Test mission with drop test. Also, the CDR deadline.

Since we had not dealt with similar projects before, we started the work without experience.

The planning took more time than expected, so the following task was delayed too. We also had complications with the flight hardware assembling. We balanced these out by working more than planned.

We decided not to place a camera on board, contrary to the preliminary plans. The main reason for this decision is that the on-board computer does not have more SPI communication pins, so it would have been very complicated to solve everything else to be able to connect to the on-board computer. We are currently testing the radio, which is currently the only part of the electronics that is not fully functional. We have already contacted the manufacturer of the radio about the issue. If we cannot solve the problem we will search for another model, which has more documentation online.

After submitting this document, the main priority of our work will be to find why the radio is malfunctioning. As soon as we have found it, we finalise the electronics in the frame, then the testing of the CanSat follows, which we write about in point 3.2.3. We plan to adjust the further work to the following dates:

February 19-25:	Radio fixing and testing.
February 26-March 3:	Installation of electronics to the frame of the CanSat.
March 4-10:	School holiday. We plan to perform complex field tests on all systems.
March 9:	3rd in-person CanSat meeting.
March 11-17:	Correcting any potential errors, performing the remaining testing.
March 18-22:	Final touches, the CanSat is ready for flight.
March 27:	Presenting about the competition at our school.
April 5-6:	CanSat finals

Total time:

Researching and purchasing the required parts and materials:	5-7 days
Building the first prototype and testing major pieces:	4-5 days
Assembling of flying hardware and testing it:	3-4 full days
Parachute planning, sewing and drop testing with ballast weight:	2-4 days
Field testing:	1 day
Test mission and drop test:	1 day

3.2 Resource estimation

3.2.1 Budget

The prices of the instruments that we use are the following:

- Arduino nano: 25€
- Filament for 3D printing: 25€
- Bearing: 3€
- Carbon pipe: 4€
- LoRa module: 100 €
- BME280 sensor: 4€
- GPS sensor: 8€
- Compass: 5€
- Wires: 4€
- Hall-effect sensor: 1.5€
- Battery: 19€
- UART-SPI adapter: 33€
- Parachute: 12€
- Other electrical items: 3€

Total: 246,5€

3.2.2 External support

We received help from various partners, either financially or in terms of knowledge. Huge thanks to the following:

- First of all Óbudai Árpád Gimnázium provides us with the necessary workspace, with 2 computers and a 3D printer.
- Kovács Attila provided us huge help by giving us a piece of his expertise, with which we were able to start the electronic part of the project. We also received resistors from him, and he also made the UART - SPI adapter card for us.
- Miklósi Tibor planned our logo.
- Our parents supported us, and aided us in whatever they could.
- Our physics teacher -also our mentor- aids us in formulas and calculations.

Unfortunately we do not have enough experience with 3D printing and that led to some complications.
We also had trouble with time management, due to underestimating the process planning and assembling.

3.2.3 Test plan

In order to validate the operation of our CanSat, it is essential to test all electronic and mechanical components in detail. Therefore, we plan to carry out the following tests:

- Radio test: This includes testing the effective range and the expected quantity of data loss. With these pieces of information, we could make necessary changes and reduce data loss.
- Accumulator test: It is vital to test the longevity of the accumulator, so we plan to measure how long the CanSat will take to drain with a stopwatch while leaving the system fully operational.
- Sensor test: We have to test the operation of each sensor and the correctness of the data it provides, which we plan on doing so, by creating artificial conditions which are measured by other similar instruments and comparing the data that both of them provide. If necessary, we will calibrate the sensor.
- Parachute test: We need to test the parachute, its fixing strength and its descent velocity. To test it we will install it on the CanSat with 5kgs of ballast

weight and then, we will put the parachute on a ball. We plan to determine the speed of the descent from the height data measured every second during the drop test. We also did drop tests with an object similar in shape and approximately the same in weight, where we dropped it from high elevations and tested the parachute's durability and effectiveness.

- Compliance with requirements test: Our CanSat must meet the requirements set by the organizers, especially the size and weight limits. We plan to measure CanSat in detail as soon as the final system is finished.

If we receive incorrect data in any of the tests mentioned above, we correct the error and perform the test again.

4. OUTREACH PROGRAMME

We consider it very important to promote the competition and our own work and make them known to others, which is why we try to communicate as actively as possible with interested individuals. For this reason, and so that the organisers can also know about our work, we did the following:

- We created a website, which we are updating and expanding constantly. The website's link is the following: https://arpadsat.netlify.com
- We created a YouTube channel, where we upload videos regarding our team's work. The channel's link is the following: www.youtube.com/@ArpadSat
- We have contacted the management of our school, and we will hold two lectures on March 27 for interested students: one will be about the competition and its promotion, and the other will be about the work we do and its difficulties.

Furthermore, these outreach activities are in plan:

- We would like to create another social media page (most probably Facebook), where we would inform people about the finals and the days before that.
- We are planning to contact various media that are interested in space research or similar topics so that we can publish an article about the competition with them. (e.g. spacejunkie.hu)
- We would be keen on writing an article for the school magazine.

Our team also has a logo. There are also plans of purchasing team T-shirts.

7th diagram: Our team's logo

5. REQUIREMENTS

Characteristics	**Quantity (unit)**	**Requirement**	**Eligible (Yes or No)**
Height of the CanSat	115 mm	max 115 mm	Yes
Mass of the CanSat	200-220 g (we can increase in many ways)	300-350 g	Yes
Diameter of the CanSat	66 mm	max 66 mm	Yes
Length of the recovery system	40 mm	max 45 mm	Yes
Flight time scheduled	140-150 s	Proposal: 120 s	Yes
Calculated descent rate	7-8 m/s	5-12 m/s	Yes
Radio frequency used	867.1 MHz (alterable)	Legal and alterable	Yes
Power consumption	137,1036 mAh	Under 200 mAh	Yes

Characteristics	Quantity (unit)	Requirement	Eligible (Yes or No)
Total cost	246,5 €	Max. 500 €	Yes

5.1 Preliminary energy budget

Device	Voltage(V)	Current (mA)	Power (mW)
Arduino Nano	5	19	95
LoRa WLR089U0 Radio module	3.3	100	330
BME280 Humidity-temperature and air pressure sensor	5	0.0036	0,018
HMC5883L Digital compass	5	0.1	0,5
SS49E Linear Hall-sensor	5	8	40
GY-NE06MV2 GPS module	5	10	50
Total power (sum of all)		**137,1036**	**515.518**

The accumulator used for our CanSat is 1000mAh, so we can operate our CanSat for about 6-7 hours, which is more than enough.

Declaration:

On behalf of the team, I confirm that our CanSat meets all the requirements set out in the official guidelines for the 2024 Hungarian CanSat competition.

Signature, place and date:

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Neumayerné Manger Viktória Zsuzsanna, Óbudai Árpád Gimnázium, 16th February 2024