Kaboom CanSat team

CRITICAL DESIGN REVIEW

KABOOM CANSAT TEAM

School:	City:
Budaörsi Illyés Gyula Gimnázium, Technikum és Szakképző Iskola	Budaörs

Video: https://www.youtube.com/watch?v=kH1uJ8Y-470

February 16, 2026

Contents

1 Introduction

1.1 Introduction of the team

The team is comprised of the students in the elective physics course in the Illyés Gyula Gimnázium in Budaörs. The mentor of our team is **Miklós Keresztes**, our physics teacher. The members of the team are as follows:

Péter Balczó The designer of the CanSat's recovery system.

- Time spent: 7 hours

Péter Balla Responsible for the design of the control circuit board and electrical assembly. Designed and built the ground station's antenna.

- Time spent: 30 hours

Boldizsár Fazekas Social media manager, responsible for publishing documentation.

- Time spent: 20 hours

Márton Kürthy Team lead, designer of the prototype of the secondary mission. Author of the PDR and CDR documents.

- Time spent: 40 hours

Márton Monostori The 3D and graphics designer of the team. Created our logo and the physical design of the CanSat.

- Time spent: 20 hours

Áron Regőczi Responsible for software programming, LoRa radio communications, data analysis.

- Time spent: 40 hours

1.2 Misson objectives

The Kaboom CanSat team's secondary mission is to measure the difference of radioactive radiation, specifically β and γ rays, compared to ground level and the $1km$ height that our CanSat will reach when launched using the rocket. The current scientific understanding is that as you get farther from the ground the radioactivity increases due to the decrease in atmospheric shielding. This is the main change that we are attempting to detect.

Sensing radiation at this size is a technical challenge itself, as Geiger Counters - the devices usually used for such measurements - are not really available with such small dimensions or they are not directly compatible with off-the-shelf microcontrollers. This is why we constructed our own, semi-homemade device from scratch using circuitry from a "fly swatter" and some soviet technology.

2 CanSat description

2.1 Mission overview

The satellite constructed by the team will be launched by a model rocket, that will carry it to the height of approximately $1km$. Here the CanSat will be ejected, and using its parachute it will descend back to Earth at the approximate speed of $8m/s$. During its travel, it will make measurements using the sensors on-board: a combined temperature and pressure sensor, GPS for positioning and accurate timekeeping, and a semi-homemeade Geiger counter to measure radiation to satisfy the secondary mission. The onboard microcontroller will record the data acquired from the sensors and store them onboard while also sending data to the ground once every second. The device will remain active until turned off, or approximately 18 hours.

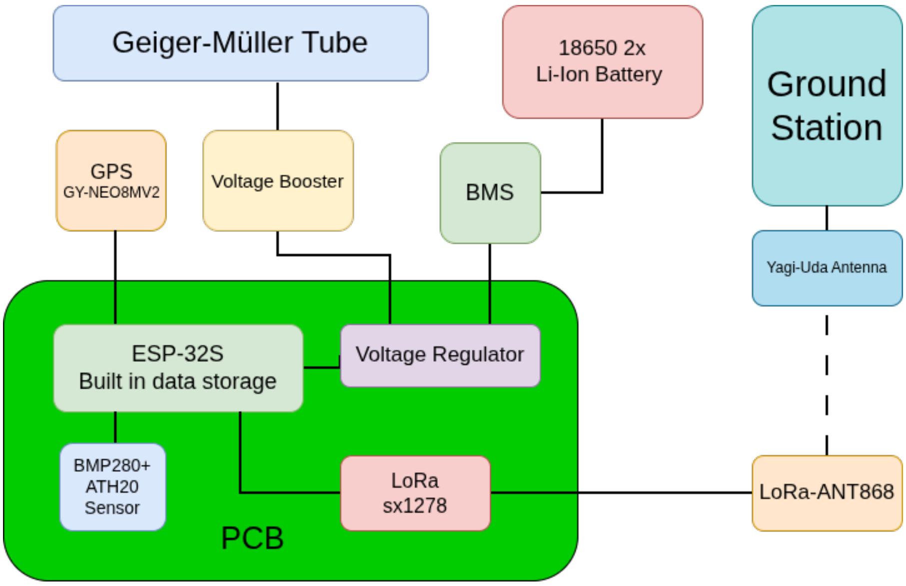


Figure 1: Block diagram of the Kaboom CanSat

2.2 Mechanical/structural design

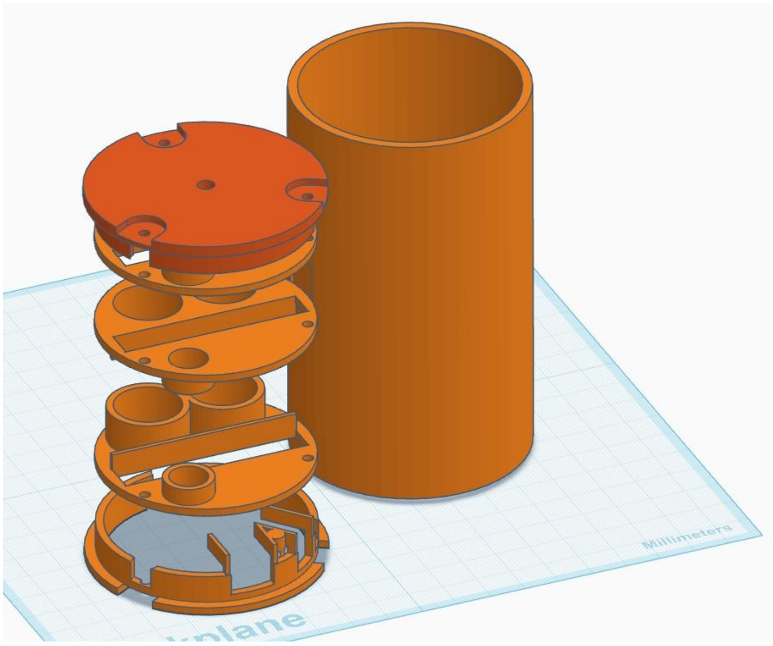
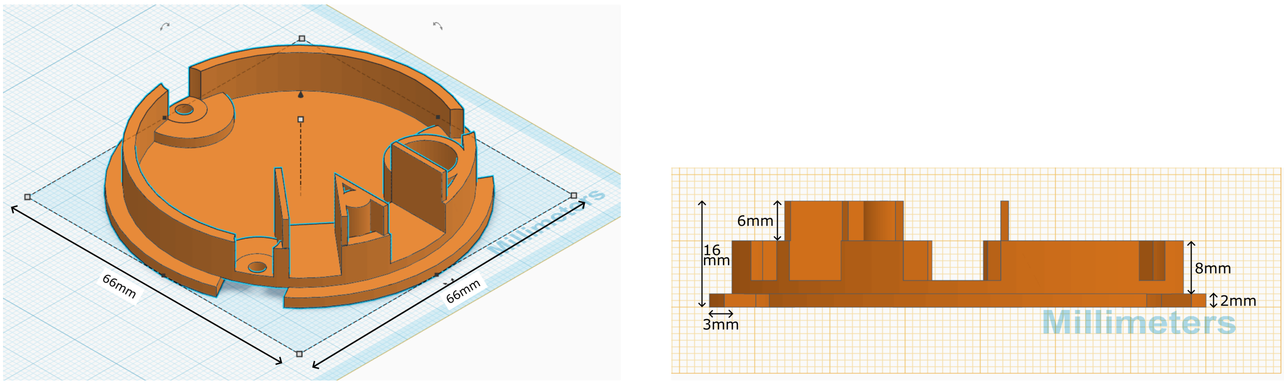


Figure 2: The structural design of the Kaboom CanSat

Our satellite's structure is made up from 3D printed disks, held together using plastic spacers. The printed parts were designed by us from the ground up adhering to the strict regulations of the competition, and printed using ABS filament.

The disks are covered by an outer shell, which is held on by the bottom and top plates being screwed together with the spacers.

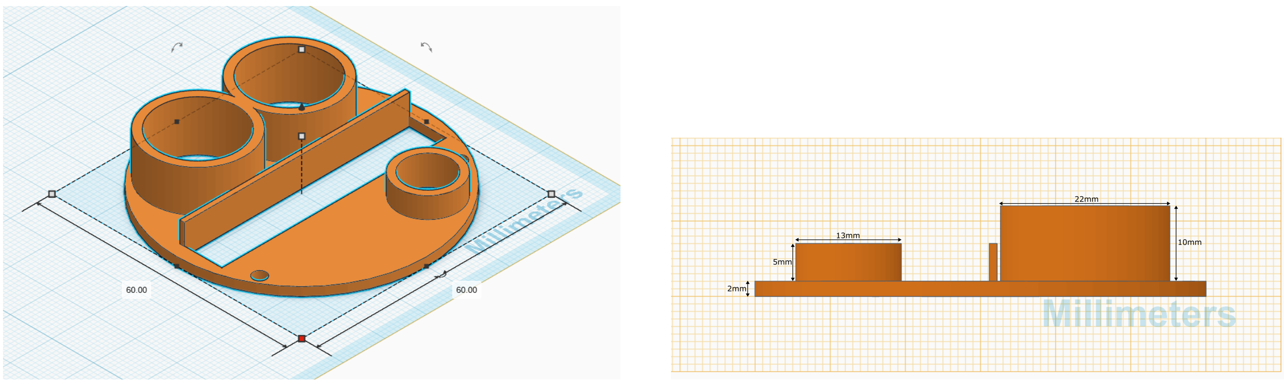
The bottom disk will house the main On-Off switch - which can cut the power of the whole device - and a power socket to charge the batteries, as after assembly they are not easily removable.



(a) Isometric view (b) Side view

Figure 3: Analysis of the bottom plate components

The two 18650 type batteries will be housed vertically and held by the two intermediate disks. These will also hold the Geiger-Müller tube and the PCB with all the control and supporting circuitry. Wedged between the two cells sits the BMS board ensuring the safety required when working with LiIon batteries.

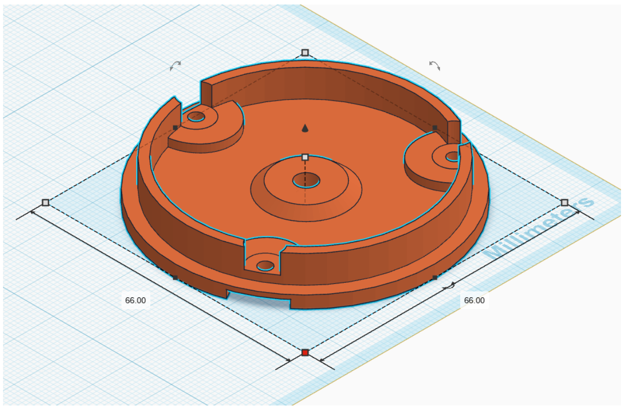


(a) Isometric view (b) Side view

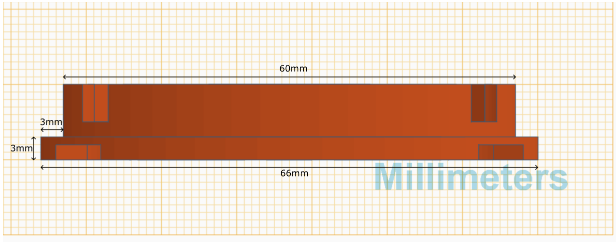
Figure 4: Analysis of 2 intermediate plate components

The top disk will hold the GPS module and its antenna, while also stabilising the Geiger-Müller tube, which almost spans the whole height of the CanSat, at $108mm$.

The disks have a $2mm$ base thickness, while the top lid is $3mm$ with extra supporting structures around the screws and parachute connection in order to be able to withstand the forces when the recovery system opens.



(a) Isometric view

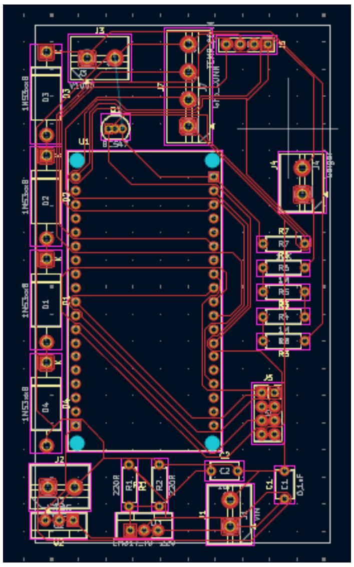


(b) Side view

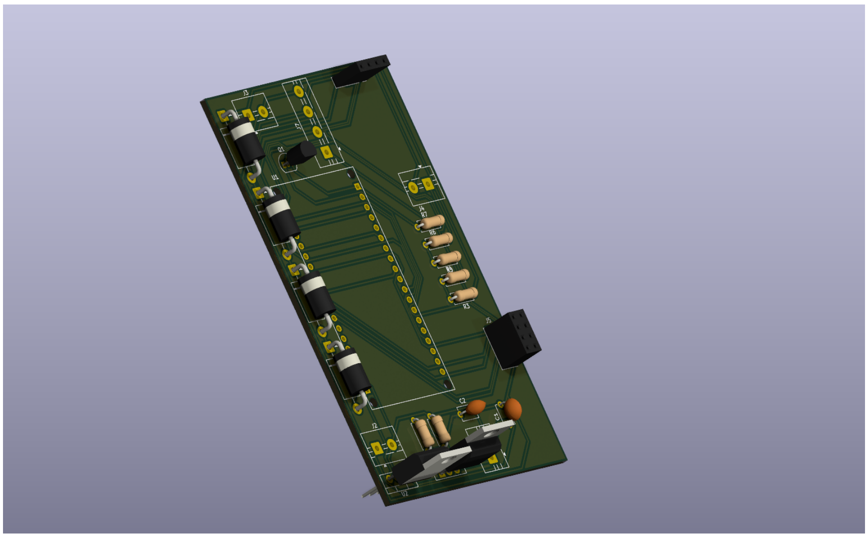
Figure 5: Analysis of the lid

All components will be held in place using industrial strength glue and/or screws depending on what mounting options are available for specific modules. The Geiger-Müller tube, due to its sensitivity to harsh physical shocks will be secured using silicone adhesive not only to prevent it from moving, but also absorb the vibrations expected during operation.

2.3 Electrical design



(a) Routing of PCB



(b) 3D representation of PCB

Figure 6: Analysis of circuit board

Vertically inside the CanSat sits a long PCB which houses the main electrical components. This serves as a breakout board for the microcontroller and place for supporting electrical componentry. Certain modules are placed in different spots inside the satellite due to their dimensions. Due to manufacturing difficulties the PCB was not able to be constructed in before the CDR's deadline, so currently all of the components are soldered onto a "prototype board" the same size that the circuit board will be.

Due to the size of the circuit, its functions will be explained broken into parts. The first is the power section, which contains two voltage regulators for creating the required voltages for the other components from the $7,4V$ from the batteries. An $\mathrm{L7805}$ linear, non-adjustable regulator provides the $5\mathrm{V}$ for the ESP microcontroller, and a $\mathrm{LM317T}$ adjustable linear regulator with a 240Ω voltage divider creates a stable $2,5\mathrm{V}$ for the booster circuit to function properly. Two filtering capacitors are also added to reduce any unwanted electrical noise.

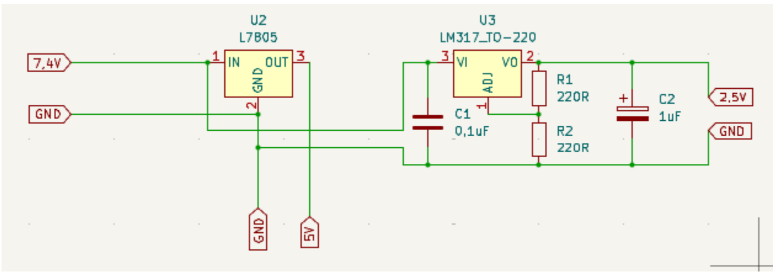


Figure 7: Power distribution system of the CanSat

As a power source 2 18650 batteries with the capacity of 2000mAh will be used. To ensure the high safety standards needed when working with LiIon batteries they are connected via a BMS system that prevents shorts, overcharging and over-discharging the cells.

The main component of the satellite is the $\mathrm{NodeMCUESP-32S}$ type microcontroller, which handles all data processing storage, and communication with the ground station. The $\mathrm{BMP280+AHT20}$ combined temperature, barometric pressure and humidity sensor is connected via the I2C protocol, the $GY-NEO8MV2$ GPS for accurate positioning and timekeeping is also hooked up via UART, as well as the $\mathrm{SX1278}$ LoRa module through SPI for communicating with the ground station.

2.4 The inner workings of the Geiger-Müller counter

To fulfil the secondary mission's objective we needed to construct a Geiger-Müller counter circuit. These devices usually consist of a special tube made of metal with a thin wire running inside. The said cylinder is filled with low pressure inert gases, and then a high voltage, typically around $400-600V$ is connected across the body and the thin wire. When a radioactive particle hits the gases inside electrons get "knocked loose" and are pulled towards the wire. This creates an electrical pulse inside the tube which can be detected using a speaker, or in our case by electronics.

The most difficult part of constructing a particle counter is supplying the high enough voltage. Fortunately the current consumption is negligible, and for this reason a very simple switching circuit can be used, called a **Joule thief**. Such circuits require a transformer, which can be near impossible to construct at home at this size, so for this reason we borrowed the whole booster circuit from an "electric fly swatter", which we then shrunk by removing unnecessary components in order to fit into the confined space of our CanSat. The following circuit[1] is similar to the one we purchased, but some component values my vary.

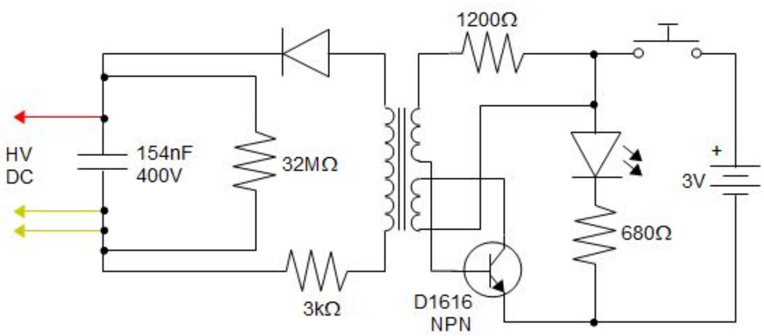
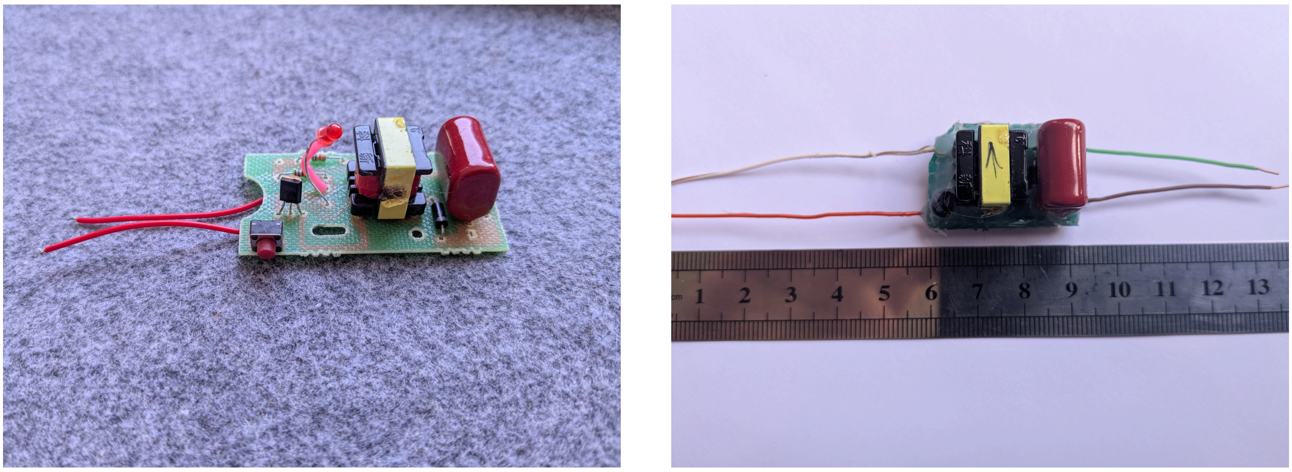


Figure 8: Unmodified swatter circuit

To compact this design even further we removed the unnecessary indicator LED and also the push button switch. The remaining circuit was then soldered onto a prototyping board and encased in electrically isolating glue to prevent any dangers that may arise from dealing with high voltages. The final circuit produces $1400V$ at its nominal $3V$ input, so we run it at $2,5V$ where it still works reliably but produces only around $600V$.

[1]Diagram courtesy of rimstar.org



(a) Original booster circuit from swatter

(b) Reduced circuit

Figure 9: Analysis of shrunken booster circuit

The Geiger-Müller tube used is the trusted and well known $\mathrm{SBM20}$ from the Soviet Union, acquired online used. It requires $5M\Omega$ series resistor to operate (which we replaced with 5 $1M\Omega$ due to easier procurement) and a $400V$ operating voltage. To regulate the boosters output we simply use 4 $\mathrm{1N5378B}$ 100V Zener diodes connected across its output. Although this is not the most efficient solution it sill produces negligible heat, while also being easy to implement.

The clicks from the tube are sensed by a $\mathrm{BC547}$ NPN transistor with a $10K\Omega$ resistor in the following circuit. The transistor is connected up to the ESP microcontroller's input pin, and in case of a detected particle it pulls the pin low. This is sensed by the ESP's code using an interrupt to reliably detect a short pulse.

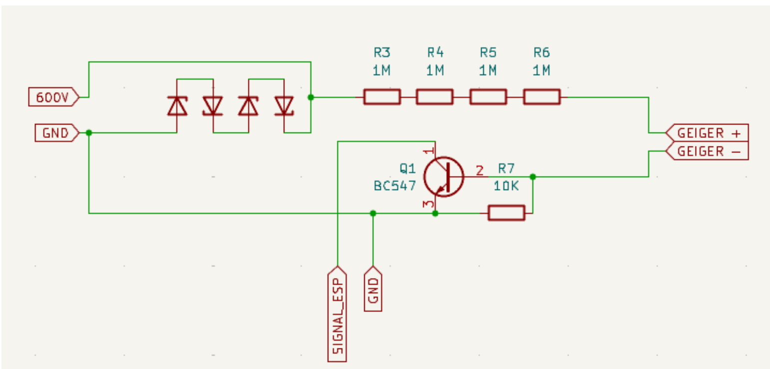


Figure 10: Supporting circuitry for the Geiger counter

2.5 Software design

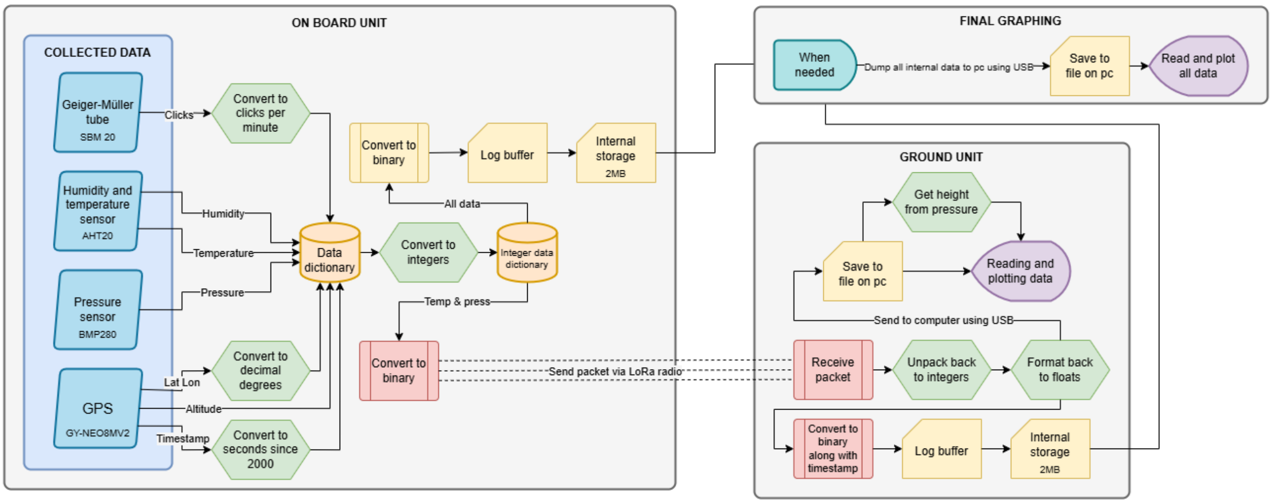


Figure 11: Logic diagram of the Kaboom CanSat's code

2.5.1 On-board software design:

Upon initiation the microcontroller on the CanSat starts running the main transmitter script. First the code imports all the required libraries and drivers, then sets up and configures all the components. The main transmitting loop gets all the sensor data (temperature, pressure, humidity, latitude, longitude, altitude, radiation levels) every second, then performs multiple operations on them to first convert them into integers, then into binary. Both the latitude and longitude have to be modified into decimal degrees since they are originally in a degree, minute and hemisphere format. Time is received in six different numbers indicating date and the time of day and must be calculated into a Unix timestamp. For the binary packing and unpacking we use the $struct$ library. Afterward the converted data is saved into a local file and the temperature and pressure are sent out using LoRa radio.

2.5.2 Modes

Our CanSat has four primary modes of operation. The first, the pre-launch or ground mode which is simply used to warm up all the functions of the CanSat, like the radio, GPS and other sensors. In this phase we do not transmit data, but we do save it locally.

The second is the ascend mode. Here most of the functions of the CanSat are turned on.

All the sensors are being read, the radios are transmitting and all the data is being saved both on ground and in air. This phase is turned on when the microcontroller notices that the average vertical speed of the CanSat exceeds 8 m/s of ascending (this number may be fine-tuned in the future).

The third is the descend mode. Here the cansat is still using all of its capabilities, to read, transmit and save all of the data. This phase is triggered when the last mode was the ascend mode and the average vertical speed of the last 10 seconds has been negative.

The fourth is the beacon mode. Here the cansat is still reading and recording all the data, but now instead of transmitting temperature and pressure, it begins to send its current position in order to let us know its location every 10 seconds.

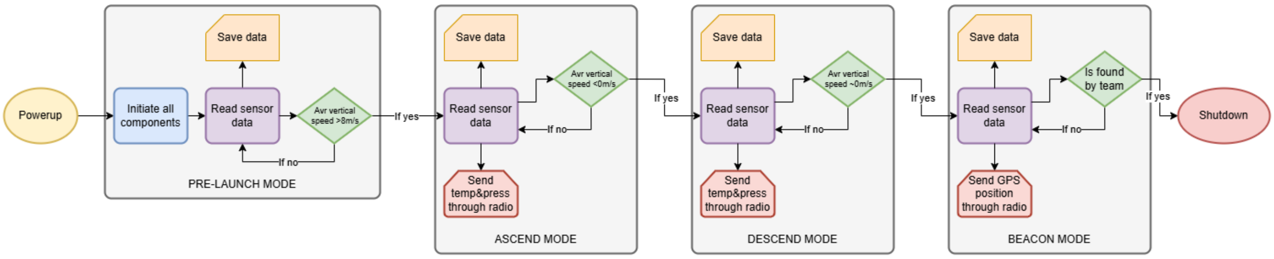


Figure 12: Operations of the different modes of the CanSat

2.5.3 Data handling

All the data is saved and transferred in binary formats that are packaged by $struct$, to ensure efficiency and save on storage. For storage we use the internal flash of an ESP32S which is 2MB of mostly free space. Every time we save, it takes up $25bytes$. That would fill up our $2MB$ in about 21 hours.

2.5.4 Radio design

The Kaboom CanSat uses a $SX127x$ type radio module operating at $868.0Mhz$, with a simple stick antenna with its shell removed, that has a gain of $2dBi$. The characteristics of the transmission are detailed in the table below.

Parameter	Configuration Value
Frequency	868.0Mhz
Transmission Gain	14dBm
Transmission Power	25mW
Bandwidth	250kHz
Spreading Factor	SF10
Coding Rate	3/4
CRC	Enabled
Packet Size	4 Bytes
Airtime	**100 ms**

Table 1: LoRa radio settings

2.6 Recovery system

The Kaboom CanSat's recovery system is strongly based on the cross parachute design specifically made and sold for CanSats by LMR Technologies. Using the details provided by the manufacturer[2] we recreated our own parachute from $40\mathrm{g/m^2}$ bright orange ripstop fabric and kevlar strings.

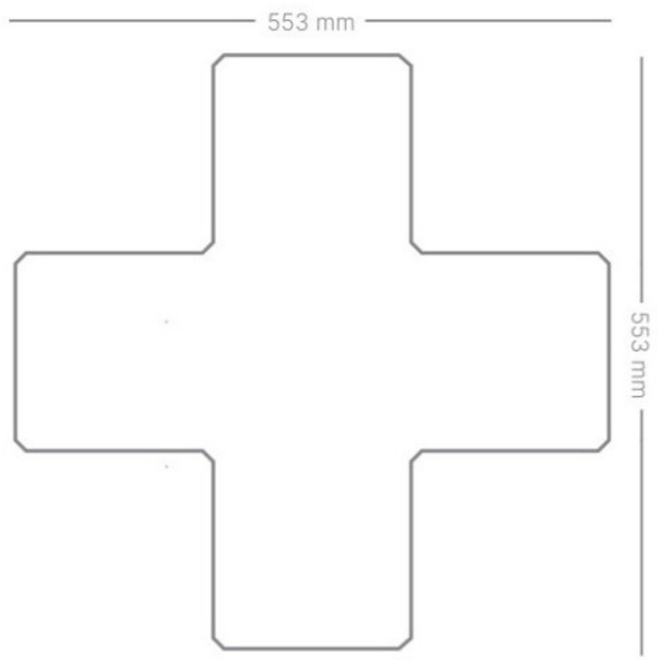


Figure 13: Original sewing pattern for parachute

[2]Diagram courtesy of LMR Technologies

Although the manufacturer suggests that with this design the terminal velocity will be $6,5m/s$ our testing suggested that that is not the case. As our goal is a descending speed of $8m/s$ we calculated, that the parachutes enclosing square should be extended to $774mm \times 774mm$.

The parachute's strings are tied together through a metal washer and are attached to the top of the CanSat through a ball bearing swivel to prevent unwanted spinning while in the air.

2.6.1 Preliminary parachute testing

The above stated parachute design was tested with a dummy can filled with bolts weighing $350g$. It was dropped from a second story window, which we previously estimated to have a height of $8,5m$ using trigonometry. We took video of our drop test, and averaged out the times. Knowing the height and time of the drop the terminal velocity can be estimated using the following formula, and graphing software like Desmos.

$$f(v_t) = \frac{v_t^2}{g} \ln\left(\cosh\left(\frac{gt}{v_t}\right)\right)$$

With the formula we got a result of $v_t \approx 15m/s$ which exceeds the allowed range for CanSats. For this reason we will construct a new parachute with the above mentioned size.

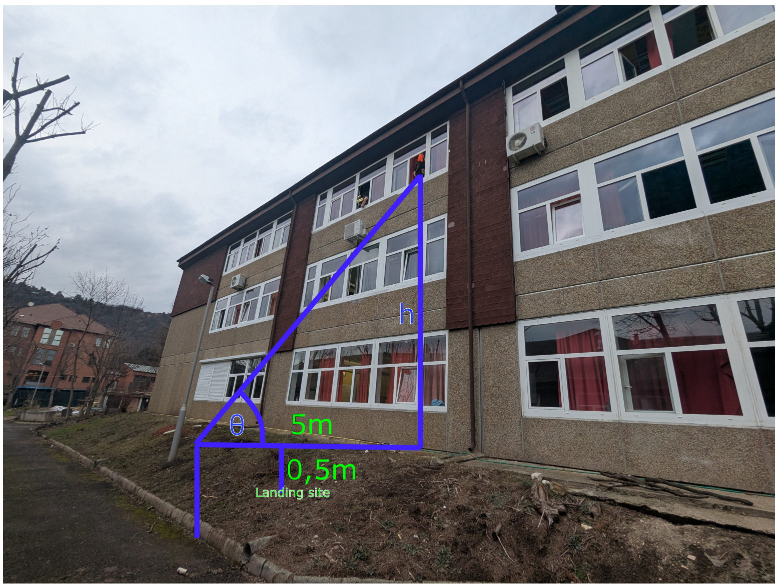


Figure 14: Conditions of the drop test

The height was calculated based on the angle measured $\theta = 60^{\circ}$ to be $5 \cdot \tan\theta \approx 8,66m$

2.7 Ground station

Our base consists of 3 components. A LoRa32 V3 containing an ESP32S3, an sx1262 LoRa node and 128px-64px OLED display connected to any computer with a USB port, and also a Yagi Uda antenna for receiving the radio signals from the satellite even at high distances.

Due to constraints around the transmission power and more importantly the duty cycle, only the required data: temperature and barometric pressure is transmitted via radio, the rest is stored only onboard the CanSat. We also approximate altitude from barometric pressure, which is then used to decide the CanSat's mode. Ground receiver saves the data to a file while also sending it over to the computer, which graphs it live on screen. The data is also readable on the ESP's built in OLED screen.

2.7.1 Yagi Uda antenna

To increase the range of the radio communication we opted for building a Yagi Uda antenna for the ground unit.

We use a 9 element Yagi-Uda antenna in our immobile system. The type of gamma-match we built in this antenna is called "modified gamma-match", which doesn't include any capacitor in its adjustable circuit. The antenna is connected to the ground station through coax-cable.

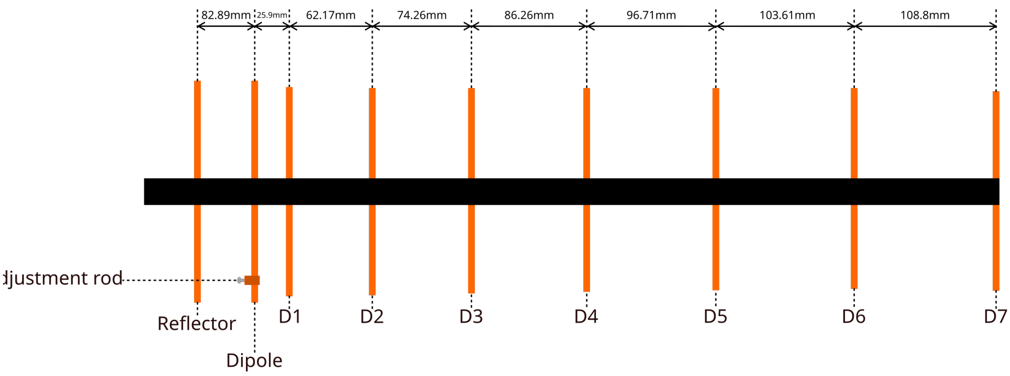


Figure 15: Schematic diagram of Yagi antenna

As stated before, the antenna doesn't use a capacitor in its adjustment circuit. For the modified gamma match to work the adjustment rod needs to be set at exactly $0,05 \cdot \lambda$ to tune the it to the exact frequency.

The materials used are: PVC pipe ($d = 20mm$), brass pipe ($d = 5mm$), coaxial cable (50Ω), connector block (max. 6 mm), SMA connectors. The dimensions of the antenna were calculated with the Steeman Yagi Antenna Calculator[3].

General Parameter	**Value**	
Wavelength	345.38 mm	
Boom Length	640.69 mm	
Approximate Gain	11 dB	
Element	**Position (Relative)**	**Length**
Reflector	0 mm	166.47 mm
Dipole	82.89 mm	166.47 mm
Director 1	108.80 mm ($P + 25.90$)	156.94 mm
Director 2	170.96 mm ($P + 62.17$)	155.43 mm
Director 3	245.22 mm ($P + 74.26$)	154.06 mm
Director 4	331.57 mm ($P + 86.35$)	152.80 mm
Director 5	428.27 mm ($P + 96.71$)	151.66 mm
Director 6	531.89 mm ($P + 103.61$)	150.62 mm
Director 7	640.69 mm ($P + 108.80$)	149.69 mm

Table 2: Yagi-Uda Antenna Design Specifications

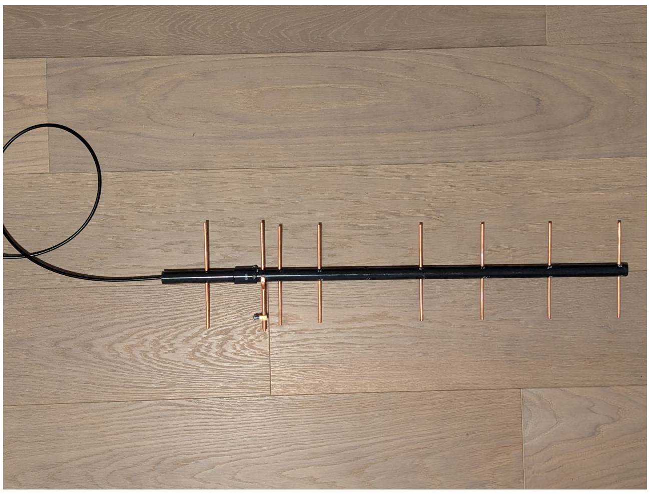


Figure 16: Finished antenna

[3]https://www.steeman.org/Antenna/Yagi-Antenna-Calculator

3 Project planning

3.1 Time schedule of CanSat preparation

September 2025
- Team assembly, Name & Logo

October 2025
- Finalize mission & Tasks
- PDR development

November 2025
- Submit PDR
- Start electronics & Return

December 2025
- 3D/PCB Design
- System test (Failure)

January 2026: Pivot
- New mission: Geiger counter
- Design refinement & Testing

February 2026
- Assembly & Final testing
- Ground station antenna

March 2026: Launch
- LoRa range & Stress tests
- Final Launch

3.2 Resource estimation

3.2.1 Budget

Component	Price (€)
BMP280 + AHT20 Sensor	2,00
LoRa SX1278	3,56
ESP-32S	4,54
18650 Battery (2x)	2 × 3,14
LoRa Antenna	2,00
GY-NEO8MV2 GPS	10,26
Fly swatter	3,74
SMB-20 Geiger Tube	18,24
1N5378B Zener (4x)	2,32
BC547	0,38
L7805CV	0,43
LM317T	0,49
Resistors and Capacitors	2,00
ABS Filament	8,75
Sum	**€64,72**

Table 3: Budget table

Please note, that the cost of solder, glue, wires, screws and spacers is not shown in the table, as their cost is negligible compared to the rest of the components.

3.2.2 External support

We hereby declare that the Kaboom CanSat team did not receive any external financial or in-kind support from any company, organisation or expert.

3.2.3 Test plan

To test that all of the custom designed parts are functional we conducted two preliminary tests before assembling the CanSat satellite.

Due to the concerns expressed by the rocket team at the Satellite Meetup about the fire safety of the high voltage systems, we conducted a 5 hour stress test, which confirmed that the whole Geiger-Müller circuitry is safe for prolonged use. The test was video documented, and is watchable on YouTube: `https://www.youtube.com/watch?v=slQ7Fv_jdv8`

Preliminary drop tests with a dummy weight were also conducted, detailed in the recovery system section above.

While some radio range testing was also conducted, which lead to the construction of the Yagi-Uda antenna, due to terrain conditions its results were highly inconclusive.

Before launch a prolonged test of the whole assembly will take place, similar to the Geiger circuit. Radio range tests and drop tests using drones will also be conducted in the foreseeable future to confirm the radio's range and the operation of the recovery system over larger heights.

4 Outreach programme

The key part of our outreach programme is our website. This website houses both our CanSat's schematics and our blog. Our blog is where the results of all our tests and where all the documentation is housed.

We also have both an Instagram and a YouTube account. The main purpose of our Instagram is to popularize our website, so our posts are kept short and simple. Our YouTube channel houses longer tests and our CDR video.

We also have a GitHub repository where all our code, scripts and their respective documentation can be accessed.

In the future we plan on creating more Instagram content and extending our blog on our website. We also plan on hosting a presentation in our school to popularize the CanSat competition and space research.

Media	**Link**
Instagram	`https://www.instagram.com/kaboom.cansat`
GitHub	`https://github.com/Grandturkboy/Kaboom_Cansat_2026`
YouTube	`https://www.youtube.com/@kaboom_cansat`
Website	`https://kaboom.honaphire.net`
School's post about project	`https://www.facebook.com/share/p/1DBTS3mgoT`

Table 4: Means of communication and outreach

5 Requirements

Characteristics	**Quantity (unit)**	**Requirement**	**Eligible**
Height	115 mm	115 mm	Yes
Mass	312g	300-350g	Yes
Diameter	66mm	66mm	Yes
Length of recovery system	40mm	45mm	Yes
Flight time scheduled	120s	120s recommended	Yes
Descend rate	8m/s	5-12m/s	Yes
Radio frequency used	868,0Mhz	Hungarian laws	Yes
Power consumption	0,9W	-	Yes
Total cost	€64,72	€500	Yes

Table 5: Table of requirements

5.1 Preliminary energy budget

With two 18650 Batteries with $2000mAh$ capacity at $3,7$ volts installed the combined capacity is $14,8Wh$. With this capacity the satellite is expected to function for approx $18h$

Component	Voltage	Current	Power
ESP + Temp. Sensor + LoRa + GPS	5V	75mA	0,375mW
Geiger Boost Circuit	2,5V	175mA	0,438mW
Sum	-	-	**813mW**

Table 6: Table of power usage

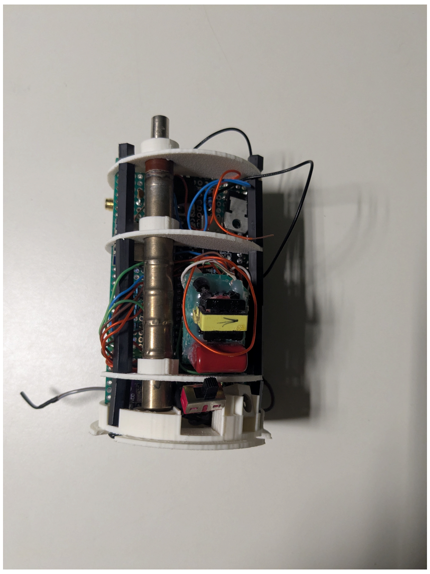
which even with losses added exceeds the required minium time.

5.2 Declaration

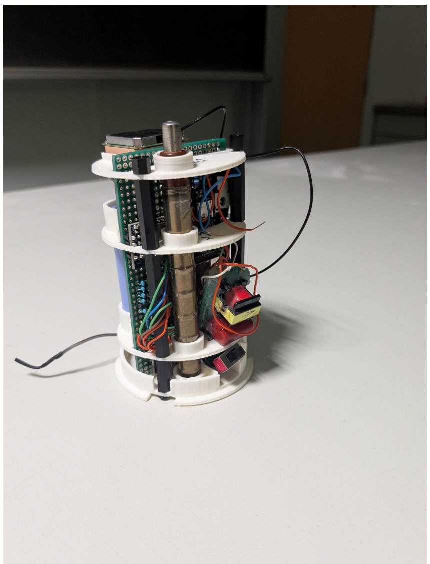
On behalf of the team, I confirm that our CanSat meets all the requirements set out in the official guidelines for the 2025 Hungarian CanSat competition.

Budaörs, 16. February 2026. ....

6 Assembled CanSat



(a) Laying on side



(b) Upright

Figure 17: Assembled CanSat

We would like to thank the following people for their invaluable general contributions and community insight: Luca Kormos, Hunor Villási, Ákos Monostori, Erzsébet Barotai