CANSAT

Team TerraSat

by TerraSat Team
Consisting of Adam Szkaradek, Aleksander Iskra, Aleksander Gnitecki, Stanisław Lewandowski, David Giltinane, Piotr Sujecki

Supervised by Adam Markiewicz

CANSAT

Team TERRASAT

Created by TERRASAT Team

Consisting of Adam Szkaradek, Aleksander Gnitecki, Aleksander Iskra, Stanisław Lewandowski, David Giltinane, Piotr Sujecki

Supervised by Adam Markiewicz

Critical Design Review

Agenda:

1. Abstract

1.1 Overview of the competition

The CanSat competition consists of two main missions: primary and secondary.

The primary mission is based on measuring the temperature and pressure throughout the flight. To accomplish this mission, the probe is equipped with additional sensors which make those specific measurements.

The data obtained from the primary mission is going to help us determine the current height of the Can above the Earth, which will further make the acquired data during the secondary mission more accurate.

The secondary mission of our project is designed to create a 3D model of the area which the Can is flying over. The main objective is based on a usage of a micro rangefinder laser which is going to be placed at the bottom of the Can. This specific placement of the laser will allow us to emit laser beams, from the Can to the surface of the Earth, which will later be reflected.

Those laser beams are going to come back to the Can allowing us to obtain data of the distance between our satellite and the Earth underneath. As the micro rangefinder laser emits hundreds of beams, we will be able to map lots of points over the surface area over which the Can is currently flying above and later create an accurate topographical map of the Earth scanned by the laser placed inside of the Can.

1.2 Why is our mission worth pursuing?

The idea for our project was born after reading the “Voyage 2050” one of the key developments which the European Space Agency wants to pursue is the exploration and further analysis of environments on different planetary moons in the Solar System.

Therefore, our probe would be able to provide more information about the structure of the planet before sending a space rover to collect samples of the crust or of the atmosphere of a particular moon. This would allow ESA to limit the damage of different devices as researchers would simply have more information about the moon itself than just pictures.

However, our research vessel could also be used on a much smaller scale. For instance, it could be integrated with rescue choppers. As the device is very small, it can be installed inside the chopper's floor. This would give the rescue teams more information regarding the terrain in which they are going to operate. This grants them knowledge about which equipment is the best for the current situation.

This project not only gives our team the amazing opportunity of further developing our skills in computer science, physics, and mathematics; it also gives us the chance to contribute towards something greater than we could have imagined.

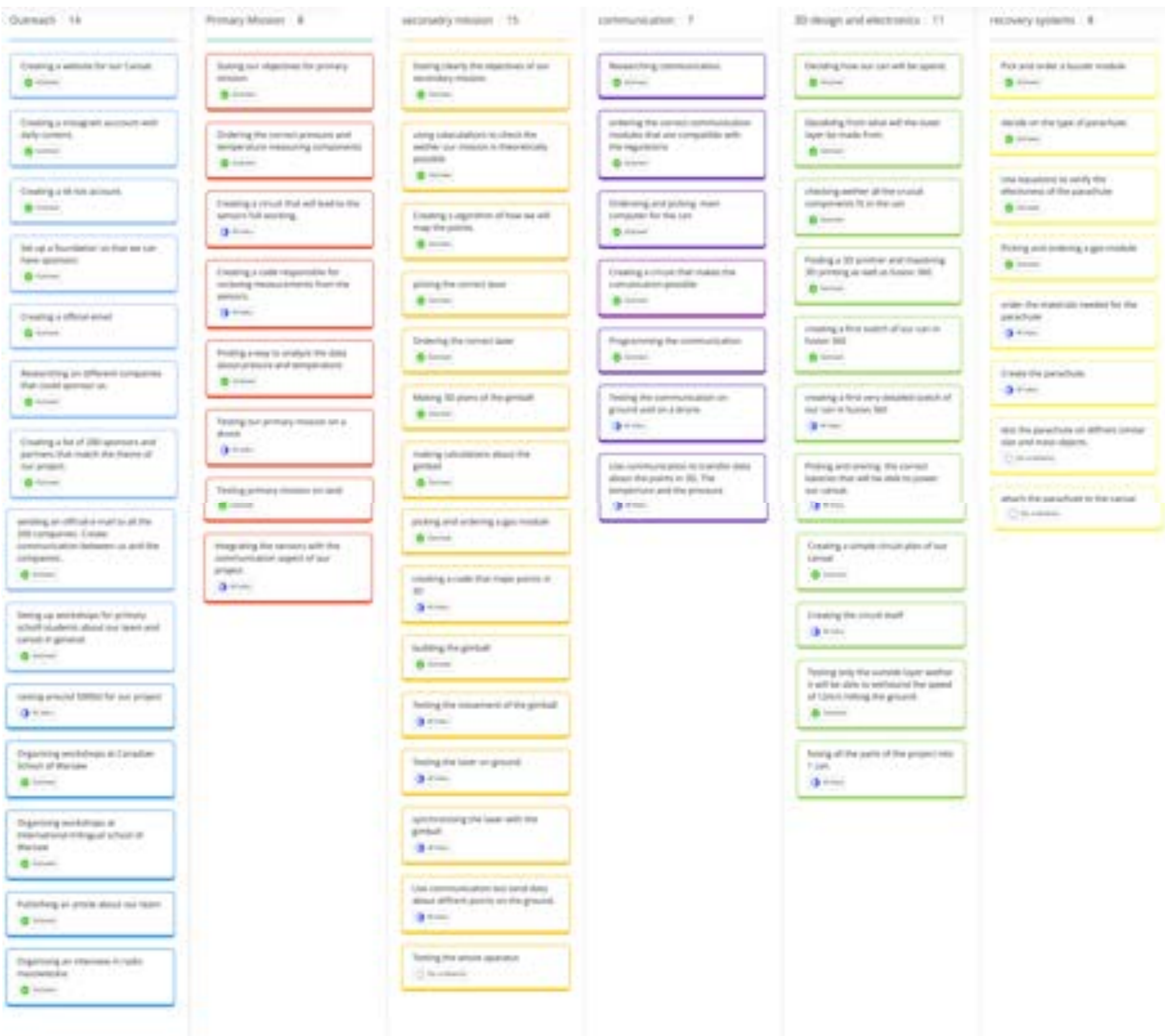
1.3 Changelog

Date of decision	Change	Comments
17.08.2024	Creation of Cansat Team.	To get started early on and establish a strong base for our project.
19.08.2024	Choosing roles for our teammates.	Allow our project leader to assign tasks to each member and develop our idea.
23.08.2024	In-person meeting between members, discussion of potential ideas.	This meeting was important as it allowed us to compare different ideas each member had for the project in its entirety.
25.08.2024	Decision was made regarding our Secondary Mission.	Our plan was to have a camera mounted at the bottom of the Can and use AI to recognize different species of plants of the terrain below.
02.09.2024	Meeting in person regarding choosing components for the Can(camera, filament, arduino/raspberry Pi).	This was important for our main programmer to start writing code, our 3D engineer to start approaching design, and marketing to begin content creation.
14.09.2024	Meeting to assess what each person has done, assigning tasks, and creating marketing content.	A critical meeting, since we were able to identify which people were more comfortable with the workload, identify weaknesses, and discuss future ideas.
18.09.2024	Meeting with Dr. Bochiński from Creotech Instruments S.A.	This was one of the most important meetings. Dr. Bochiński was able to direct us in our Secondary Mission; and identify aspects in which we could make our idea more original.
19.09.2024	Team member integrational meeting, with burgers and game night.	This was essential for team morale, since after we were forced to change our idea, we were not highly motivated. This was important as it allowed us to re-focus on the competition and get to know each other.
23.09.2024	Return to the drawing board.	Each member was tasked with creating a new idea and developing it. After we had all presented our ideas, we chose a new

		Secondary Mission. The one we have currently.
25.09.2024	Sharing important components with other team members and comparing compatibility.	Allowed us to identify what components we want to use. Allowing our 3D designer to integrate these into the Can's design, and our electrical engineer to begin coding.
27.09.2024	PDR writing session # 1	We have created a google DOCS. This has allowed us to collaborate simultaneously on the project and divide roles to different team members.
30.09.2024 - 17.10.2024	PDR writing session # 2, 3, 4, 5	We have been consistently writing the PDR. These sessions have helped us to write, analyze, and develop our ideas further.
18.10.2024	Visit to the Canadian School of Warsaw, to the 6th grade.	We have secured a visit to one of the 6th grade classes in CSW. There we were able to spread the knowledge about our project with the younger generation.
19-20.10.2024	Final changes to the PDR.	Here we reviewed the PDR and have made the correct adjustments. This makes our project more cohesive, scientific, and reputable.
25.10.2024	Changing our laser to a different module.	We realised how the size of our laser might drastically impact our free space in the Can for other essential components.
27.10.2024	Creating a list of all components to order and a cost estimate for the new parts.	Ordering the essential components.
30.10.2024	Started the creation of our parachute.	Started creating a typical circle sized parachute.
30.10.2024- 30.12.2024	A time space in which we started to build our separate parts of our CanSat. This led us to finding major obstacles along the way.	Firstly, one of the problems we found out was the precision of our components, the laser, GPS, the gyro and accelerometer as well as finding some problems with our idea for 3D design.
15.12.2024	Reaching 20000 views on our instagram.	Improving the outreach part of our project.

01.01.2025-09.01.2025	Brainstorming to find a solution to all the problems. Finally finding solutions to nearly all of them.	For the imprecision of where we are we will use raw data from the GPS and our altitude we have to count anyways for our main mission to plot a graph of position over time of our CanSat to minimize the imprecision of our position.
01.10.2025	Creating a new design for our parachute that solves some of our problems.	Creating a design of our parachute that will let us stabilize the Can and make it go one direction to extend the flight time.
30.10.2024-10.01.2025	Developing our relations with many companies sending out thousands of emails and making hundreds of phone calls. Coming to agreements with sponsors.	This helps our finances and makes it possible for us to publish yet another article.
09.01.2025-	Working on our CDR	In this time, we focused on conveying our thoughts, questions and problems towards the CDR in hopes of extensive feedback that will help us solve the issues.

1.4 Tasks that need to be done for our mission to be completed



2. Introduction

2.1 Our motivation

The CanSat competition is an exciting opportunity for all of us to explore and pursue our passions. Since we are all Science and Mathematics oriented students CanSat seemed like an obvious choice. It gives us the opportunity to lead our own project, while also giving us hands-on engineering experience. As the whole project is student lead, meaning that it must be our own innovative idea from the start to finish. Furthermore, it busts our creativity and social skills, as throughout the competition we will face many challenges. This will require us to communicate. Only with cooperation can we overcome those challenges. Finally, we get to create something that might be used in real life, for exploration of the universe.

2.2 Our team & how we are working

The TerraSat team is supervised by Mr. Adam Markiewicz – a person who has dedicated many years of study to cosmology, and the theory of fundamental interactions. Each of our team members, apart from lessons such as: physics, mathematics, chemistry, and computer science, dedicates about 5 hours weekly of independent work to designing the CanSat. In addition to independent work, our team carries out weekly meetings on Discord.

TerraSat apart from our supervisor consists of 6 members:

- The Team Leader and secondary coder is Adam Szkaradek. For his A-levels, Adam chose Mathematics, Further Mathematics, Physics and Spanish. Apart from his main studies Adam is also interested in coding, as well as cosmology.

- TerraSat's Electrical Engineer is Aleksander Iskra. For his main final exams, he chose Mathematics, Physics and Chemistry. Additionally, he is taking part in Biology Olympiads, his best result was obtained in the "Biotechnology Competition" in which he was awarded first place in Poland.

- Our Team's Mechanical Engineer is Aleksander Gnitecki. For his A-levels Aleks chose Mathematics, Further Mathematics, Physics and Spanish. He has previous experience with modeling drones and is interested in Kinematics and Dynamics.

- The Team's Main Coder is Stanisław Lewandowski. For his main final exams, he chose Mathematics and Physics. Furthermore, Stanisław is taking part in Computer Science and Chemistry Olympiads, and like every team member, he is ecstatic about space.

- TerraSat's 3D Designer is David Giltinane. For his A-levels he chose Mathematics, Further Mathematics, Physics and Chemistry. David has previous experience with 3D design, which helps with specific elements of our research vessel.

- Our Team's Marketing representative is Piotr Sujecki. For his A-levels he chose Mathematics, Further Mathematics, Physics and Chemistry. He is interested in Kinematics, he also has previous experience with public speaking, which will help making connections with potential sponsors.

As CanSat is a very time demanding competition our work revolves around communication through social media. We all meet once every two weeks, where each team member concludes which tasks have been completed, and discuss further objectives of the project. During those meetings our Team Leader assigns new tasks to each team member. As many tasks require collaboration between different sectors, we also organize separate meetings between ourselves to move past the issue which we are faced with.

Those meetings are short, time efficient, and kept to the point as all our schedules are tight since our academics require lots of time due to their complexity.

Our team also receives help from Dr Bochiński, with whom we meet every four weeks from 10am to 2pm. These meetings are crucial for the development of our Can, as Dr Bochiński has previously mentored CanSat teams, meaning that he has a lot of resources which our team can use.

2.3 Matrix describing each team member's tasks

Team Member	Objectives for which they are responsible
Adam Szkaradek	• Assigning tasks to each team member • Helping each team member with their tasks • Creating the website
Aleksander Iskra	• Merging the parts of our Can together • Responsible for recovery systems
Aleksander Gnitecki	• Designing the gimbal, as well as the Monte Carlo simulation
Stanisław Lewandowski	• Creating the code for our CanSat • Choose vital components • Electrical Engineering
David Giltinane	• Designing the Can in Fusion 360 • Designing crucial parts for our Can • 3D printing parts
Piotr Sujecki	• Contacting potential sponsors • Social Media development • General outreach and idea presentations

2.4 Primary mission: What should be accomplished for the mission to be considered successful?

1. The data collected by our vessel will be transmitted to the ground station at least every second.
2. We should obtain enough data to plot a graph.

2.5 Secondary mission: What should be accomplished for the mission to be considered successful?

1. Neither the laser nor the gimbal should malfunction during the flight.
2. The gimbal inside of the vessel should be rotating smoothly.
3. The laser should start to map the points once the parachute opens.
4. The laser should map a large number of points on the ground.
5. The amount of data should be accurate enough to create the 3D model of the scanned area.
6. The parachute should minimize the damage done to the vessel during the landing.
7. The 3D model created should represent the area mapped by the laser.

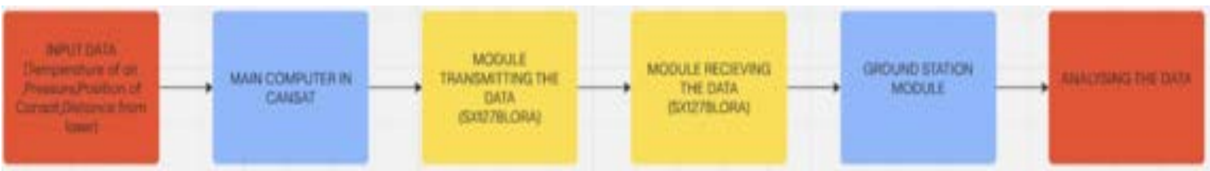
2.6 Expected results

1. The primary mission's transmission of data will be successful - we will obtain enough data to plot the graph, and data will be transmitted every second.
2. The laser will map enough points to create the 3D model of the scanned area.
3. The 3D model will be accurate.

3. Communication

The communication system is an extremely crucial part of our CanSat. It lets us transfer all the data directly from our probe to the ground station where they can be analyzed and stored safely. Moreover, it becomes very useful during the procedure of CanSat recovery after the mission. Faultless activity of the communication system must be provided to make the whole CanSat campaign successful. It is the part of our probe that integrates and makes effective the activity of all other systems operating inside the Can. SX1278 as a transceiver is fulfilling the function of both - transmitter and receiver - in our communication system. Making our mission successful will require the use of the two devices described. The first one is going to be attached to the Raspberry Pi model 3B+ connected to the computer located in our ground base. The second one is integrated with the Raspberry Pi Zero 2 W positioned inside our CanSat.

There is going to be two-way communication. After receiving the data from devices working inside our probe, they are transferred to the main board and saved there. Then they are encoded into binary format and are transmitted to the ground station using SX1278. Our transceiving will be using the LoRaWAN (Long Range Wide Area Network). Its usefulness is overwhelming, so we choose this protocol in our communication. It has small data losses and transmission range fulfilling our needs. Moreover, it does not require a high energy supply and allows bi-directional communication. The transmission capacity provided is particularly important to transceive all, obtained by CanSat, data in reasonable time. For successful encryption of the files containing the data collected from the sensors we will use a program written into python. It offers extremely easy control of the input and the output. It also includes easy to use libraries needed in handling such procedures. After data is encoded into binary language, using Frequency-Shift Keying it modulates sinus waves, stretching periods corresponding to zeros in binary language. Our waves will be transmitted in the 433MHz frequency, which is the frequency allowed for private use in the European Union. Waves are going to be received by our ground modules and decoded in the reverse way to the encoding method. Communication system used in our CanSat will have the range of transceiving up to 10 kilometers in clear weather conditions.



To ensure that our communication system is working we have already held a test of transcribing the signal between two modules placed 20 meters away from each other. In between them, there was a wall obstacle. Tests were held in neutral weather conditions. There was simulated data of temperature transmitted. Procedure went correctly - all the data was sent and received. There was no data loss, and if some information was not properly transmitted during the first try, the ground module asked for retransmission of lost data, which ended successfully in all cases.

We are currently planning to uphold more tests requiring the use of more sophisticated equipment like drones. We are going to attach a transceiving module to the drone and then test the transmission from different distances and with various ground obstacles. We will test whether there are losses of information. How the speed of transmission changes. We will verify if the information exchange is maintained and will count the number of retransmissions that occurred.

We conducted tests with the communication sending files from one raspberry pi to another to which you may find the proof above. This photo showcases that our communication works flawlessly but we don't yet have sensors attached to it, but we are currently in the process of attaching them.

4. Primary mission

4.1 Overview

The Primary mission is one of the most essential elements of every CanSat project. The competition requires us to complete two different tasks - the primary and the secondary missions. While the secondary mission varies from team to team the Primary mission stays constant for all, according to 2024/2025 regulations the primary Missions objectives are two: Firstly, use the temperature (LM35 sensor) and pressure sensor (BMP280) in order to measure parameters outside the Can. Consequently, the data registered by the sensors will be sent to the ground station at least once per second using the LORA SX1278 radio modules that operate at a frequency of 433Hz. Lastly every team should present their idea of how to use and analyze their data. Our team to tackle this problem decided to use such components:

- Raspberry Pi zero 2W (main on-board computer)
- 2 units of SX1278 Lora van (one being the transmitter and the other being the receiver)
- The LM-35 temperature sensor
- The Bmp-280 pressure sensor
- Raspberry Pi 3B+ (as the main computer on our ground station)

4.2 How will we tackle the analysing aspect of our data?

We will utilize the data obtained from the sensors to plot graphs of change of temperature and pressure over time. These graphs due to high frequency of incoming data will help us to see whether our GPS is working correctly. Also, it will help us to estimate the travel time of our probe that in return will also help us to find the distance of flight of our CanSat. This in return might in the future help us in finding our Can. What is even more, we plan to use the data especially in our secondary mission where we explore the shape of planet Earth that in the future might be an unobtrusive way to map terrain on newly found planets. After receiving the data about pressure and temperature of air we will explore its correlation with the shape of our planet and possibly find some reasons for, why the outside core of our planet looks how it looks. Especially the pressure on Earth might have a significant impact on the shaping of the planet's outer core. Furthermore, we plan to use the barometric formula to estimate the altitude of the Can. There are two well-known formulas that link pressure with height on planet earth-like conditions.

To correlate pressure with altitude we will use the well-known formula:

$$P = P_b \left[1 - \frac{L_{M,b}}{T_{M,b}}(h - h_b)\right]^{\frac{g_0' M_0}{R^* L_{M,b}}}$$

Were:
Pb is the reference pressure.
LM, b is temperature lapse rate.
TM, b is reference temperature.
h is the geopotential height at which the pressure is calculated.
hb is geopotential height of reference b
R is a universal gas constant.
g0 is gravitational acceleration.
M0 is the molar mass of earth's air.

The primary mission objective is to gather measurements of air temperature and pressure at a certain altitude. We will be able to receive information about all the important data that will be used to calculate during the flight the height of the CanSat.

Then we could use the data also to find certain anomalies on Earth that will be easier to verify using the formula and comparing it to simpler ways such as change of pressure and temperature over time graphs that will in a very broad way show how the Can loses its altitude moving towards the situation when the satellite eventually opens its parachute.

Furthermore, we could also use the formula to estimate the significance of the parachute in the motion of the CanSat. We should be able to also notice anomalies that might implicate the importance of wind in the final position of the Can.

4.3 How are we going to test it?

To test our components, we firstly plan to test communication between the transmitter and the receiver and when we can, without any errors, transfer information through radio-waves, meaning that the communication is stable, and all signals are received. At that point, we will integrate the sensors into the system. Then we will take tests in mild conditions seeking a situation where every second we receive new information about temperature and pressure and then store the information. After the tests in mild conditions, we will proceed to tests in more extreme conditions. After this part we will pursue tests that imitate the conditions in the CanSat as much as possible. To utilize this idea, we will create a way to test long range communication with our CanSat in which many obstacles may occur. Therefore, testing longer distances on the ground such as 0.1km,0.3km,0.5km and so on. When we add sufficient technical improvements that will lead to our success in long-range communication, we will try to simulate the in-Can conditions. One of our ideas is to attach the components as well as the radio modules onto a drone and try to receive and transmit data about temperature and pressure every second back to the ground. We will also use different complex weather forecasts to estimate the validity of our measurements. We conducted tests with the communication sending random data from one raspberry pi to another to which you may find the proof above. Furthermore, we are now in the process of adding the temperature and pressure sensors that will finally let our primary mission be fully complete.

5. Secondary Mission

5.1 Overview

Humans since the beginning of their civilizations always wanted to look at the world from the air perspective. They really wanted to see their surroundings as a coherent part of the environment. Seeing things from above revealed to them new patterns and landscapes. After the first balloon flight, when people fulfilled their initial curiosity, they started to think about how to capture an aerial view of the world. It would allow them to efficiently plan urban developments and to monitor the change of the natural environment without interfering in it. The first solution was to use art such as paintings and photos. However, the main problem connected to both is their inaccuracy and deforming perspective. While shooting the air photograph we are unfortunately losing the height perspective between different ground objects.

At the same time, their attitude would come in handy while using the footage to goals earlier mentioned. In the second part of the 20th century humans invented a new way of creating high-resolution ground maps. It was named Lidar, which is a method of mapping the ground with lasers. Main advantage distinguishing it from other solutions is the maintenance of real distances between objects and high accuracy of the process. To create such a view the method only uses information about the time needed for reflected light to return to the receiver and the angle at which laser beam was emitted. Our secondary mission wants to utilize this idea by making it on a smaller scale, but more affordably and equally accurate way.

5.2 Devices responsible for our Secondary Mission:

5.2.1 GPS

During the start of the physical building part of our CanSat we finally realised how truly vital for our secondary mission is the role of our GPS. The GPS is the only possible instrument that will be able to estimate the position in longitude and latitude of our Can during the flight. Initially we thought that the GPS precision is very high but without a doubt our perception has shifted in time. Realising that if we don't find a way to more efficiently use the data from the GPS, we will nearly always have an uncertainty of a few meters. That's why we decided that in order to reduce the uncertainty we will store as well as send raw data and then create a graph of position over time of our CanSat. This data will let us create a function that will let us create a function of our CanSat's position in time which in return should lower our uncertainty. The model we will use to do so is the GLONASS, QZSS - Waveshare 23721 module.

From the specification we found out that 50% of the results created by the module are within a 2m range from the module. This compounded with a height maximum frequency of measurements that can reach to 5Hz meaning 5 measurements per second will help us to get a precise function of position over time. Furthermore, another component of our position is our altitude that is calculated in our primary mission. The formula has an uncertainty of 20 cm which compared to the other uncertainties like the GPS is very small. Which is why it should even enhance the information from our GPS which uncertainty is 2m but in a straight line in any given direction in a 3D coordinate system. Furthermore, to make our position function over time we changed the shape of our parachute that would help us move in a direction less randomly then if we had a circular parachute. To sum up, to decrease the uncertainty in our positioning we will use the GPS altitude and a special design of a parachute just in order for us to be able to create a reasonably precise function of our CanSat's position over time.

5.2.2 Gyroscope

The Gyroscope will let us know the orientation of the satellite and will in return establish the real direction of the laser beam being shot. Since during the flight the Can will surely experience a lot of external forces and surely will not always be pointing directly to the ground. Knowing the orientation of the CanSat will help us to measure the orientation and then it will let us find the exact direction of where the laser is being sent of course considering the uncertainties of the gyroscope without it we wouldn't be able to map the ground due to the imprecision of the assumption that the Can will be always facing the ground.

5.2.3 Laser

Firstly, and foremost it is important to mention that there are many possible range finding lasers that could be useful in our project, therefore it is highly probable that in the upcoming weeks we will change our module. For now, we would like to stick with the LSP-LRS-1000 module that should be, without a doubt, capable of measuring long distances between the Can and the ground. The laser is said to measure well the distances between things which are about 1.0km apart from each other.

After thorough research we decided that this laser is the best option available on the market for our project due to numerous factors. The biggest positive of this specific module is its resolution is 0.1 m, and an accuracy of +- 1 m, meaning that the obtained data about the distance from the CanSat and the ground is extremely precise.

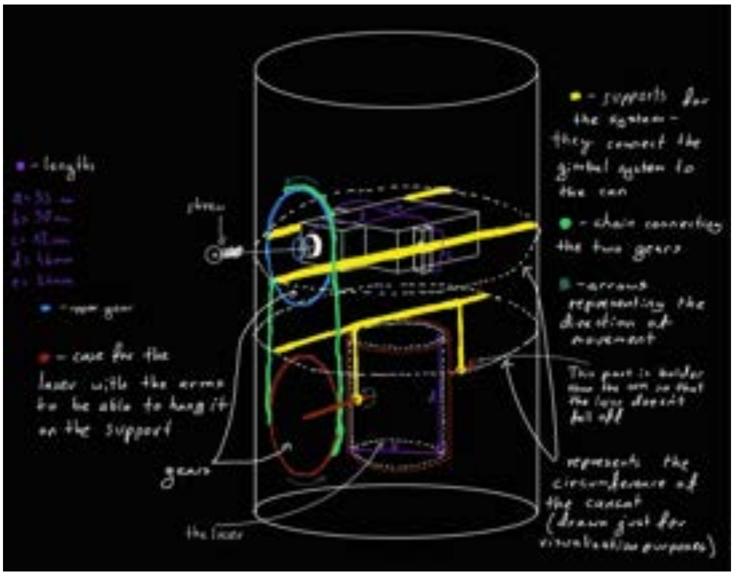
Another factor that we had to take into account is the cost of the device. There are many options for the laser which we could use for our project. However, many of them significantly exceed the price of 600 (EUR). Therefore, our team has managed to find a cheaper option with extremely well-fitting dimensions 25x25x12 mm for our satellite. Its small size leaves us with a greater amount of space inside of the satellite, compared to other lasers which are significantly bigger than LSP-LSR-1000.

5.2.4 Gimbal

One of the most important parts of our CanSat, which is a huge factor in the success of the secondary missions, is the gimbal. Our initial assumption was that we were going to fit into our CanSat two servo motors which would enable our laser to rotate either about the yaw and pitch axes or pitch and roll axes. In practice, imagining our eyes being aligned with the laser, it would mean either that we could move on a circle and define the circle's radius or that we could move up, down, left, and right. This would effectively allow us to move the laser in any direction, of course within the 0 - 25 degree range of pitch and roll as mentioned previously. Unfortunately, we could not pursue this approach due to the pure nature of this kind of system as well as the dimension restrictions of the Can.

1. In case when we would like to use the two rotors simultaneously, one of the rotors would have to rotate just the laser, however, the other one would have to rotate the laser and the previous rotor. This is impossible to do unless we stack the servos on top of each other and use the first combination of the two rotors (rotation about yaw and pitch axis). Then we could put a 360-degree-rotation servo at the top, which with high likelihood, would be able to rotate both the 180-degree-rotation servo below and the laser. The problem with this solution is again the space limit. Stacking on top of each other laser and the two servos would not fit into our Can.

2. The second case is rotation of the two servos separately. This would mean that both the roll and pitch axis rotations would be independent. There are two main problems with that. One of them is the extremely high level of complication of the design that would have to be introduced in order to achieve the independence between the two axes. The second problem is the speed of such a system. Because we are mapping the points using light, we are dealing with tiny time intervals that matter. Adding the time to switch between the two motors on top of the time taken for the motors to move significantly delays the movement of the laser from one point to another.



Fortunately, we have produced a way to simplify the gimbal in a way that it fitted into the Can. The idea involved only one 180-degrees-rotation servo motor which meant that the laser was going to be able to rotate only about the pitch axis. Here is a sketch of how our gimbal was going to look like:

It is important to note that the sketch was not drawn to scale. We also wanted to highlight that the design was surely going to be enhanced later, but we hoped that this sketch showed the feasibility of the gimbal and helped visualize how it was going to work.

One might have questioned why we used a gearing system in the gimbal. This was because if we put the laser side by side with the motor, it would be impossible to align the laser with the center, because of the width restriction of the Can. The central position was desired for a couple of reasons. One reason was the range of movement of the gimbal, which was the largest at the center. The gearing system allowed us to translate the angular momentum from the servo to the laser even when their axis of rotation was parallel but not aligned which allowed us to use the height of the satellite which is larger than the width. The dimensions of the two gears on the sketch in reality might have been different as we were going to try to find the golden mean between the accuracy and dynamism of the rotation. Because the battery was going to constitute a relatively high fraction of the total mass of the Can, we were planning to put it lower in the Can to make certain that the probe was falling with the laser pointing downwards. One example of where we could put it was between the servo motor and laser (above the bottom u-shaped support).

In our original idea, contrary to appearances, the fact that we wanted to use only one servo would not affect the mapping process that much. The simplification of the mechanical design shifted the difficulty to the software side of the gimbal. We came up with an idea to utilize the already high, angular velocity that the laser would have due to the Can falling and which would be impacted by many different factors. The whole crux of the matter laid is in identifying the patterns in rotation of the satellite about the yaw, pitch and roll axes during the free fall. The rotation about the yaw axis would be present, because of the mass imbalance in the CanSat, air resistance and wind. The rotation about the roll would of course be present as well, which at first sight might have seemed to disprove our simplified version of the gimbal, however, that was not the case. Both the roll and the pitch motion were going to be oscillatory, as the center of mass of the CanSat was going to be positioned lower in the Can (closer to the laser). This would allow us to take a lot of measurements with every oscillation about the roll axis taking into consideration the speed of the light emitted by the laser, and the fact that we would be in control of the movement about the pitch axis.

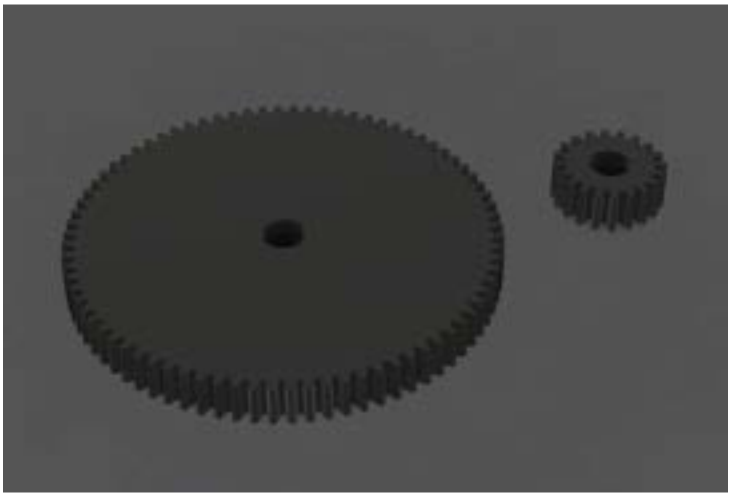
As one can already guess by now, the job of the software was going to be to analyze the data from our 9 dof gyroscope, accelerometer and magnetometer (specifically chosen to ensure the highest accuracy and precision of the measurements), then from the data, estimate the orientation of the Can in the short time interval after the measurement, and adjust the pitch of the laser accordingly, so that the laser would map the points that are relatively close to each other guaranteeing high enough density of the points.

In the near future, Aleksander Gnitecki and David Giltinane, were going to create a 3D design of our gimbal in fusion 360. It was going to involve determining the correct thickness and shape of different components presented in the sketch, in a way that balanced durability with weight and cost. We would achieve that by using the built-in tools in the 3D designing software or by mathematical modeling. In the meanwhile, we were also planning to model the Can's free fall with different combinations of placement of the components, to ensure that it was going to fall in the desired manner.

Although the structure of the gimbal did not change much from our previous idea. The only changes are regarding the gears. The gears are going to be touching directly. The original purpose of the gimbal component has been drastically changed recently. As we pursued a more realistic approach to our secondary mission and attended workshops with Dr Bochiński, we have realised that our laser won't be able to map as many points as we previously supposed it would. This conclusion pushed us to develop a different structure of the mission. Unlike we previously stated, the role of the gimbal isn't, anymore, to ensure a uniform density of points across the terrain that we are mapping, but to stabilise the unpredictable movements of the CanSat in one axis. We are going to map the points along the curve above which our satellite is flying.

The stabilisation approach makes the same question arise as we have encountered with the previous mission plan, which is, how are we going to operate with just one axis of rotation? Here comes into play, our parachute. The parachute will have a certain dimensions and shape in order to ensure that the CanSat is flying in one direction. Thanks to that, we can align the gimbal's axis of rotation with the CanSat's direction of flight. This setting is going to be used to cancel out the sideways movements of the Can by moving the laser in the opposite direction, effectively keeping the laser near the vertical in this axis of rotation for most of the time. We are going to use a PID control loop, or a simplified version of it (for example just a PD controller), to achieve that. This will allow us to constantly account for the error, and how quickly it changes in order to minimize it. What we mean to do with this, is to make use of the limited number of points that we can map, in the most effective way, and to map smaller region, but more accurately.

The movements along the other axis of rotation (front to back), on the other hand, are less significant, because even though the CanSat will be tilted a bit to the front or to the back, we are still mapping the points on the curve. It also doesn't affect our uncertainty in a drastic manner, because we are still getting an accurate value of the angle by which the Can is tilted so we can map the point where the laser is pointing without any issues, and it positively contributes to our map of the terrain. We performed a Monte Carlo simulation of the mission with the uncertainties, which also helps to visualize the idea of our new mission.



In order to minimize, as much as possible, the amount of uncertainty that we have in our measurements, we have decided to make the gimbal uncertainty so small that it is almost negligible. We already have some source of uncertainty that we cannot help, due to the price, size and legal restrictions, thus we didn't want to add anything on top. We have changed the previous analog servo motor with plastic gears, to a slightly more expensive one but with the same dimensions, which is digital and has metal gears. Although it looks like a minor change, it makes a big difference, as metal gears give less error and won't wear out, and the digital servomechanism provides us with a smaller deadband of just 1µs compared to the 10µs in the previous servo. 1µs deadband allows the servo motor to make very accurate movements to just 0.18 degrees. Although this sounds very accurate, in practice, the accuracy will likely be smaller, so we decided to make the minimum movement even smaller. We have picked a 1:4 gear ratio between the servo gear and the laser gear, respectively. This lowers our minimum rotation of the laser to theoretical 0.045 degrees which is unrealistically small, but it gives a perspective on how negligible the uncertainty of our gimbal will be, after calibration. To further condense the mapped points, we will modify the curvature of the CanSat frame by making two recesses on both sides of it, so that the laser is not bounded by the frame. Thanks to this approach, even with a stronger wind and deviations from the vertical, higher than 25 degrees, the gimbal will still be able to cancel them out and keep the laser pointing down.

5.3 Our theoretical calculations

5.3.1 Will the laser beam be transmitted by a Can moving at high speed?

The key elements of our secondary mission are the Laser, the Gimbal, and the GPS. Firstly, we found a way to map the ground using such information as the position of the Can that will be provided by the GPS. Furthermore, another piece of information necessary for us is the direction in which the laser will be shot. Lastly, the information about the distance recorded by the laser will enhance our formula. In order to check whether our idea is possible we made few theoretical calculations. Will the laser beam be transmitted by a Can moving with a great velocity. Firstly, to reduce this factor, we decided to shoot the laser at max 25 degrees sideways from the direction exactly below. Therefore, we estimated that the maximal distance the laser will travel is around 7 km (2/cos (25) *3km to be precise) having the assumption that the maximal altitude the CanSat reaches is 3km. Then we calculated the time it takes for a laser to travel 7 kilometers it takes exactly(7/300000s) which is less than 0.000025s. Therefore, let us check how much the CanSat could have moved by, after intaking information from many teams that have already sent their CanSat into the air we know that the speed of the CanSat at free fall reaches a maximum speed at around 70 m/s therefore in an extremely bad scenario the laser will move from the shot to the receive by 0,00175m(70m/s*0.000025s) which is equivalent to 1,75mm which seems to be a very small value especially regarding our quite big model that has a diameter of 2cm. What is more, we acknowledge the fact that this difference could be big enough for the laser beam to come back. However, after we open the parachute the CanSat moves around 7 times slower, and the maximal travel is also at least 3 times lower. Therefore, when we open the parachute in our CanSat in a very extreme scenario the laser will move by 0.0875mm which is small enough for our laser to receive the beam.

5.3.2 Checking the theoretical capabilities of our system to map terrain in 3D

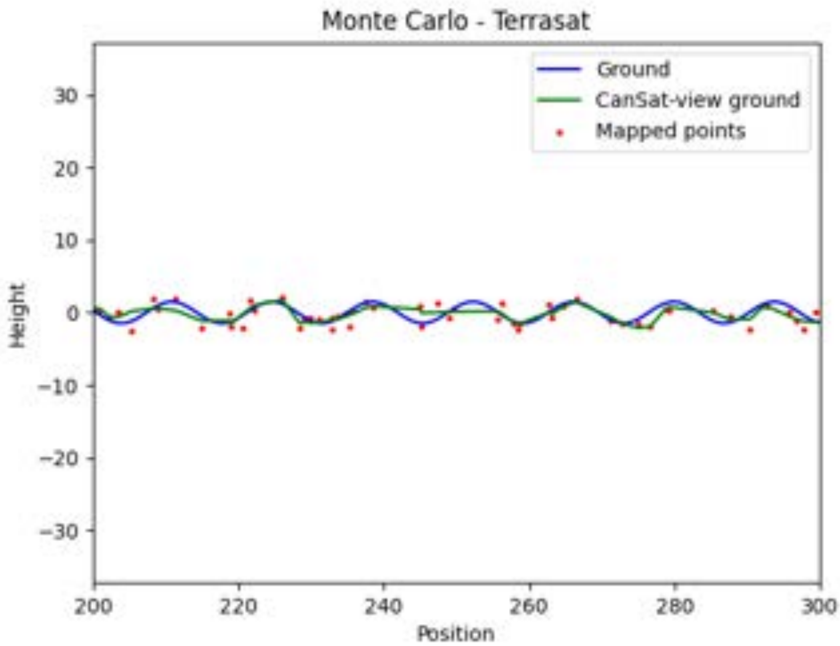
What is even more important is to check the capabilities of our idea to map terrain. We examined the average number of points we would be able to receive on 1 m^2 of terrain In theory the CanSat would fall for at least 120s $\left(2k * \frac{1}{5}\right)^{\frac{1}{2}} + \frac{1000}{10}$s we have attended many presentations of the last year team Satelink from which we received real time data knowing that the time of flight of CanSat regarding all the forces we do not take into account in here was around 575s therefore we took 500s as our time of flight. This lets us create the assumption that we will be able to take at least 500s/0.0000125s, which is around 40 million points, but we did not consider that some of the beams will not return, and that the gimbal must move in that time. Therefore, it is safe to assume we will receive information about at least 10 million points. Furthermore, after opening the parachute which will be maximally at a height of 1 km our laser will be able to map an area of 0.66km^2 and the time till the can lands will be equal around to 100s which means in this time our CanSat will make 8 million points that, as we already showed, should all be received. Therefore, we calculated the mean number of points per m^2 of the ground which is around 12 points per m^2 especially with the CanSat being closer to the ground the value will increase but 12 points per m^2 should be enough to create an accurate 3D map of the terrain. Furthermore, at the time when CanSat is at an altitude of 500m the can will be able to find points at a maximum are of 0.17km^2. Knowing that, we will, in theory be able to map 4 million points this means that in this specific area we will have 24 points per m^2 of terrain which is enough to create a very detailed map of the ground.

5.3.3 Theoretical way in which we will calculate the coordinates of points we shoot at in 3D

Originally, we thought that we would be able to map the ground by using vectors. In order to know the direction in which our laser shoots we need to know the exact coordinates of the end of the range-finding laser which we will name as {x,y,z}. We would get them from the internal GPS our CanSat is equipped in. Furthermore, we also needed to represent the direction of where we would be pointing our beam, this would be represented as a vector. We acknowledged the fact that during the time of flight the bottom of the can will not, at all times, be facing the surface of the Earth. To resolve this issue, we needed a gyroscope in our can that will give us the orientation of our vessel towards the ground which will be represented as a vector. Therefore, to find the real magnitude of our vector we would need to sum both vectors. We labelled the summed vector coordinates (x,y,z) we created a the factor k therefore to calculate k we need to take the distances and divide it by ($\sqrt{x^2 + y^2 + z^2}$) then the coordinates of the point that we just mapped would be equal to (x+ak, y+bk, z+ck). Therefore, all the points would have their real-life coordinates that we would store and send back to the ground.

However, after workshops with Dr Bochiński we concluded that we will not be able to do it this way. Therefore, we decided to use the Monte Carlo module. The module is based on the same equipment: GPS, Laser and gyroscope, but the method by which we will calculate the 3D coordinates of the points is different.

5.3.4 Monte Carlo Simulation



*The values on the graphs correspond to meters

In order to estimate how the output from our flight will look like, we have created a Monte Carlo simulation. We have performed the simulation in 2D as we expect the gimbal to cancel out most of the sideway movements. Both the outliers in the sideways movement, in cases when the gimbal won't manage to cancel out the deviations, as well as the sideways uncertainty from the GPS can be managed by generating a curve of best fit between the mapped points from the top-view, which will show as more or less the trajectory of flight, which will reduce the sideways uncertainty. The simulation we performed accounts for the following uncertainties: GPS position, laser measurement, height from barometric formula.

Barometric height formula generally gives accurate values, so we have used an uncertainty of +- 0.1m. Our GPS module is said to have an accuracy of 2m CEP, meaning that 50% of the measurements are within a radius of 2m from the actual position. Thus, we have assumed the accuracy of +- 4m, which would likely be the radius capturing almost all of the measurements. This is a big uncertainty, and unfortunately, we are unable to decrease it because of legal purposes. Our laser has an uncertainty of +- 1m and frequency of measurements of 3hz. We have implemented a special technique for retrieving the actual shape of the ground. The idea of the technique is that we are splitting the data into smaller overlapping subsections of a specific width and overlap and adjusting the smoothing factor accordingly. To find the best smoothing factor, width and overlap, we have used Bayesian optimization. Then we performed 1000 simulations for a sinusoid shaped ground with a height of 1.5m. Across all 1000 simulations we have achieved an average error of around 0.69 meters. The graph above represents a cut out from one of the simulations. Unfortunately, there are some uncertainties that we cannot decrease, which are causing quite significant errors, however we are going to do everything we can to extract as much as possible from the data we will obtain.

5.4 Plan for the mission

Phase 1: CanSat emerges from the rocket and the laser starts shooting in different directions. In this phase we do not hope for a lot of beams to come back due to high speed and long distance from the ground. If any points are found, coordinates are stored on the SD card and are sent to the ground station.

Phase 2: CanSat reaches an altitude of 1km from the ground. The laser still moves and shoots beams in different directions but now we expect that at least 80% of the beams will come back, and we have some points in 3D sketched. The parachute should have already opened at this point.

Phase 3: CanSat reaches an altitude of 500m. Then once again the laser moves and shoots beams in different directions, but now we expect to get a great scan as we will simply have more points mapped of the area beneath.

Phase 4: CanSat crashes, then the SD card is retrieved and all the points that were not sent yet are then taken from the card and put into our 3D model.

5.5 How are we going to test the secondary mission?

Firstly, we plan to test the specific laser on larger distances outside of the can. Afterwards, we will integrate the laser to our main computer on board and write a small code that will take into account everything that is necessary and see whether all the points have the correct coordinates and information about them is transferred well. Then we will integrate the Gimbal to the process and try using the gimbal for our communication and the laser to map a series of points on the ground to create a less complex sketch.

5.6 Recovery Systems

Parachutes are often overlooked while designing the CanSat, but this is one of the most important parts of all probes. It ensures that the CanSat lands safely, and without a safe landing it can potentially be damaged beyond repair. Moreover, the parachute comes with another advantage for us. It reduces the acceleration of the free fall of our CanSat, which increases the amount of time available to collect data. When the probe is falling from a low height, close to the ground as it is in case of the CanSat, the weight can be estimated as mass of the probe in kilograms (0.35kg) times gravitational acceleration (around 9.81 $m*s^{-2}$). It would be the only force acting on the can if it was dropped in the vacuum. However, we have the atmosphere on Earth, which creates additional force acting on the body in the opposite direction to weight. It is named air resistance. The amount of the drag depends on the density of the fluid (in our case it is the air), velocity of the falling object, cross sectional area and the drag coefficient. While drag acting on the CanSat can be overlooked we need to include drag created by parachute. In this case we need to properly adjust the surface area of the parachute and its shape as it affects the value of drag coefficient.

We can use the formula below to calculate the value of drag force:

$F_{Drag} = \frac{1}{2} * C * \rho * A * v^2$

A -> surface area of the parachute

C -> drag coefficient of the parachute, depending on its shape/geometry

ρ -> local density of air (1.225 kg*m^{-3})

v -> descent velocity of the CanSat

As the probe's velocity is increasing the drag force also increases to the extent when it is equal to the weight and net force acting on the body is zero. That is when it stops accelerating and reaches terminal velocity. We are going to reduce the falling velocity by releasing the parachute, which would drastically increase the drag force. In order to collect as much data as we can we are estimating the falling velocity of around 10 m*s-1. Trying to reduce it further would result in the drifting of the probe far from the launch side, making it harder to find and risking problems with communication. In order to find a fitting parachute, we have to calculate its required surface area which would fulfill our mission objectives. We have decided to use a flat parachute, because of its simplicity, low costs, and reasonably high drag coefficient (0.8 in our case).

By rearranging the formula, we can calculate needed area:

$$A = \frac{2 * M * g}{C * \rho * v^2}$$

According to the presented data, the surface area of our parachute will be around 0.07m^2. Generic flat parachute because of its design can be inscribed in the circle. With equation for circle area, we can calculate predicted diameter of our parachute:

$$\text{Diameter} = 2 * \sqrt{\frac{A}{\pi}}$$

With our numbers required diameter is predicted to be around 0.3 meter. That is why we have decided to buy a flat parachute with 0.45 meters diameter from Raketenmodellbau Klima GmbH. It is composed from bright red material which will help in recovering our cansat after the mission.

Extremely important aspect of our parachute is its elliptical shape. It would ensure that our CanSat would move in one distinct direction while falling. It is crucial for our secondary mission success because it would allow us to map the largest area of land we possibly can and minimize risks of our Can falling in the fixed geographical position which would make the laser map the same point all over again. We have decided to buy a circular flat parachute with diameter of 0.45 meters, which is a bigger area than we need, to cut an elliptical parachute out of it of the required area of 0.3 meters. To make such parachute we had to use the equation for area of ellipse and use acquired earlier data:

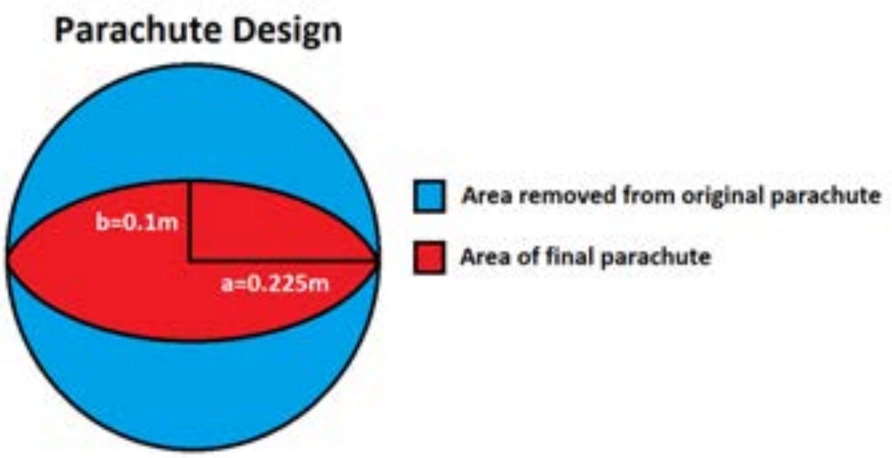
$A = \pi * a * b$ which can be converted to $b = \frac{A}{\pi * a}$

A -> final surface area of the parachute (in our case it is 0.07m^2)

a -> length of the semi-major axe (it is the radius which equals to half of 0.45 meters)

b -> length of the semi-minor axe

According to calculations, the length of the semi-minor axis must be equal to around 0.1m.



Parachute will be attached to the CanSat with a bunch of strings, which are going to be sewn by us to the fabric. We have also decided to attach to our CanSat a streamer produced by Raketenmodellbau Klima GmbH which is a 0.9m long, red ribbon made out of tear-resistant material. This flutter tape will be rolled up very compactly and hidden inside the Can and then released during the flight. Its function is to stabilize our can during the flight by reducing movements of the whole CanSat and making ground mapping more accurate.

6. The ground station

6.1 What devices does it consist of

It will consist of 3 main objects:

1. The laptop will be used to store and analyze the data quickly since only the laptop will have sufficient processing power to do so.
2. Raspberry pi module connected to a receiver. This will ensure that on the ground we will receive all the information sent by the CanSat.
3. An antenna that will help us receive the radio waves sending crucial information from our Can.

6.2 What processes will take place on the ground?

Firstly, we will store all the data sent by the lora radio modules as well as combine them with the data stored on the SD card in the CanSat. Then we will use matplotlib and so on to make sure that the data from the sensors is analyzed. On the other hand, we will also use pre prepared algorithms.

6.3 How are we going to analyse this data?

In order to get the final result, we need to be able to determine “ground zero” for the mapped points. As we discussed with Dr. Bochiński, we will make the said plane by mapping four distinctive points, and therefore creating a square on our 3D model which will show us the general elevation of the plane. We will map those points by walking with the GPS and measuring the height over the sea level, and then applying the data collected onto our 3D model. Then we will take the data measured by the CanSat and plot it on this graph, which will be processed by developed algorithms, this will show us the relative height compared to the “ground zero”, this square will make it easier to distinguish holes and hills present, as we will be able to compare the data to the plane which is almost completely flat (is only shifted as a whole not as specific points).

We will be only receiving raw pieces of data like Position from the GPS, pressure, temperature, and orientation of the Can and distance of the traveled by the laser beam. We will use the data from position and time to estimate the erection of movement of the CanSat over time. The data now will be more precise since we will use the altitude formula to estimate the height with an uncertainty of just 20cm. Furthermore, in order for our direction of motion to be more precise we decided to change our parachute to for our CanSat to move in a specific direction. Therefore, we should be able to plot a relatively well-rounded position vs time graph. After doing so and knowing the orientation of the Can the, the time of shot the distance we will be able to find this point in 3D. Then, on the other hand, we will use the supplemented heights of the ground in different places to subtract the average from our results in order for us to showcase more effectively the different features of the terrain.

Moreover, after receiving the information about the exact coordinates of points in 3D we can easily comment on what type of landscape it is. Furthermore, we could use the data to analyze all points where in the future a rocket might land. What is most important is the main goal of our mission, so we plan to create, knowing specific coordinates of the points on the surface, a 3D model of the earth's surface with the points we were able to map. We plan to intake all these points into python and use 3D sketching libraries that will create the 3D model for us.

7. Desing of our CanSat

7.1 3D and structural design

Our CanSat will be designed using Fusion 360, an industry leading software which is capable of creating 3D CAD models. Our 3D designer/engineer is David Giltinane; he is responsible for the creation of the models, making sure all the components fit inside the Can, and securing the structural rigidity of the CanSat. We are very lucky to be able to use one of our main partners Akademeia High School, physics labs where we have access to their 3D printers, as well as other valuable equipment which is incredibly useful in constant improvement of our Can.

The Can will be made from PC as well as PETG. We have chosen these materials as they have shown durability in our research, however we are aware that together with the further development of our project we might find a more suitable filament. Since the Preliminary Design Review, we have decided to slightly alter the structure of our satellite. Previously we wanted to go for the classic approach of having four threaded rods and connecting everything on top of one another. However, while designing the Can, we consulted with Dr. Jakub Bochiński, who has been a great help to our mission in clarifying design issues, understanding advanced mathematical models for our laser, as well as supporting us through the process

Our updated design will feature a proprietary design which will balance structural integrity as well as provide an optimal solution for integrating our components. What we like to call a "*BookSat",* a design where our Can will be effectively split into two parts: the payload side, as well as the power side. When coming up with our improved design we referred to the **ECSS-E-ST-10C Rev. 1 Standard** for "*Project planning and implementation"* following ECSS guidelines (October 2024); these standards made it easier for us to apply real world knowledge and implement them into our own project.

On the Payload side we have decided to mount our gimbal, this will be done using specifically integrated parts from our CAD design. The Servo Motor will be mounted using a dedicated holder to ensure it is structurally secure and does not move. Additionally, we will include a small opening on each side of the Can to maximise the visibility of the laser. This will help the gimbal to calibrate the laser so that it is always pointing downwards. This is incredibly important as in order to maximise our precision which we will be able to obtain, it is necessary that all variable external factors which could influence the measurements be reduced. Secondly to mount our laser we will mount it directly to the large cog wheel, which in turn will be mounted directly to our CanSat by using a 3D printed base. This design allows for additional sensors such as the gyroscope, temperature sensors, or other measurement devices to be mounted in the area above our gimbal.

The Power side of our Can is much simpler. The semi-circular design will be outfitted with a flattened-out bottom, allowing for a multitude of mounting positions. Due to the gimbals design and dimensions, it will protrude out-side of the Payload side, therefore using the space leftover is a perfect location for the brains of our operation Raspberry pi Zero. This side will be outfitted with a shelf design where we will be able to stack components on top of one another by using "shelves".

These design improvements have come to be through persistent trials and errors. After printing and testing our previous design concept we realised the work we had to do; by analysing the structural integrity of those designs we gained valuable lessons on how to improve our Can's design. These trials and tribulations led to where we are known, and we cannot wait for all the lessons which we have yet to discover.

7.2 Integrating the components

The integration of all components in our CanSat is a carefully coordinated process designed to ensure a compact, highly efficient, lightweight system for terrain mapping. At the center of our system is the Raspberry pi Zero, which functions as the 'brain' of our Can. It connects seamlessly to the various sensors, GPS modules, and processing data received by our laser. The 3D printed casing plays a vital role, by providing custom and lightweight housing for all our components. The casing's design includes specific mounting points for all elements, such as the Li-Ion batteries, laser, and temperature and pressure sensors. The 3D design of the Can is a vital part of our CanSat in making sure that all our parts are securely mounted and can withstand the forces encountered by the CanSat's descent. The casing also accommodates for ventilation and openings for the laser to function properly. The LSP-LRS-1000 laser is the most important component, responsible for 3D mapping the terrain below during the descent. It is powered by a dedicated transformer to ensure consistent voltage, allowing it to function independently from the other systems. This laser is mounted on a servomotor-controlled gimbal, directed by the Raspberry pi Zero as well as the gyroscope. This system allows for the laser to alter its angle and orientation as needed. The gimbals' precise movements are essential for mapping the terrain accurately, creating a detailed 3D map of the landscape below the Can. Meanwhile, environmental data such as temperature and pressure are collected through the LM35DZ temperature sensor and BMP280 pressure sensor, both of which are integrated directly into our Raspberry pi Zero. These sensors gather real-time data regarding the environmental conditions as the CanSat descends, providing valuable and real-time data for the mission.

Power management is a critical aspect of the system, handled by the Li-Ion 18650 batteries. These batteries were chosen for their high energy density and ability to provide stable power throughout the mission. To ensure efficient distribution two transformers are used: one dedicated to the laser system and another to the core electronics, like the Raspberry pi Zero. This separation causes high energy components such as the laser to work independently from the rest of the components which run on different voltages.

The GPS module (GLONASS, QZSS - Waveshare 23721), which is directly connected to the Raspberry pi Zero, provides our team with real time accurate location. This allows for data to be geo-tagged, which means that it can be traced back to where each data was collected allowing for more precise and in-depth perception of data collected.

Additionally, the LORA SX1278 radio module ensures long-distance communication between the CanSat and the ground station. This allows real-time transmission of data, such as pressure, temperature, and GPS. The radio module's long-range capabilities are essential for maintaining contact during the Can's flight, ensuring that critical data is transmitted always. To add an extra layer of safety, we will also encode all data to the SD card. The SD card will be retrieved after the Can returns to earth.

Once the Can reaches the ground, a 5V Buzzer is activated to assist in recovery, emitting a loud sound to help locate the CanSat after it lands. This is critical for finding the Can after it has landed.

These ensure that all components remain firmly in place throughout the mission. The casing and internal structure are designed to absorb impacts that might affect the Can.

Finally, the ON/OFF switch (S332-1) is included in the design to ensure that the Can can remain turned on or off whenever the need arises. Additionally, the key allows for precise control of when the Can knows it should be activated and when not. This impacts safety and allows for more efficient power consumption, additionally it is a precaution which our team has taken to prevent the satellite turning off during the starting procedures.

7.3 Matrix of dimensions, pricing and mass of specific components

Component	Cost (PLN)	Mass (g)	Dimensions (mm)
Batteries - Li Ion 18650 x2	29.90 (each)	48 (each)	18.55 x 18.55 x 65.25
Raspberry pi Zero 2 - Raspberry Pi 0	89.90	9	65 x 30 x 5
Radio Module - LORA SX1278	38.29	1.8	1.7 x 1.7 x 1
Temperature Sensor - LM35DZ	23.0	20	20 x 10 x 10
Pressure Sensor - BMP280	10.0	2	20 x 20 x 5

Buzzer - 5V 12mm - THT	1.90	~1	12 x 12 x 9.5
GPS – GPS L76K	65.90	18	65 x 30 x 2
Laser - LSP-LSR-1000	120 (USD)	10 ± 5	25 x 25 x 12
Servo motor - MG90S	49.00	13.4	22.8 x 12.2 x 28.5
Gyroscope - BNO085 9-DOF IMU	129.00	2.5	25.6 x 22.7 x 4.6
SD card	13.00	2	(Inside of Raspberry pi)
ON/OFF Switch - S332-1	26.75	unknown	16 x 16 x30
Voltage Regulator - Step - Up	5.20	30	35 x 17 x 8
Voltage Regulator - Step - Down x 2	18.40 (each)	20 (each)	62 x 26 x12

7.4 Matrix of our CanSat's compliancy with the regulations

Regulation	Value for each regulation	Compliant/Not Complaint/Partially Compliant
Mass	350(g)	Compliant
Cost	600(Euro)	Compliant
Falling velocity	5 - 12(m per second)	Compliant
Strength of the signal	20 (dBm)	Compliant

8. Electrical Engineering

8.1 Starting algorithm

Through our CanSat's journey we did a lot of research about frequent failures that might occur in a CanSat. One of them was that the Can would start or stop working not in the correct time. In order to tackle this problem, we will add a physical switch. On the other hand, we will also use our GPS position to estimate whether we are above 2.5km. We will implement a code that will let our CanSat truly start working when it reaches a height of 2.5km so it will still have some time until our laser will start to shoot.

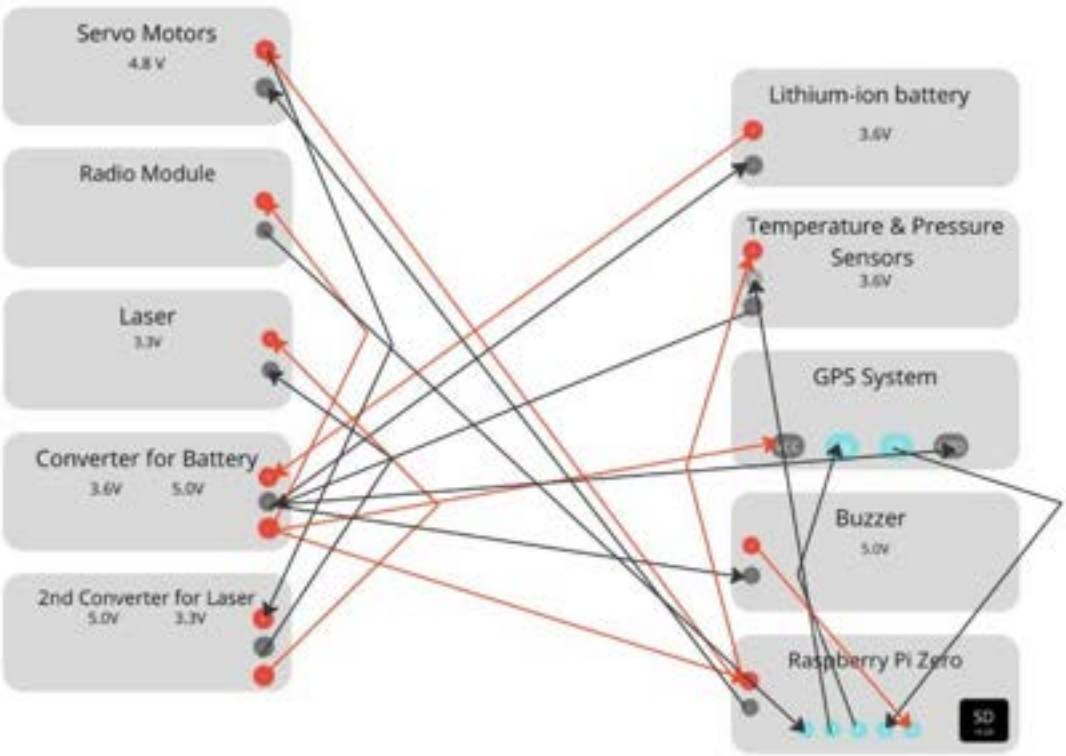
8.2 How will we connect our electrical devices in practice

We can basically segregate all our components into 3 distinct sets. Set 1 being the batteries that will be connected to raspberry pi. Then set 2 the Raspberry pi itself. Set 3 containing all the instruments needed for measurements and our mission. The devices connected to the raspberry pi in set 3 will be: Temperature & Pressure Sensors, GPS, Radio modules, Buzzer, switch, Gyroscope. Which all will be transmitting data to the raspberry pi, and which will then send it both to the ground and will be stored on a SD card in the Can. Since many of our components operate at different voltages, we will have to use both step-up and step-down converters that will change operating voltages in such a way it will satisfy all the operating levels of all the components. In order for our CanSat to work flawlessly we picked the li ion 18650 batteries that each are 3500mah which makes us confident that the CanSat won't run out of the electricity. We will use the step-up voltage regulator that will change the voltage from 3.6 to 5 changing the voltage from the battery to the raspberry pi. On the other hand, we will use the step-down voltage regulator that we will use twice to convert voltage from raspberry to both GPS and radio module that operate at 3V and use a second converter to change voltage from 5V to 4V for our pressure and temperature sensors.

8.3 Matrix of how much energy does each component of the Can use

Component	Voltage (V)	Current (mA)
Raspberry Pi 0	5.0	-
Servo motors	4.8 – 6.0	Max 360
Lithium Batteries	3.6	2600 (mAh)
Radio Module	2.6	93
Buzzer	5.0	30
GPS system	3.3	-
Laser	5.0	-
Temperature & Pressure Sensors	4.0	60

8.4 Our electronic components connected



9. Outreach

9.1 Outreach strategy

Our outreach plan revolves around contacting potential sponsors and partners via email, phone calls, and social media. In addition, our team also plans to perform a radio interview and advertise our project at school assemblies where our focus group will be our colleagues. At the school assemblies we planned one big presentation which is planned on the 28th of January, and a series of short updates about our project. This will give us additional practice before meetings with potential sponsors and partners. To ensure sponsorship, we will be sending out a brochure describing our goals and our mission, it will also contain information about our team members and the process of how the project is going to look like.

The brochure was sent out via email to specific companies based in Europe, however we are also considering extending the targeted list of companies to be outside of Europe. The Companies which received the brochure have been chosen during a thorough research process done by our Marketing Representative. Piotr S. has researched companies which have previously invested in CanSat, and companies which might be interested in investing in our team as their main developments are like our secondary mission. This will give us a higher chance for positive responses, as the companies which have been emailed have similar interests to ours.

9.2 Current sponsors

Currently we have secured six partnerships. First one from Akademeia High School from whom we are receiving mentoring and financial support. Second one from Creotech Instruments S.A. from whom, we are provided with mentoring, regarding the most efficient design of the Can. Mr. Jakub Bochiński has also helped us with choosing our secondary mission, his intake into our project has been particularly useful, as he has supervised a couple of teams in previous years. This means that Mr. Bochiński has a lot of experience with CanSat, and we are grateful for the opportunity to work with him. The third partner is a company called Blue Dot Solution which provided us with the possibility of publishing our article on a website called Kosmonauta.net. Fourth Sponsor is called Geo-System. They provide us with financial support in the figure of half a thousand PLN, also they provide us with access to their website called Geo Forum, where we will be able to publish yet another article about our team. Fifth partner is called Romny Enterprise, from whom we are receiving financial support. Sixth sponsor is called PureTech from whom we are also receiving financial support.

Furthermore, our team is currently in negotiation with two other companies: Radmor, KP Labs and ICEYE, additionally we are currently waiting for a response from several other companies based in Poland, if we do not receive any additional responses, we will move to the process of contacting companies outside of Poland.

9.3 Social Media

TerraSat is present on social media platforms such as Instagram, LinkedIn or Facebook, where we post content connected with our team and project. The outreach done by social media has been divided into two phases. The first phase was called daily phase of profile development. Which meant that we were posting posts and insta stories every day. Those posts vary in content: from members of our team to specific parts of our project such as designing the Can. This process helped us with reaching as many accounts as possible, as the Instagram algorithms promote accounts which post daily, meaning that we have a higher chance of going viral. Additionally, this gave us the opportunity to reach a younger audience, and maybe even inspire students to develop their passions, as we will show them that it is possible to combine fun with work.

The second phase is called maintenance. During the maintenance phase we planned to post two times per week, however, we have noticed that the content which we would be sharing with our followers would be very repetitive, so we have decided to post each time a certain mile stone is achieved in our project, as it will still allow us to keep the present followers by giving the insides about what is currently happening in the project, while also giving us the opportunity to attract new followers. To ensure that our profile is developing constantly we decided to invest 120 PLN in an advertisement which lasted 15 days and gave us almost 15 thousand views on the best performing post. To further increase the number of followers we will be investing in another advertisement.

9.4 Website

The original website which our team has developed, was fully coded by our electrician Stanisław L. and our team leader Adam S. In its principals the website was a success, it was translated into three languages English, Polish and Spanish, it was displaying the information about our team and our mission. However, the one issue which we experienced was related to the fact that we hosted the website from our personal server. Unfortunately, this meant that it took a long time for the website to load, decreasing the interest of potential sponsors and followers. Therefore, our team decided to launch a new website, with the same features and domain. However, it will be hosted from a public server, therefore the time for it to load will be significantly decreased. Additionally, the website will be more appealing for the eye as it will be developed from a template, not coded from scratch, which was the case for the original website. The most useful thing which the website provides is the ability to post the logo of our partners, as it gives them something in return for the support which they are giving to our team.

9.5 Merch

Our team's outreach program also contains a part which revolves around creating TerraSat's merch for our team. The T-Shirts and hoodies which we will create are going to be black with our logo and logos of our sponsors on the back, as it will present the idiom "having someone's back". Meaning that the sponsors are supporting us throughout the competition, and they agree with our ideas. However, our merchandise will only be bought right after we finish negotiations with all the potential sponsors, as only then they make sense, otherwise we would be wasting money on several versions of the same clothing which only differs in logos on the back. We are still considering printing out our 3D tokens and distributing them around in our schools as it will give us the opportunity to reach out to our communities and gain more support from teachers and students.

9.6 Visits in primary schools

Our team has also planned visits to primary schools in Warsaw. First school that we visited was the Canadian School of Warsaw, where we organized a workshop regarding our project. We have conducted these workshops with 6th grade students. These workshops helped students broaden their horizons and have introduced them to the CanSat competition. The students were able to learn more about how we design our Can, who our team is, and the many stages of the competition. Additionally, we distributed 3D printed pins to each student, these were designed by David G. in Fusion 360 by using the "Canvas" feature and later extruding a sketch of the logo's outline.

Consequently, we printed these on a PRUSA 3D printer, using PLA filament. These pins were aimed towards spreading knowledge about our project and allowing students or parents to follow us on our Instagram and broaden knowledge regarding our project. These workshops were particularly useful for our team, as we were able to see a more creative approach to our project. These students were particularly interested in how our Can is designed, printed and tested. Through our presentation we were able to explain, in detail, each step of the process. The second school that we plan on visiting is called International Trilingual School of Warsaw. The workshop is planned for the 30th of January, the agenda is very similar to the agenda for the workshop performed in the adian School of Warsaw.

The social media accounts, the website, the 3D tokens, and the workshops conducted in the primary schools, helped us with spreading our idea to different focus groups, which further enlarges the number of people who know about our project. Furthermore, it gave us the amazing opportunity to spread knowledge and inspire younger students to explore their passions.

9.7 Contact

Instagram:
https://www.instagram.com/terrasatcansat?utm_source=ig_web_button_share_sheet&igsh=ZDNlZDcMzIxNw==
Email:
Terrsat.cansat2025@gmail.com
Article:
Zespół TerraSat – uczestnik konkursu CanSat