AEROTRACKNOW

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1 Introduction

Precision is the future of small-scale spaceflight, and AeroTrackNow transforms that vision into practical reality. Our CanSat unites autonomous navigation, real-time data, and guided parafoil control to achieve a guided landing. Our project focuses on the integration of a guided parafoil recovery system with real-time telemetry and positioning capabilities, aiming to demonstrate controlled descent, navigation, and accurate landing within a designated recovery zone. In the process it is generating empirical data valuable for future autonomous recovery research.

The essence of our mission lies in combining precise flight control with advanced GNSS systems. By employing high-accuracy GNSS modules, barometric altitude sensing and LoRa-based telemetry, the CanSat will transmit flight data and positional coordinates throughout its descent. This data will enable the creation of a live flight map and status visualization on the ground, allowing for a detailed analysis of its trajectory and control response.

Our primary objective is to achieve a stable, predictable flight path and a targeted landing through parafoil deployment and servo-actuated steering mechanisms. The system is designed to autonomously respond to environmental factors and maintain controlled glide, serving as a proof of concept for cost-effective, small-scale aerial delivery or return systems.

This Preliminary Design Review (PDR) report outlines our team's technical concept, component selection, and design methodology. It presents the rationale behind our mechanical, electrical, and communication subsystems, as well as our testing plan and mission objectives. Beyond demonstrating precise landing and telemetry, our project emphasizes the broader application of autonomous flight control and real-time data tracking within compact aerospace platforms. We also seek to inspire younger students and the broader public by showing an alternative to traditional non-guided landings.

Through this project, we aim to showcase how innovation, interdisciplinary collaboration, and iterative design can merge into a system capable of emulating key aspects of satellite recovery and controlled descent missions. The following sections describe the engineering principles, mission plan, and development stages that form the foundation of our technical approach and our commitment to advancing the state of student aerospace experimentation.

1.1 Team Roles and Responsibilities

Within our project, teamwork is the foundation of our progress. Each member contributes specific skills in electronics, programming, mechanics, 3d design, and coordination, allowing us to work efficiently toward our end goal. Every Wednesday, the school organizes an official two-hour meeting where we discuss our progress with our supervisor. On weekends, we self-organize work sessions on Saturday and Sunday afternoons, each lasting around six hours, focused on prototyping and report writing. In addition to group meetings, each team member also works independently on assigned tasks resulting in an average individual workload of around 15 hours per week.

For daily communication, we use WhatsApp for quick updates and Microsoft Teams for structured calls and file sharing. This setup keeps all information accessible and helps us collaborate effectively even outside of dedicated meeting times. We mutually examine the work of each team member to ensure that everyone remains on course toward the defined objectives.

To stay organized and ensure steady progress, we use specific techniques to manage our work. At the start of each week, we plan our goals using a simple task board inspired by the Kanban method, which divides our work into stages such as "to do," "in progress," and "completed." This helps us visualize progress and quickly see which tasks need attention. We also use short review meetings called stand ups, where each member summarizes what they have finished, what they are working on, and any problems that need assistance. When developing hardware and software, we apply a cycle of building, testing, and improving until the results meet our expectations. This structured but practical approach allows us to work efficiently, remain focused, and make steady improvements every week.

The AeroTrackNow team is based on frameworks used in professional aerospace projects ensuring clear targets designated specifically for each team member, interdisciplinary collaboration, and continuous integration across all mission domains. Each role has defined deliverables, so the workload is managed efficiently.

Jakub Darowski - Project Manager
- Oversees the design of the whole system to ensure mechanical, electrical, and software subsystems operate coherently
- Leads the core design of the CanSat, selecting components and shaping both the internal layout and external structure
- Assesses Risk to decide whether to advance with actions, sets milestones for clarity and maintains the project schedule to establish organized work

Franciszek Józefczuk - Mechanical Engineer
- Oversees the steering geometry of the system and verifies that the configuration of the servos is in alignment to maintain a stable glide and land in the designated zone
- Defines operational weather constraints, accounts for different meteorological variables by alternating the system and mitigates the losses caused by adverse climate conditions.
- Designs an efficient recovery system that enhances post landing visibility and detection

Stanisław Gacek - Structural Engineer
- Designs the casing of the CanSat in fusion 360, ensuring all components fit properly and are well protected.
- Handles the 3D printing of all components, choosing the best materials, ensuring they are adequate to the mission.
- Works tightly with all team members ensuring all components cooperate accordingly in the casing

Matvey Shkel - Electrical and Software Engineer
- Oversees the design process of the PCBs, defining power, signal, and telemetry connections.
- Applies computational physics to PCB Design and develops avionic software, using CAD Modelling for system layouts.
- Integrates electrical systems with avionics and verifies signal quality, and communication reliability.

Szymon Krzowski - Technical Engineer
- Oversees and manufactures the parafoil system and its connection to the cansat to ensure safety and performance
- Manufactures the fail safe system around the descent and ensures mission reliability and guideline compliance.
- Maintains all project documentation, evidence, and version control, ensuring organized and traceable updates across the team.

Mikołaj Nowak - Community Outreach Coordinator
- Designs simple, clear materials such as slides, posters, and short summaries for events or media and keeps a record of all outreach activities and contacts with schools, media, and mentors.
- Manages communication with schools, media, and mentors, ensuring updates are clear, accurate, and aligned with the project's goals. He also manages financial issues.
- Writes and edits the main project reports, combining inputs from all subsystems into a consistent technical document.

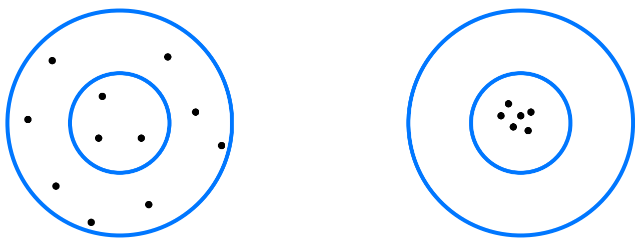
1.2 Mission Goals and Overview

For our primary mission, our objective is to measure and record the altitude of the CanSat during descent by using a BMP280 pressure and temperature sensor connected to a Teensy 4.0 microcontroller. The sensor will provide continuous measurements that will be transmitted at a rate of one hertz through a LoRa 433 MHz radio module equipped with a flex PCB antenna. These data will also be stored on an internal SD-card for later verification. By graphing received data values at the ground station, we will be able to calculate the descent rate of the CanSat.

For our secondary mission, we aim to demonstrate autonomous guidance and controlled descent using a parafoil steering system. The CanSat will adjust its flight path using two servo motors connected to the parafoil's suspension lines, enabling it to steer toward chosen landing coordinates. Guidance decisions will be based on data from the GNSS module, IMU, and barometer, allowing our onboard software to calculate relative position and orientation to the chosen landing point. Through this setup, the CanSat will autonomously correct its course to achieve a precise landing, demonstrating the potential of small autonomous systems for controlled aerial recovery. The data collected will also be transmitted via the LoRa radio module to the ground station where we can use it to create a three-dimensional flight path the CanSat took during its descent.

1.3 Research Direction and Scientific Background

This project investigates the concept of guided descent using a parafoil system controlled entirely by onboard software and electronics. The main research direction of our project is to create a method for steering small payload during descent to a very accurate landing point. Our idea is inspired by modern recovery systems of spacecrafts such as SpaceX's booster landings, which need to be very accurate to be fully recovered. Another example can be seen in the European Space Agency's Schiaparelli lander from the ExoMars mission, which attempted an autonomous descent on Mars using onboard sensors and control algorithms. A simplified guided landing system like the one we are developing could have helped in landing in a specific location in a controlled manner. These real-world applications show how precise control during descent can increase mission safety and reusability.



a) Passive Descent a) Guided Descent

Figure 1.3.1 - Comparison of landing dispersion between passive and guided descent systems

In future planetary missions such as the Rosalind Franklin rover from the ExoMars program that is expected to launch in 2028; a guidance approach similar to ours could assist in achieving a more precise and controlled landing. The concept of using real time sensor feedback to adjust descent trajectory can help reduce landing inaccuracy and improve the safety of surface deployment. Although our system functions on a much smaller scale, it demonstrates how compact electronics and simple control logic can contribute to solving the same challenges faced by large-scale missions, such as maintaining stability and accuracy during atmospheric entry and landing.

During the construction of our CanSat we aim to investigate and test different methods to improve landing accuracy and safety. Our main goal is to gain knowledge about how sensor data can be combined to steer our CanSat towards a precise landing point under different conditions. This will involve studying how changing data values from the GNSS receiver, barometer and IMU sensors can be used to correct the direction of travel and minimize the final distance from the target. The results of this research will help us better understand how basic guidance and control methods can improve landing precision in small aerial systems. By analyzing how our parafoil responds to sensor input and control adjustments, we hope to identify simple yet effective ways to increase accuracy and stability during descent. This knowledge can then be applied to future projects that explore autonomous flight and recovery.

2 System Design and Description

2.1 Mission Summary

During the primary mission our CanSat will measure its altitude throughout its descent using a BMP280 pressure and temperature sensor. The sensor is connected to a Teensy 4.0 microcontroller, which collects data and calculates altitude based on the barometric relationship between pressure and altitude:

$$h = \frac{RT}{gM} ln(\frac{P_0}{P})$$

This form of the barometric equation expresses the logarithmic decrease of pressure with height and is suitable for the calculation of altitude based on data from the BMP280 temperature and pressure sensor. After this, the data is transmitted once per second through a 433 MHz LoRa SX1262 radio module using a flexible PCB antenna. Simultaneously, all readings are saved to a microSD-Card for later verification. At the ground station the received data is plotted in real time allowing us to determine the descent rate of the CanSat.

As for our secondary mission, our CanSat will demonstrate fully autonomous guided descent using a controllable parafoil system. Our goal is for the CanSat to steer itself to a previously chosen or randomly generated landing spot after deployment, drastically improving landing precision compared to a passive parachute. The parafoil is controlled by two servo motors connected to suspension lines, which adjust the canopy's direction of flight. The control system uses input from an ArduSimple Micro ZED-X20P GNSS module and BNO085 IMU to determine position and orientation of the CanSat in real time. The ground station also sends RTK corrections to the can via a LoRa module and Yagi antenna for centimeter level precision. Based on these readings, the onboard software sends commands to the servos to gradually align the trajectory towards the selected landing coordinates.

All flight data are transmitted via the LoRa radio module to the ground station and also stored in the internal memory. At the ground station the received data is then used to create a three-dimensional flight path of our satellite.

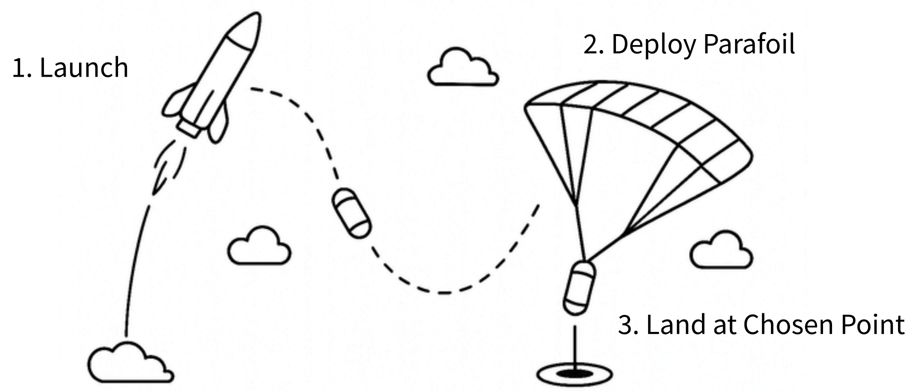


Figure 2.1.1 - Diagram outlining secondary mission

2.2 Structural Concept and Manufacturing

The structural design of the CanSat was designed using the educational edition of "Autodesk Fusion 360". Using our team members Bambulab X1 Carbon 3d printer, we printed initial prototypes of our casing. The X1 Carbon has an accuracy of up to 50 Microns, enabling us to implement detailed features into our model. Initially we used Polylactic acid (PLA) for our prototypes, however after getting accustomed with manufacturer recommendations we chose to acquire a range of different filaments. The materials we are currently working with are Polycarbonate (PC), Acrylonitrile Styrene Acrylate (ASA), and Thermoplastic Polyurethane (TPU). Our casing consists of five components; each precisely developed in the Fusion 360 software by our structural engineer:

Top Lid: The top lid houses the GNSS antenna, which only operates properly when there are no metals between the GNSS antenna and the GNSS satellites. The lid is printed using [redacted] which makes it a very impact resistant and also light component, with a mass of 9.53 g.

External Casing: Our external casing is optimally designed for the easiest access to all components, featuring a hollow interior and thick external walls to protect the internal casing. This part of our can is currently being tested with the [redacted] filament, as it provides a low density of 1.20 grams per centimeter cubed and an impact resistance of 34.8 kJ per meter squared. The can's design is secured with 8mm m4 type screws positioned on the top and bottom of the can. Furthermore, all internal components are protected by the casing, ensuring all internal parts stay intact when exposed to impacts. The weight of this component is 57.52 grams.

Servo Holder & Separator: The servo holder and separator are both components consisting of a main plate, separating components into 3 main sections (Battery compartment, main electronics and servo compartment). Both components are going to be printed using [redacted] as the rods used as supports have a thickness of 1 mm which makes them prone to breaking if any other material would have been used. The servo holder weighs only 10.77 grams, and the separator weighs 8.85 grams.

Internal Casing: The internal casing holds all the components together; it consists of 4 guiding rails which enable the Separator and Servo Holder to glide into the can. The Internal Casing is connected to the External casing via 2x m4 12mm screws. This component is currently being tested using [redacted] as it is an essential structural component of our can. The bottom of the Internal casing has 4x 8mm holes which help the bottom absorber connect with the casing. The internal casing weighs 20.83 grams

Bottom Impact Absorber: The impact absorber is going to be installed at the bottom of our can. The current prototypes are being tested using Bambu Lab's special [redacted] as it provides a low density of 1.18g/cm^3 and an impact strength of 124.2 kJ/m^2. TPU is an amazing impact absorber, which is why we are placing it at the bottom of the can to decrease the magnitudes of forces exerted on the main casing. The weight of the bottom absorber is 9.97 grams.

All components were tested prior to the PDR, ensuring that all parts fit within the Casing and that all components are durable enough to withstand large impacts. During [redacted]

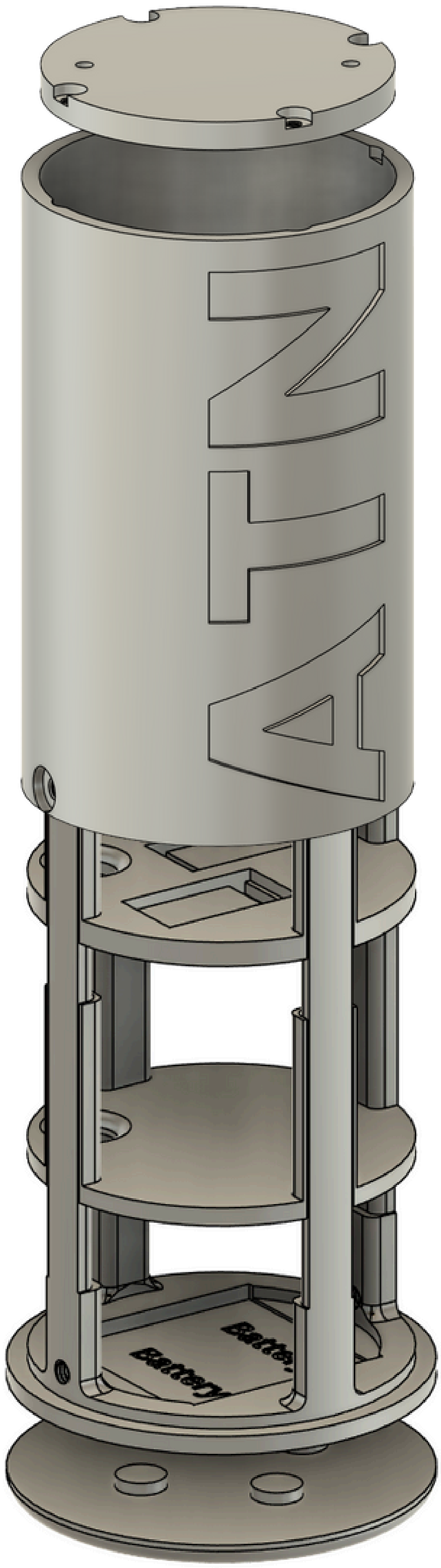


Figure 2.2.1 - The casing designed for the accommodation of all six components

2.3 Electronics Overview

2.3.1 PCB Development

The CanSat has 4 different PCB's that are stacked on top of each other. From the top the first PCB contains the GNSS module connected to a 3 stage 45mm antenna. The second PCB which can be seen in *figure 2.3.1.1* contains the Teensy 4.0, BMP280 sensor, BNO085, and a SD Card Holder, and finally the two servos which are placed on both sides of the can. The third PCB contains the LoRa SX1262-LF module alongside a flex PCB antenna. The fourth PCB contains two step-down converters, one 5V and one 3.3V.

The modules are connected using SMT board to board connectors which ensure stable electrical and mechanical connections between the stacked PCBs. These connectors prevent disconnection or signal loss even during impact with the ground or other objects. The components are mounted onto the PCBs using standard soldering techniques to complete all electronic pathways. Once all components and connectors are soldered in place, the PCBs will be mounted in a similar manner to the other layers in the 3D design of the CanSat, ensuring proper alignment and stability.

A 3D model of the second PCB was generated in KiCad to visualize the placement and interconnection of all components. The schematic libraries and footprints for the sensors and modules were imported directly from verified online sources to ensure accuracy and compatibility with the actual hardware.

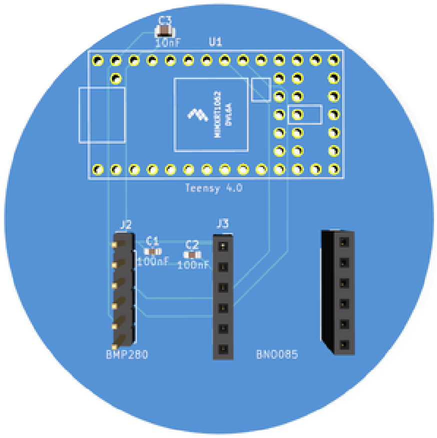


Figure 2.3.1.1 - Second PCB

2.3.2 Component Selection and Performance Evaluation

The selection of components for the CanSat was guided by the requirements of low mass, low power consumption, and high reliability under dynamic flight conditions. Each electronic subsystem was evaluated based on precision, communication compatibility, and integration feasibility.

For the main control unit, a Teensy 4.0 microcontroller was chosen due to its high processing performance in a small form factor and native 3.3 V compatibility with all onboard components. Its processing speed of 600 MHz enables real-time sensor data handling and precise control of the parafoil system.

The communication system uses the LoRa Core1262-LF module operating at 433MHz. It was chosen over the older SX127X family because it offers higher sensitivity, lower power consumption, and greater reliability under weak signal conditions. The Core1262 features improved noise immunity, which extends the practical range of communication while maintaining compliance with the 20 dBm power limit defined by competition regulations. For the antenna we chose the Taoglas 450MHz flexible PCB antenna. Our decision came from not being able to place a flexible omni-directional antenna on top of the CanSat because we chose to prioritize the placement of the GNSS antenna there, ensuring it maintains a clear view of the sky for maximum satellite visibility and positional accuracy. Additionally, the LoRa antenna cannot be placed within the field of view of the GNSS antenna, as this would introduce interference and reduce positional precision. Due to this, a flexible antenna that hugs the inside wall of the CanSat was chosen, as it allows us to maintain reliable communication while keeping all components within the required dimensions and avoiding interference with the parafoil deployment system.

For the GNSS system we decided to use the ArduSimple Micro u-blox ZED-X20P receiver paired with a compact 25x25mm L1 + L5 stacked active patch antenna (AGVLB256.A.07.0100AO). We decided to use a RTK receiver instead of a normal GNSS only module to get centimeter level precision thanks to RTK corrections which will allow us to have much better accuracy when landing. We also considered the older u-blox ZED-F9P which uses L1 and L2 bands, however we finally decided on the ZED-X20P since the L5 band is newer and more reliable than the L2 band. Additionally L1 + L5 dual band antennas are much more compact than their L1 + L2 counterparts. This combination allows us to reach centimeter precision while remaining lightweight and compact. Both the GNSS module and antenna are compatible with 3.3V logic systems allowing for easier wiring and no need for additional buck converters.

For orientation and stability monitoring, the BNO085 IMU was selected due to its reliable 9 axis fusion algorithm and built in calibration features, allowing accurate real time attitude estimation. The barometric and temperature measurements are handled by the BMP280 sensor, chosen for its accuracy, stability, and cost efficiency, providing altitude and temperature data essential for the primary mission.

For control of the parafoil, two Tower Pro MG92B 180° servo motors are used to actuate the parafoil steering lines. These servos were chosen for their high torque to weight ratio, high quality construction, and overall reliablitity.

The selected components provide the necessary accuracy, reliability, and low power use for the mission. Each part was chosen to work efficiently within the limited space and weight, ensuring stable operation and effective data transmission during the entire flight.

2.3.3 Power Delivery

The CanSat is powered by two Keeppower 16340 Li-ion batteries connected in series, which forms a 2S 7.4V configuration. Because each battery is 3.7V and 950mAh the total capacity will remain 950mAh since the cells are wired in series. This results in an energy content of around 7.0 Wh. The batteries are ideal for our CanSat as they have a high energy density and their dimensions allow us to place them at the bottom of the cylinder, further optimizing space.

Power from the battery is distributed through two separate step-down converters. A 5V step-down converter supplies the servos. For this task we selected the Pololu D24V22F5, a buck converter with a high efficiency of 85% - 95% and up to 2.5A of continuous current, which ensures that it is able to deliver peaks from the servo motors. A separate 3.3V buck converter powers the Teensy 4.0 microcontroller, GNSS receiver, IMU, Barometer and the LoRa module. This separation limits noise and minimizes interference with sensitive sensors.

Additionally, a low-dropout (LDO) regulator is used to supply the GNSS module with a stable 3.3 V, ensuring accurate signal processing even during power fluctuations. Decoupling capacitors are also placed close to the GNSS and other sensitive components to smooth voltage transients and reduce electrical noise.

Power is supplied through a two-wire JST-PH connector that links the battery pack to the main power rail of the CanSat. The two 16340 lithium-ion cells are wired in series and monitored externally during ground testing to ensure safe voltage levels before launch. A standard two-wire connection was chosen for simplicity and reduced weight.

The table below shows average power use of each subsystem over the 4–6 h active time of the CanSat.

Component (Type)	V (V)	I_{avg} (mA)	Duty (%)	P_{avg} (W)
Teensy 4.0 (Microcontroller)	3.3	80	100	0.26
u-blox ZED-X20P (GNSS Receiver)	3.3	65	60	0.13
LoRa Core1262-LF (Radio Module)	3.3	15	100	0.05
BNO085 (IMU)	3.3	6	60	0.01
BMP280(Barometer)	3.3	0.3	60	0.001
microSD Module (Data Storage)	3.3	20	20	0.013
MG92B x2 (Servos)	5.0	-	Descent	0.02
Converter losses	-	-	-	0.07
Total Average	-	-	-	0.55

Although the total average power consumption remains below one watt, the two 16340 cells provide a large safety margin. This ensures reliable operation during the required 4–6 hour active time, even under colder conditions or unexpected current spikes. The additional capacity also stabilizes voltage during servo activity and communication peaks, helping maintain consistent performance and measurement accuracy throughout the mission.

2.4 Software Plan and Overview

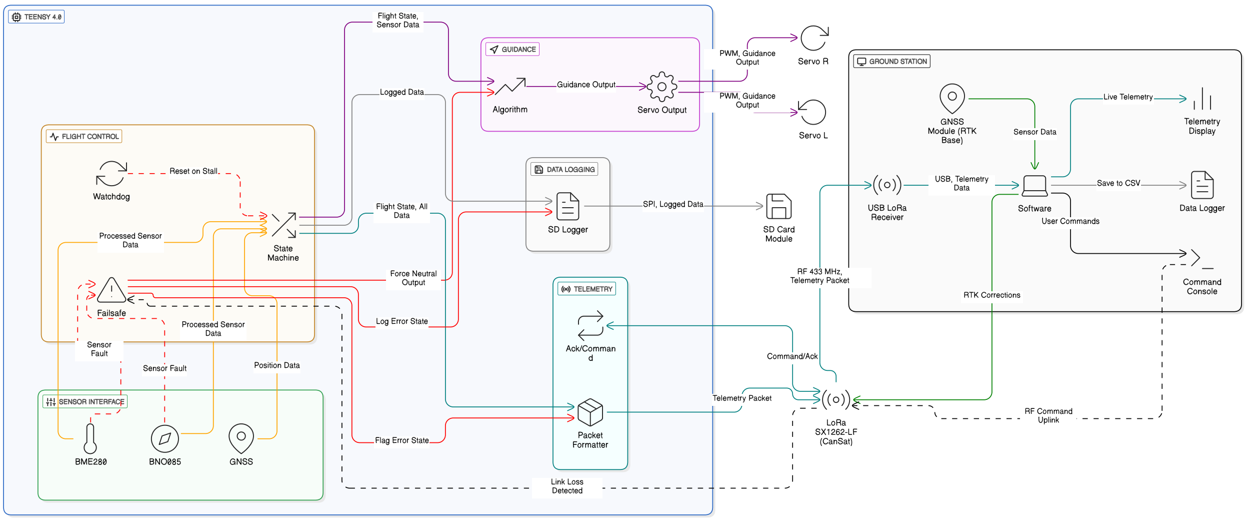


Figure 2.4.1 - Onboard software architecture and data flow

The onboard software manages all CanSat functions including sensing, control, telemetry, and power regulation. It runs on a Teensy 4.0 microcontroller (600 MHz) using an event-driven architecture that ensures reliable real-time performance across all flight phases.

The software continuously acquires data from the BMP280, BNO085, and GNSS modules, synchronizing all sensor inputs for accurate state estimation. Guidance and control algorithms process this data to adjust the parachute through two MG90S servos at 10–20 Hz, maintaining stable flight and trajectory correction toward the target.

Telemetry and communication are handled through a LoRa SX1262-LF transceiver, which operates in bidirectional mode. The system receives RTK correction data from the ground station while transmitting telemetry once per second and simultaneously storing identical data on the SD card for redundancy. A mission sequencer oversees all stages of the flight, from initialization to landing, coordinating subsystem activity and ensuring autonomous operation even during temporary link loss.

The overall software structure, shown in Figure 2.3.1, demonstrates the integration of sensing, communication, and control within a modular and fault-tolerant design.

2.4.1 Radio Link and Telemetry

2.4.1.1 Radio Communication (CanSat)

The CanSat uses a LoRa SX1262-LF transceiver operating at 433 MHz for bidirectional communication with the ground station. The onboard software manages continuous reception of RTK correction data and periodic transmission of telemetry packets. To prioritize accurate GNSS positioning, the radio remains in receive mode for about 80–90% of the time, collecting RTK correction messages from the ground station. Every second, it briefly switches to transmit mode to send telemetry data containing altitude, pressure, temperature, and orientation readings. This communication schedule minimizes packet collisions and ensures stable reception of RTK data while maintaining a consistent telemetry downlink.

2.4.1.2 Radio Communication (Ground Station)

The ground station operates in a complementary mode to the CanSat, using the same LoRa SX1262-LF transceiver with a directional antenna. It continuously transmits RTK correction messages while remaining ready to receive telemetry packets from the CanSat every second. The timing and operation of both systems are synchronized in software to ensure that transmission and reception intervals do not overlap. All received telemetry is decoded, visualized in real time, and stored for later analysis, ensuring reliable and efficient two-way communication throughout the mission.

2.5 Recovery

The recovery system uses a parafoil to combine safe descent with guided landing. A lower sink rate increases available glide time and horizontal reach, so we target 5–6 m/s (nominal 5.5 m/s), the lower end of the regulations. To calculate the surface area of the parafoil we used the lift equilibrium equation:

$$S = \frac{2W}{pV^2C_L}$$

We substitute weight for lift force since during descent with constant speed the forces are balanced therefore lift force must be equal to weight. Because of this, $W = 0.35kg \times 9.81ms^{-2} = 3.42N$. p is air density and is therefore equal to $1.2kgm^{-3}$. To calculate V which is true airspeed we must first aim for a certain glide ratio (often written as $G = L/D$ or as the ratio of horizontal distance to vertical distance). For our parafoil we decided on an ambitious but achievable glide ratio of 2.0. Now we can get the true airspeed from Pythagoras: $V = \sqrt{V_x^2 + V_z^2}$. Because the glide ratio is 2.0 and we take the sink rate of 5.5m/s which is what we are aiming for than the horizontal speed will be $2 \times 5.5 = 11ms^{-1}$. Therefore ,$V = \sqrt{11^2 + 5.5^2} = 12.3ms^{-1}$. For the lift coefficient (C_L) we used a value of 0.9, which from our research is a realistic average value for small parafoils. From these values we can calculate wing surface area to be:

$$S = \frac{2 \times 3.43N}{1.2kgm^{-3} \times (12.3ms^{-1})^2 \times 0.9} \approx 0.042m^2$$

For the first prototype of the parafoil we rounded the surface area up to 0.05m^2 due to the fabric stretch and curvature reducing the effective projected area by 5-10%. A slightly larger flat surface area compensates for this.

The materials used to create the first prototype are as follows. For the main canopy 20D ripstop polyester was chosen for its low weight, high tear resistance, and minimal porosity, which improves aerodynamic stability and reliability. 40D ripstop nylon is used for the ribs to provide a higher amount of structural strength without significantly compromising on mass. Finally, the reinforcements around line attachment points are made from 70D ripstop nylon to prevent the deformation of fabric under tension from the lines.

For the suspension and steering lines, Spectra (UHMWPE) braided lines were selected due to their tensile strength and minimal weight. The lines also have a smooth surface which reduces friction between the lines and contact points on the CanSat during servo operation. The line diameters are also optimized, thinner lines for suspension to minimize drag, and thicker ones for risers to ensure structural integrity.

The parafoil lines are pulled by two servo motors which allows for precise steering and the location of the CanSat is frequently transmitted to ensure that everything is working correctly. Due to our secondary mission being precise landing in a chosen point with an accuracy of 1 meter; If our mission succeeds it will allow us to find the CanSat quickly and efficiently since it lands at known coordinates.

Additionally, to ensure the CanSat is found in, for instance, tall grass, we also added an 85B buzzer that we tested to be audible from over 100 meters in ideal conditions.

Currently, we already have all materials needed to sew the parafoil and are planning to do so next week. We also have stencils ready for each part of our parafoil, which can be seen in Figure 2.5.1.

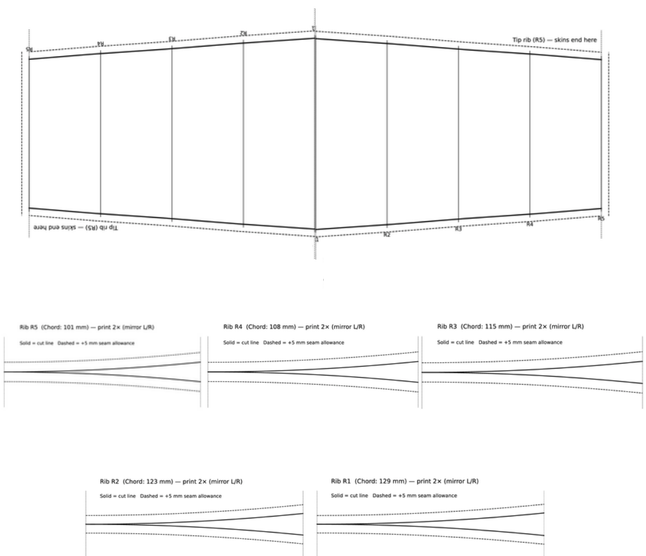


Figure 2.5.1 - Parafoil Stencils

2.6 Ground Hardware Equipment and Software Interface

2.6.1 Ground Station Hardware Selection and Justification

The components in the ground station are as important as the components in the CanSat because our secondary mission heavily relies on RTK corrections sent from the base station. Therefore, we not only need a LoRa module and antenna, but also a GNSS receiver and antenna. For the GNSS receiver we chose the ArduSimple SimpleRTK4 Optimum, due to it being based on the same u-blox module (ZED-X20P) as the receiver in our CanSat. For the GNSS antenna we chose the Calibrated Survey GNSS Tripleband + L-band antenna from ArduSimple, because of it being dedicated for ground stations and its high immunity to interference.

For the radio link we decided to use the USB LoRa stick (Waveshare 24513). It is simple to use and easily integrates with a laptop. For the antenna we decided to use the WiMo Yagis 432 MHz, and specifically the WY-7010 variant. It was chosen due to its high gain of 11.5 dBd and narrow beamwidth, which significantly improves signal quality.

2.6.2 Data Visualization and Tracking Software

During the mission, the CanSat continuously transmits telemetry data, including GNSS position, altitude, and atmospheric measurements, to the ground station via the 433 MHz LoRa link. The ground station software receives and decodes this data in real time, plotting parameters such as altitude and velocity while displaying the CanSats trajectory on a 3D interactive flight map. At the same time, RTK correction data is generated at the ground station and sent back to the CanSat, improving positional accuracy drastically and allowing for centimeter precision. This bidirectional communication process enables live visualization, precise tracking, and easier recovery.

2.7 Safety, Access, and Power Controls

The battery compartment is easily accessible by unscrewing 2x m4 screws from the base of the can and 4x m3 screws from the top lid. During initial testing, the process of removing the external casing and removing a simulated danger took 35.8s. The speed at which we can remove the battery is crucial, as Lithium Ion batteries can ignite rapidly and harm the surrounding electronics.

The open design of our casing enables all components to be easily accessed in case of an emergency. Furthermore, the separator and servo holder are each able to slide out easily to allow for adjustments to be made on each individual section.

As mandated by the regulations, our casing contains a master shut-off switch, which cuts off the power supply to all electrical components. It is located between the batteries and the buck converters, ensuring that power gets cut off to both the 5V and 3.3V logic rails

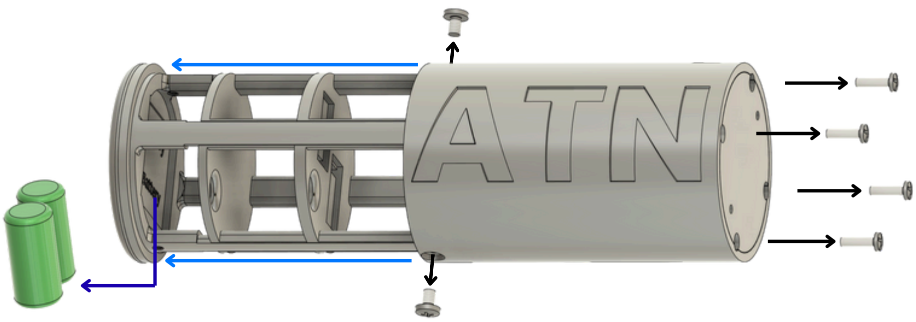


Figure 2.7.1 - shows the CanSat emergency removal system

2.8 Onboard User Interface

A single push button is mounted on the CanSat body to serve as a manual control interface. After landing, pressing the button marks the CanSat as retrieved by triggering a confirmation signal in the telemetry stream and deactivating the active buzzer. This ensures the recovery team can safely handle the CanSat and log mission completion without connecting to the internal electronics.

3 Testing Program

3.1 Environmental and Sensor Calibration

BMP280 Test:

This test verified the reliability of altitude readings from the BMP280 using the hypsometric formula. The sensor was connected to the Teensy 4.0, and data were collected while walking through a four-story house, from the ground floor up to the second and then down to the basement.

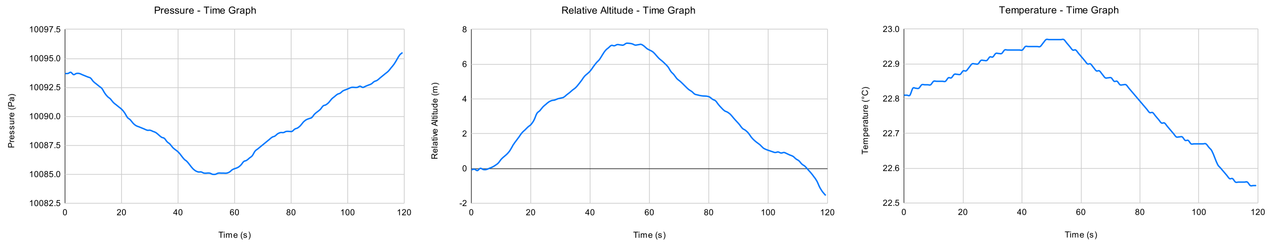


Figure 3.1.1 - BMP280 Graphs (from left): Pressure-Time, Relative Altitude-Time, Temperature-Time

The resulting pressure–time and altitude–time graphs seen in figure 3.1.1 showed smooth, consistent changes matching the expected floor height differences (~3 m per level). The readings confirmed correct sensor calibration and reliable altitude calculation. As we expected the temperature increased with relative altitude. The test was therefore deemed successful and suitable for in-flight measurements. The circuit diagram for this test can be seen in figure 3.1.2.

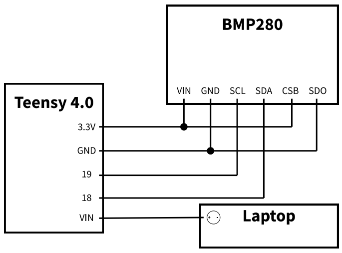


Figure 3.1.2 - BMP280 Circuit Diagram

BNO85 Test:

This test confirmed the proper functioning of the BNO085 IMU, responsible for measuring acceleration and orientation. The sensor was connected to the Teensy 4.0, and data for acceleration and rotation were recorded while the unit was slowly tilted and rotated by hand.

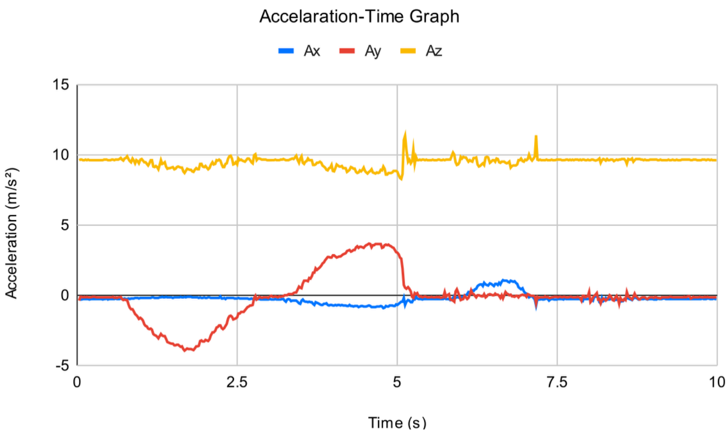


Figure 3.1.3 - Acceleration-Time Graph

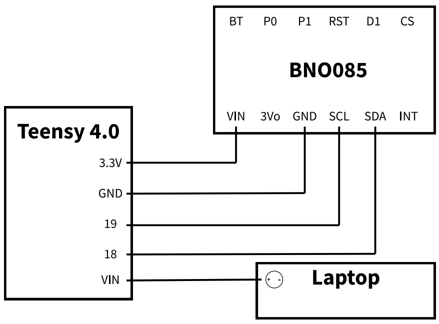


Figure 3.1.4 - BNO085 Circuit Diagram

The output graphs (figure 3.1.3) showed clear, consistent variations in all three axes corresponding to the performed motions, confirming accurate and stable sensor readings. The test was considered successful, proving the BNO085 is ready for in-flight attitude tracking. The circuit diagram for this test can be seen in figure 3.1.4.

GNSS Module Test:

Once the already ordered GNSS receiver will arrive, this test will verify that the RTK GNSS provides accurate position measurements. We will place several ground markers at known, tape-measured distances (for example 5 m and 10 m apart) and record GNSS readings at each location. The measured distances between the points will then be compared to the known separations. The test will be considered successful if the calculated distances differ by less than a few centimeters, confirming that the RTK GNSS operates correctly and maintains centimeter-level precision.

3.2 Telemetry and Communication

Lora SX1262-LF Test:

The LoRa SX1262-LF module was tested to verify long-range communication and signal stability. The transmitter on the Teensy 4.0 continuously sent heartbeat messages to a Waveshare LoRa USB receiver at 433 MHz, and the received signal strength (RSSI) was logged.

Results showed stable transmission and consistent RSSI values (around –60 dBm at short range), confirming that the link functions as expected. The test was therefore deemed successful for use in telemetry transmission.

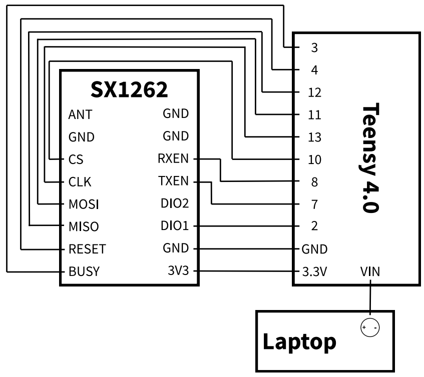


Figure 3.2.1 - LoRa SX1262 Circuit Diagram

3.3 Power and Electrical Verification

Once we receive all components this test will measure current draw and total energy usage of the entire CanSat system during operation. Using a multimeter and USB power meter, current will be recorded during idle, transmission, and active sensing phases. The purpose is to verify that total consumption remains within the capacity of the selected power source, ensuring sufficient battery life for the entire mission. The data will inform whether optimization or duty cycling is required before launch.

3.4 Parafoil Tests

This test aims to verify the proper deployment of the parafoil and to measure the resulting descent rate. The CanSat will be released from a low altitude, and the onboard sensors (BMP280 and IMU) will record altitude and motion data throughout the descent. The measured drop rate will then be compared with the predicted value from simulation. The test will be considered successful if the parafoil deploys reliably and the descent velocity remains within the expected range of 5–6 m/s. The collected data will also be used to refine the parafoil's design and improve flight stability and control in future iterations.

3.5 Combined System Evaluation

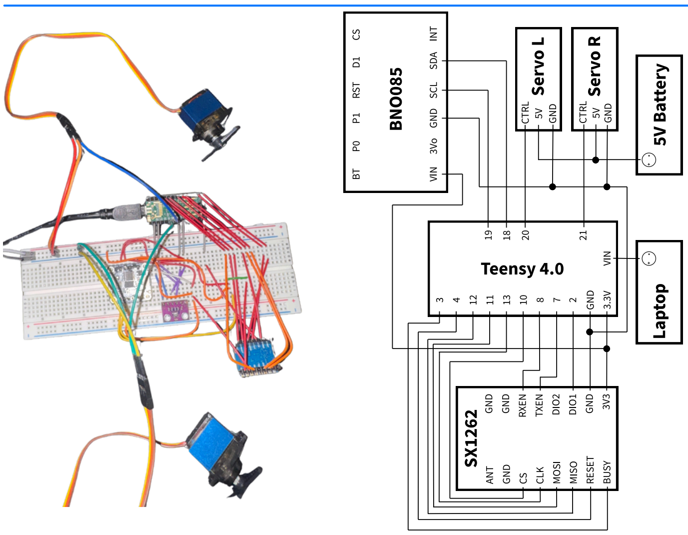


Figure 3.5.1 - Proof of concept wiring and circuit diagram

A proof-of-concept test was conducted to verify the interaction between key subsystems, the IMU, servos, and LoRa communication. Tilting the sensor caused the corresponding servo to turn, while orientation and servo angle data were successfully transmitted via LoRa to a ground receiver. This confirmed correct sensor-actuator response and stable wireless data transmission. The wiring and circuit diagram can be seen in figure 3.5.1. A future full-scale test will integrate all CanSat components, including the GNSS, power system and parafoil, to evaluate complete in-flight performance and data reliability under real mission conditions.

4 Scientific Approach and Data Methodology

4.1 Scientific Approach and Data Methodology

Our scientific approach is built on structured experimentation, quantitative measurement, and continuous refinement of results. The main research objective is to determine how combining live data from all sensors, integrating information from the GNSS, barometer, and IMU, improves landing precision and flight stability in a guided parafoil system. The investigation focuses on whether real time corrections generated by onboard algorithms can consistently reduce landing error to within a one-meter radius. Our working hypothesis is that fusing data from these sensors in real time will significantly improve descent control and accuracy compared to a passive parachute.

The data collection strategy follows an evidence-based process. Each subsystem is tested individually to establish baseline readings and later integrated into a single data workflow managed by the flight computer. Altitude and vertical velocity are calculated from barometric pressure using the logarithmic hypsometric equation. GNSS readings provide accurate geographic coordinates and altitude, while the IMU measures orientation, angular rate, and acceleration. These inputs are synchronized with timestamps, filtered to eliminate signal noise, and compared with ground station logs for validation.

Data is transmitted through LoRa telemetry to the ground station and stored simultaneously on the SD card for redundancy. The CanSat also measures and transmits air temperature and pressure during flight, ensuring compliance with the mission's primary objectives. The ground station software receives, decodes, and logs all incoming telemetry, visualizing the CanSat live flight path on a three-dimensional flight path. This system allows real-time monitoring of flight performance and provides complete data recovery even in the event of transmission interruptions.

4.2 Technical Challenges and Solutions

AeroTrackNow faces key technical challenges, including precise navigation in changing flight conditions, maintaining stable power and communication links, and keeping structural balance within the small CanSat frame. Overcoming these challenges requires careful design, testing, and integration across all subsystems to achieve reliable and precise mission performance.

1. Navigation and Sensor Integration

Reliable altitude and position are essential for control and post-flight validation. The system fuses u-blox ZED-X20P GNSS and BMP280 barometer data with aligned timestamps. Altitude is calculated from the hypsometric equation with temperature and local QNH, then converted to height above ground using the launch-site elevation. GNSS RTK corrections from the ground station refine landing accuracy. Planned checks include static barometer calibration, GNSS lock-time measurement, and consistency between calculated and measured descent profiles.

2. Power Integrity and Electrical Resilience

Servo actuation can cause voltage dips that threaten stability. A two-stage supply using an LM2596 buck regulator followed by a low dropout LDO delivers clean 3.3 V to the flight computer, while servos run on a separate 5 V rail. Power stays stable by keeping the servo and logic rails separate, using short, thicker power leads, and adding a small power buffer on the 5 V servo line. A separate ground return keeps motor noise away from the 3.3 V rail. We will run repeated servo sweeps while the Teensy logs rail voltage. It passes if 3.3 V stays in range and there are no resets

3. Telemetry Continuity and Data Reliability

A dependable link is vital for mission control and data quality. The LoRa SX1262 LF at 433 MHz sends packets with CRC and sequence validation, and all data are also written to the SD card. Integration tests will register range and telemetry transmissions loss to verify more than 95 percent delivery under line of sight. A post-flight comparison will confirm full traceability between received and stored data.

4.3 Project Evaluation and Reflection

4.3.1 Knowlage Gained

Our secondary mission involved several complex elements related to flight control and targeted movement, areas in which we initially had limited experience. To achieve our objectives, we developed a range of essential technical skills. We began by studying and testing our main electronic components, including the BMP280, LoRa SX1262 LF, ZED-F9P GNSS module, and the Teensy 4.0 flight computer. Each component required careful calibration to achieve a positional accuracy of approximately one meter from the target point, which was a critical requirement for our mission.

We also learned how to integrate all electronic subsystems so that each module operates in full synchrony, ensuring that the collected data remains accurate and consistent during flight. Through collaboration with BalticSpace engineers we gained valuable insight into PCB design, a skill that will be fundamental in future stages of our project when developing a fully autonomous flight platform. Another major challenge was understanding the GNSS system in detail, particularly the placement of the antenna, which must remain unobstructed to minimize signal noise and delay while improving positional precision.

Beyond the electronics work we studied the aerodynamic properties of parafoils under various environmental conditions, including high winds. This research confirmed that a parafoil offers superior control and the ability to travel upwind, making it ideal for precise and stable flight paths even in challenging conditions.

4.3.2 Future Applications

In the future our CanSat equipped with an autonomous parafoil system could serve as a precise and reliable delivery platform requiring no human control after launch. The destination coordinates would be preloaded before deployment, allowing the onboard sensors and control software to guide the system independently. Unlike motor powered delivery drones, this design can cover greater distances with lower energy consumption thanks to its gliding efficiency. Compared with standard parachutes that drift with the wind, the guided parafoil continuously adjusts its trajectory using onboard servos, achieving highly accurate landings even in unstable atmospheric conditions.

One potential example where such a system could have been valuable is the Mars Pathfinder mission, in which controlled descent was critical to placing the Sojourner rover precisely on the Martian surface. A guided parafoil similar to ours could have minimized atmospheric drift and improved landing accuracy. Another possible application is the enhancement of the European Space Agency's Space Rider parafoil, a system under development for controlled reentry missions. A system based on our CanSat could reduce recovery time for astronauts and payloads by autonomously directing the returning craft toward a predetermined and prepared landing zone.

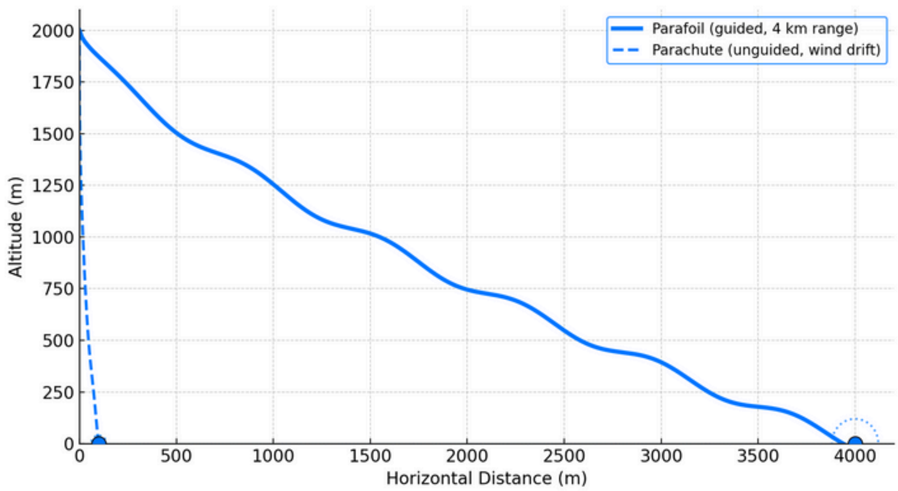


Figure 4.3.2.1 - Comparison of Parafoil and Parachute Descent Profiles

5 Project Management

5.1 Work Progress and Achieved Milestones

Task	Due Date	Status
Gather the team and assign roles	10.09.2025	Completed
Establishing the secondary mission	12.09.2025	Completed
Creating a website and Instagram page	15.09.2025	Completed
Filament testing and printer calibration	17.09.2025	Completed
Preliminary list of mission components	20.09.2025	Completed
First 3d Design prototype	23.09.2025	Completed
Ordering all Components	26.09. 2025	Completed
Strength testing of the casing	28.09.2025	Completed
Securing a sponsorship from PowerBoats	01.10.2025	Completed
Wiring assembly initiated	02.10.2025	Completed
System code integration for testing	04.10.2025	Completed
Creating Parafoil Stencils	07.10.2025	Completed
Presentation at the School Assemblies	08.10.2025	Completed
Testing Components (Exculding GNSS)	11.10.2025	Completed
Published Article in Kosmonatua.net	13.10.2025	Completed
Final casing design for the PDR	14.10.2025	Completed
Meeting with “True” brand representatives	18.10.2025	Completed
Submition of the PDR	19.10.2025	Completed
Conduct workshops for primary schools	23.10.2025	Completed
Complete wiring and harness layout	03.11.2025	To do
Power system verification and load testing	18.11.2025	To do
Parafoil sewing and line attachment	04.12.2025	To do
System Software Integration	15.12.2025	To do
Guidance algorithm implementation	20.12.2025	To do
First full integration test	06.01.2025	To do
Field test #1 – stabilized descent	13.01.2025	To do
Field test #2 – guided flight attempt	15.01.2025	To do
Submition of the CDR	18.01.2025	To do
Field test #3 - Full flight test	15.02.2025	To do
Second run of workshops in schools	20.03.2025	To do
Ground-station RTK + mapping validation	22.03.2025	To do
Submition of the FDR	29.03.2025	To do
Field test #4 – final guided descent	10.04.2025	To do
Official CanSat starting campaign	18.04.2025	To do
Mission Presentations	26.04.2025	To do
Develop our idea into a scalable prototype	01.05.2025	To do
Begin product commercialization	01.09.2025	To do

5.2 Risk Evaluation and Mitigation

Managing risk is essential to mission reliability and safety. Each potential hazard is carefully analyzed across hardware, software, and operations, with preventive measures applied early and verification tests confirming that mitigation strategies are effective before flight.

1. Environmental Factors

Wind, temperature, and pressure affect glide and sensor bias, so the system adapts in real time within defined weather limits. During flight the BMP 280 continuously measures temperature and pressure to update air density and vertical rate estimates, and wind is derived from GNSS ground track drift together with barometric descent rate. The landing zone remains fixed, and we adjust only the approach: lower bank angles and turn rates in stronger winds, use wider and shallower S-curves with longer wings-level legs, and trigger the flare earlier when descent rate increases.

2. Loss of Control During Descent

The main risks for the autonomous parafoil CanSat come from brief software errors, sensor dropouts, actuator, cable faults, or power loss. Any of these can cause unexpected turns, push the CanSat off course, or lead to speeds outside the safe range, increasing the chance of leaving the recovery area. To solve these risks, the system integrates fused GNSS, IMU, and barometric data for stable navigation, and maintains continuous LoRa telemetry with onboard SD logging to ensure full data traceability.

To mitigate these risks, the system is set up to default to a neutral, flat glide if control is lost, so it behaves like a standard parachute instead of steering away. We set the neutral by adjusting both steering lines to equal length during ground tests until the parafoil glides straight and stable, then save that position so the system automatically returns to it if control is lost. Steering system is limited to prevent aggressive turns, simple geofencing keeps approaches aimed at the target area, and the parafoils natural drag keeps the descent within the allowed speed band. Even without guidance, the stable glide gives a controlled, predictable landing inside the zone.

5.3 Budget Planning and Resources

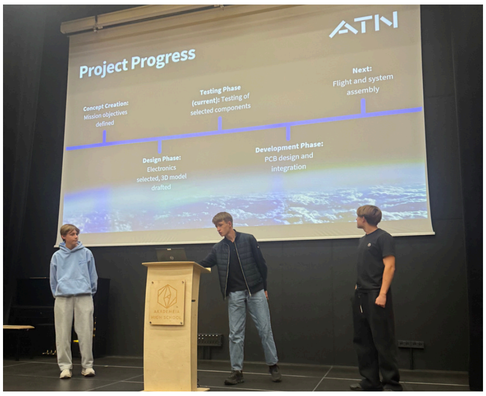
After planning out the costs of all components needed for testing and prototyping, we managed to acquire 3000.00 PLN from a range of sponsors. By focusing on purchasing the components directly from manufacturers we managed to optimize the total cost of our can. We calculated the cost of our filaments using data available from Bambu Labs studio. We estimate the cost of our CanSat to be 2415.12 PLN, which includes all parts used. This cost also includes estimates for parts we plan to use in the future.

Component	Name	Weight (g)	Price (PLN)
Microcontroller	Teensy 4.0	2.8	129.90
GNSS Receiver	ZED-X20P Micro	6.0	1318.10
GNSS Antenna	AGVLB256.A.07.0100AO	30.0	119.88
IMU	BNO085	6.0	135.00
2x m3 & 4x m4 screws	Combination head screws	9.4	4.50
SD Card & Holder	Sandisk 16GB & Pololu 2597	1.5	33.71
2x Servo Motors	TowerPro MG928	27.6	138.00
Barometer + Temp	BMP280	0.6	9.90
2x Battery	Keeppower 16340	37.0	77,68
Converters	Pololu D24V10F3 & D24V22F5	8.0	111.80
LoRa Module	Core1262-LF 433MHz	9.1	63.05
Polycarbonate (PC)	Bambu Labs PC	117.5	21.70
TPU Filament	Bambu Labs TPU 90A	10.0	1.90
Others	PCBs, Capacitors, etc.	est. 70	est. 250.00
Total:	-	335.5	2415.12

6 Outreach and Coordination

6.1 Media Presence and Articles

Since the beginning of our project, we have been consistently expanding our outreach efforts to promote our CanSat project to a wider audience. Firstly, following our request, we were given the opportunity to present our project during a school assembly in front of 5th and 6th form students, showcased our project to well **over 300 people** in total. This allowed us to share the vision and technical details of our CanSat with our school community and spark interest among our peers. The presentation not only helped inform others about our mission but also inspired many students to follow our path, potentially taking part in future editions of the CanSat competition.



Our Instagram page, @aerotracknow, is continuously growing and in this moment already has over **385 followers**, with regular engagement on our posts. We post regular updates on our story, including behind-the-scenes looks at our progress and events. In the last month, since we started the CanSat, we've reached over **7,000 views** in total on our posts.

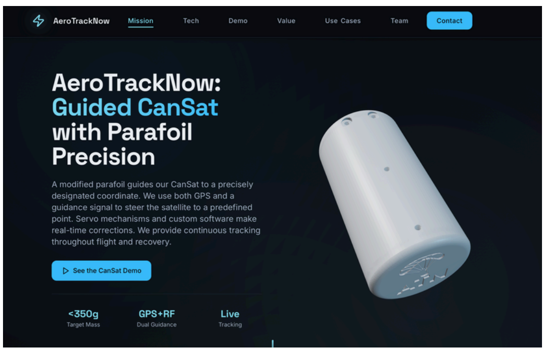
Another one of our initiatives was an interactive presentation and workshop with primary school students from a local school in our area. We introduced key concepts regarding the CanSat project, outlining the missions and stages of the competition. Next, we encouraged them to brainstorm ideas for a Secondary Mission, collected their suggestions, and demonstrated how these ideas could be turned into real, feasible projects. Finally, we conducted a fun practical activity using butane and water to engage the students in building a working model rocket.

The workshop was a great success — we received very positive feedback from the enthusiastic students we worked with. We are now planning to organize another workshop soon to share our passion for space exploration with an even larger group of young learners.

In addition to our presentations and social media growth, we are proud to share that we have **written and published an article** about our project on **Kosmonauta.net**, a leading Polish platform for space and science news.

The article is an overview, highlighting our mission objectives, technical details, and team goals, helping us spread the word about our idea. We purposefully made it concise, but with all our crucial details, to make it accessible to a very wide audience. Article:

https://kosmonauta.net/2025/10/aerotracknow-druzyna-bioraca-udzial-w-konkursie-cansat-2025-2026/



Anyone can also learn more about our team, mission details, and creatively engage with our CanSat on our interactive website: aerotracknow.com. On there you can find a simulation of our landing, where the preliminary conditions can be chosen however you like, and see the precision of our system. There are also ways of contacting us, details about our project's real-life application and many other facts about us and our work. We have created it in order to provide an intuitive use for everyone to learn, interact and see the joy that our project can bring.

Through all these efforts, our outreach program continues to serve its main purpose: to inform, inspire, and attract support for our CanSat project. With a growing online presence, community engagement, and published content, we aim to demonstrate our work to everyone, not only science-focused students. We only aim for the top, hence we will continue improving our project in every aspect possible, including its outreach.

6.2 Sponsors and industrial partners

Already before the first deadline of the competition, our team has gathered several ambitious and helpful sponsors and partners, who believe in us and support our journey.

The first of our sponsors is the Polish company **Power Boats Poland**. This firm specializes in the distribution of luxury boats and yachts. We are very proud of this sponsorship as our goals have a lot in common.

Our soon to be sponsor, **True**, is a male skin care producer, which also eagerly got engaged with our project through a recent meeting we conducted presenting our current achievements and future possibilities, even though, at first glance, our work does not have much similarity with their's. We are especially proud of this because we are gaining interest from people and organizations of all types of specialization, not only centered around physics and the cosmos.

We also contacted both **POLSA** as well as **CreoTech** to conduct meetings that will support us in future development and application of our cansat in real world scenarios. CreoTech is a space tech company working with the production of satellites as well as their internal components. The cooperation with POLSA, the official Polish space agency, will allow us to further explore our CanSat space application possibilities.

Also, as a major partnership, we have gotten engaged with **BalticSpace**, a Polish non-profit organization focused on developing the European space sector by making suborbital research more accesible. We have already met once with members of the organization in the form of an open talk about our project and received helpful tips. Their expertise is and will be of very significant use to the development of our project.

7 Design Summary

Parameter	Figure	Unit/Notes
Height of the CanSat	115 + 40	mm
Diameter of the CanSat	66	mm
Mass of the CanSat	335.5	g
Descent Rate	5.5	m/s
Operating Voltage	3.3/5	V
Telemetry radio frequency	433	MHz
Estimated time on battery	6.43	h
Target Landing Accuracy	≤1	m
Cost of the CanSat	2415.2	PLN