Critical Design Review

Team Euclidean
Team Number : 2024-ASI-ROCKETRY-063
RITM0012869

July 9, 2025

Contents

Abbreviations Used

BOM = Bill of Materials
PDR = Preliminary Design Report
PCB = Printed Circuit Board
GCS = Ground Control Station
CDR = Critical Design Review
GNSS = Global Navigation Satellite System
MCU = Microcontroller Unit
SD Card = Secure Digital Card
FSW = Flight Software
RTOS = Real Time Operating System
API = Application programming interface
CSP = Cubesat Space Protocol
I2C = Inter-Integrated Circuit
SPI = Serial Peripheral Interface
CAN = Controller Area Network
MAC = Media Access Control
TCP/IP = Transmission Control Protocol/Internet Protocol
LED = Light Emitting Diode
RTC = Real Time Clock
LDO = Low-Dropout Regulator
CAD = Computer Aided Design

Chapter 1

Team Composition and Management

The team is composed of the following members:

Sl.no	Full Name	Role
1	Dr. Krishna Sesha Giri	Faculty Advisor
2	Dr. Anoop Akkoorath Mana	Mentor

Table 1.1: Team Composition

Sl. No	Full Name	Course	Branch	Year of Graduation	Role
1	Kevin R Jacob	B-Tech	Electrical Engg.	2025	Team Lead and Avionics
2	Aditya Ravindra Sonawane	B-Tech	Mechanical Engg.	2027	Structural Design
3	Siva K M R	B-Tech	Electrical Engg.	2025	Launch and Recovery Part
4	Ashwin R Nair	B-Tech	Electrical Engg.	2025	Launch and Recovery Part
5	Shri Gokul K	B-Tech	Electrical Engg.	2025	Avionics Lead
6	Krishna Murari	B-Tech	Mechanical Engg.	2025	Structural Design
7	Divya Aryanshu M	B-Tech	Mechanical Engg.	2025	Rocket Motor Design
8	Bonkuri Venu	B-Tech	Electrical Engg.	2025	Flight Software Configuration

The Team Hierarchy is given by:

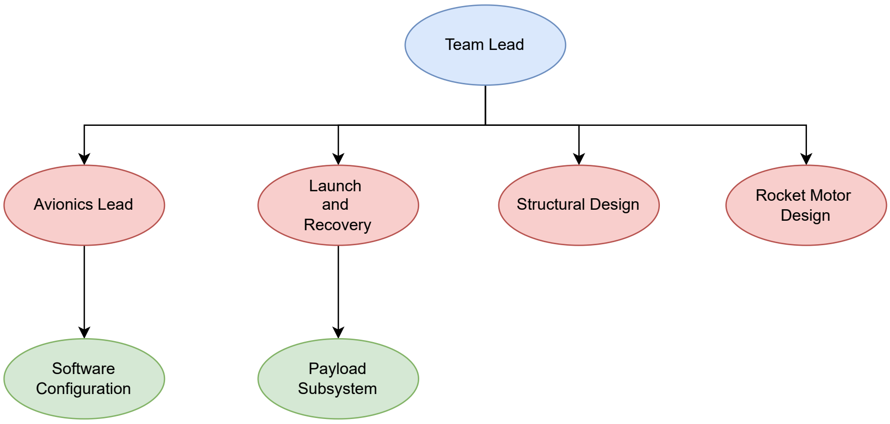


Figure 1.1: Team Hierarchy

1.1 Project Milestones

The major milestones for the rocketry project are as follows.

1. Conceptualization of design
2. Preparation of Bill of Materials (BOM)
3. Initial design iteration
4. Submission of Preliminary Design Review (PDR)
5. Design revisions based on PDR Feedback
6. Final design iteration
7. Submission of Critical Design Review (CDR)
8. Manufacturing and assembly of rocket
9. Integration of electronics and recovery Systems
10. Ground testing (structural, vibration, and thermal)
11. Flight simulation and validation
12. Launch preparation (logistics and safety checks)
13. Rocket launch
14. Post-launch recovery and analysis

PROJECT DATA			GANTT SCHEDULE
TASK	START DATE	COMPLETION DATE	June, July, August, September, October, November, December, January, February, March, April, May, June
Registration	**06-06-2024**	**15-08-2024**	
Submission of Required Documents	06/06/24	15-07-2024	
Release of PDR guidelines	15-07-2024	15-08-2024	
Preliminary Design Report	**16-08-2024**	**30-09-2024**	
Conceptualisation of Design	16-08-2024	30-08-2024	
Subdividing the work to different Subsystems	21-08-2024	30-08-2024	
Testing and Research of different configurations through iteration	21-08-2024	15-09-2024	
Preparation of PDR	15-09-2024	30-09-2024	
Internal PDR Review	21-09-2024	30-09-2024	
Payment of Fee and Submission of PDR	21-09-2024	30-09-2024	
Post PDR and Workshop	**01-10-2024**	**30-11-2024**	
PDR Review and Payment of Workshop Fee	01-10-2024	31-10-2024	
Extensive Design Review	01-10-2024	30-11-2024	
Attend Workshop	01-11-2024	30-11-2024	
Critical Design Review	**30-11-2024**	**19-02-2025**	
Finalisation of Design and BOM	01-11-2024	15-11-2024	
Purchase of components	07-11-2024	15-11-2024	
Testing of Components	15-11-2024	30-11-2024	
Manufacture of Components	15-11-2024	15-12-2024	
Rocket Integration	15-11-2024	15-12-2024	
Subsystem Level Tests	21-11-2024	31-01-2025	
Submission of CDR and Fee Payment	12-01-2025	19-01-2025	
Flight Readiness Review	**01-02-2025**	**30-06-2025**	
Completion of Manufacture Process	20-01-2025	28-03-2025	
Completion of Required Tests	01-01-2025	28-04-2025	
Review and preparation of travel to launch site	01-05-2025	30-05-2025	
Launch Preparation	01-05-2025	30-05-2025	
Documentation and planning	01-06-2025	30-06-2025	

Figure 1.2: Gantt Chart

Chapter 2

Mission Overview

2.1 Main Objectives

- Design, construct, and test a fully functional rocket under the given constraints.
- Achieve a target apogee of 1000 meters.
- Carry and deploy a 1 kg CANSAT payload successfully.
- Recover the CANSAT and rocket intact and safely for data verification.

2.2 System Overview

2.2.1 Rocket Configuration

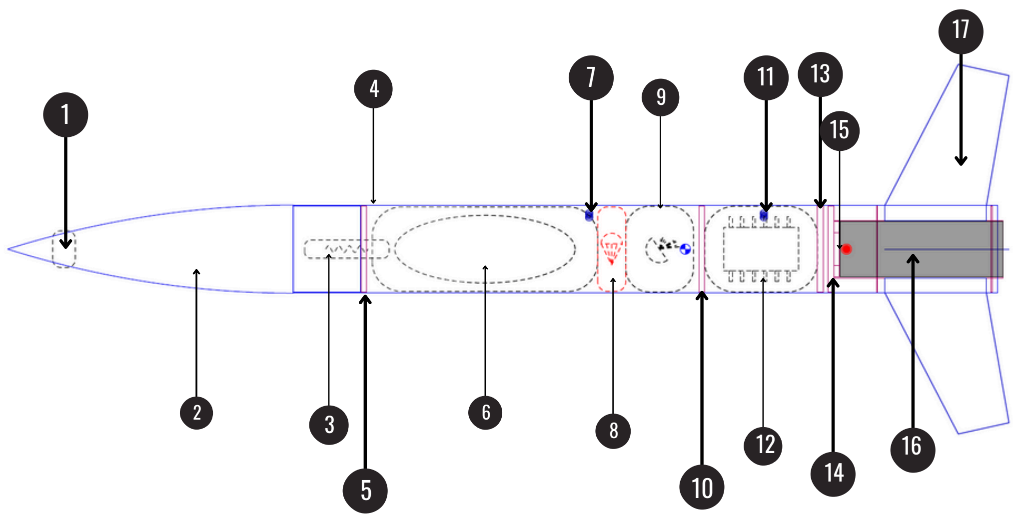


Figure 2.1: Rocket Configuration Exported

Table 2.1: Rocket Components

#	Component Name
1	Dead weight
2	Nose cone
3	Shock cord
4	Body tube
5	Bulkhead
6	Payload
7	Rail button
8	Parachute
9	Ejection System
10	Bulkhead
11	Rail Button
12	Avionic System
13	Bulkhead
14	Bulkhead
15	Engine Block
16	Motor Tube + Motor
17	Fins

2.2.2 Major components

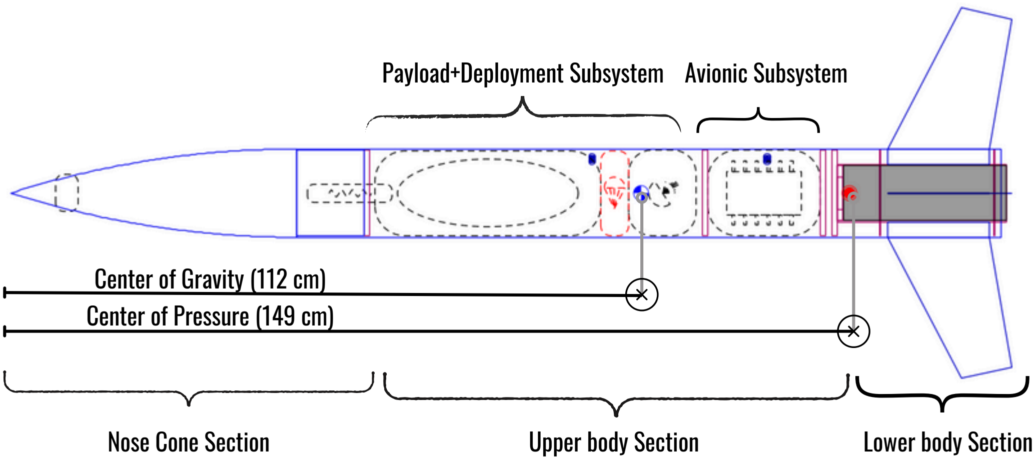


Figure 2.2: Major components of rocket subsystem

2.2.3 Launch and descent strategy

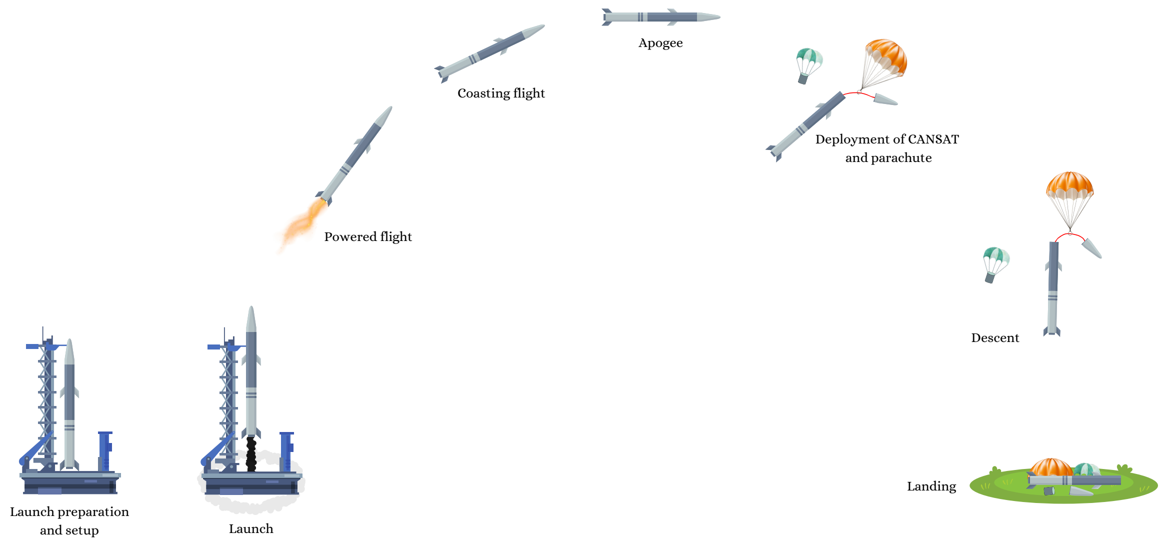


Figure 2.3: Launch and Descent Phases

Launch Strategy

The launch strategy involves setting up the rocket on the launch pad with a minimal vertical angle and locking it in place with launch pad.

Ascent Phase

The powered flight duration of the rocket is extremely short as it is completely dependent on the motor characteristics. Typical motors for this application have short burn times. After the burnout of the motor the rocket continues to ascend while decelerating reaching its maximum point, the apogee. At the apogee or at the target altitude, the payload is deployed.

Descent Phase

After the payload is deployed, the parachute of the rocket is deployed immediately after, allowing the rocket to make its descent slowly downwards. The parachute will be the only descent control mechanism, and the radio on board will continue to transmit the location of the rocket throughout the descent.

2.2.4 Post-launch recovery

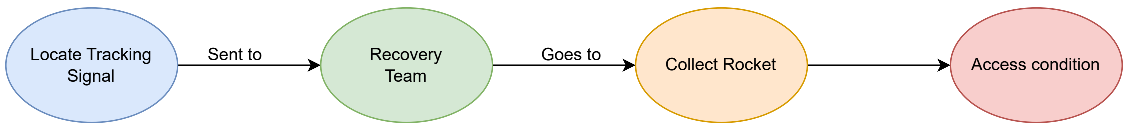


Figure 2.4: Post Launch Recovery Plan

Recovery Process

The rocket is continuously tracked by the ground station and its location is known in real time. From the predicted direction of travel, the recovery team sets out to collect the rocket with portable handheld antenna. After locating the rocket, the condition of the rocket is assessed.

2.2.5 Data retrieval and analysis

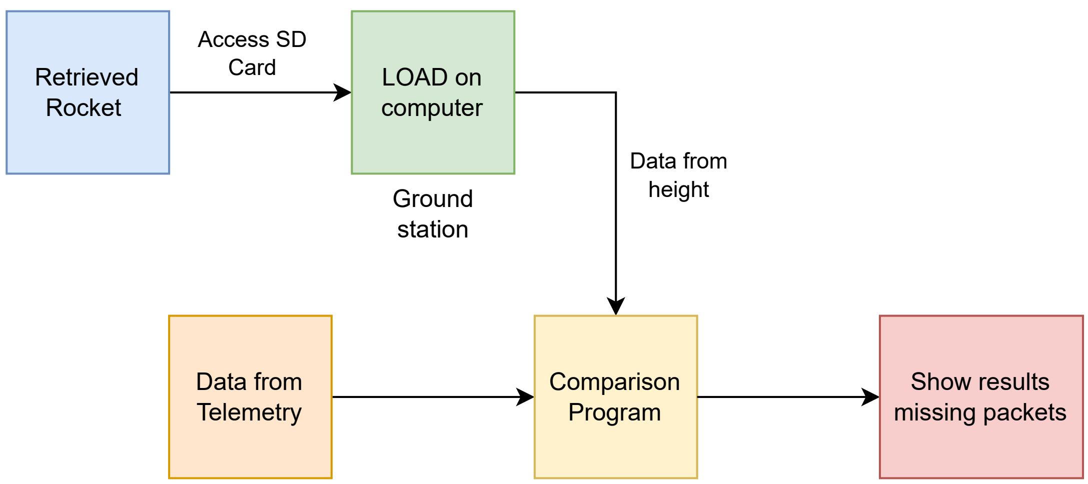


Figure 2.5: Data retrieval and analysis

2.3 Innovations

2.3.1 Material

1. Using PETG for making the Nose Cone.
2. Using Polycarbonate for manufacturing fins.

2.3.2 Ejection Mechanism

1. Using flower shaped ejection mechanism for cansat and parachute deployment.

Chapter 3

Subsystem Details

3.1 Payload

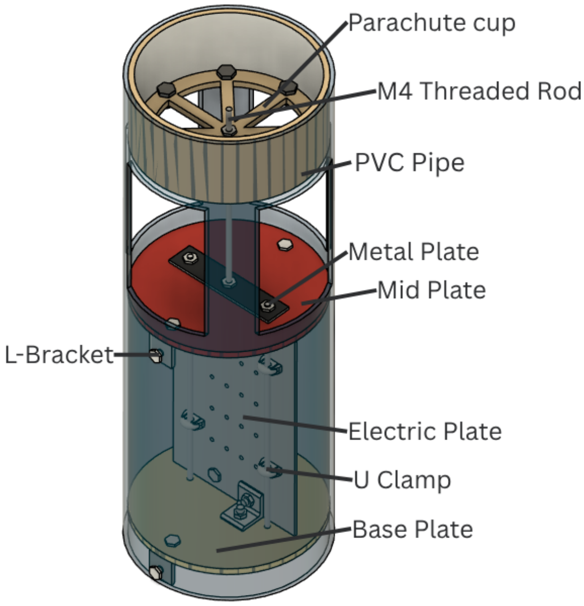


Figure 3.1: CANSAT cad model

Tentative Design of CANSAT

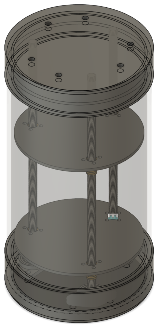


Figure 3.2: PDR CANSAT Model

3.1.1 Components of CANSAT

Base plate

Purpose: It is the last plate of the cansat for enclosing the avionics part from below.

Manufacturing: Manufactured through laser cutting from an acrylic sheet of thickness of 5mm.

Placement: Outer cover of the CANSAT.

Design Specification
• **Dimensions:** The diameter of the base plate is 133.4mm and the thickness is of 5mm. • **Holes:** – There are two holes of diameter 4mm used for attaching the M4 threaded rods on which the electric board would be attached. – There are 4 holes of diameter 5mm , out of which 2 holes that are close to the 4mm holes are used for attaching the electric plate to the base plate using the – The two holes of diameter of 5mm near the circumference are used for attaching pvc pipe to the base plate using a L-bracket.

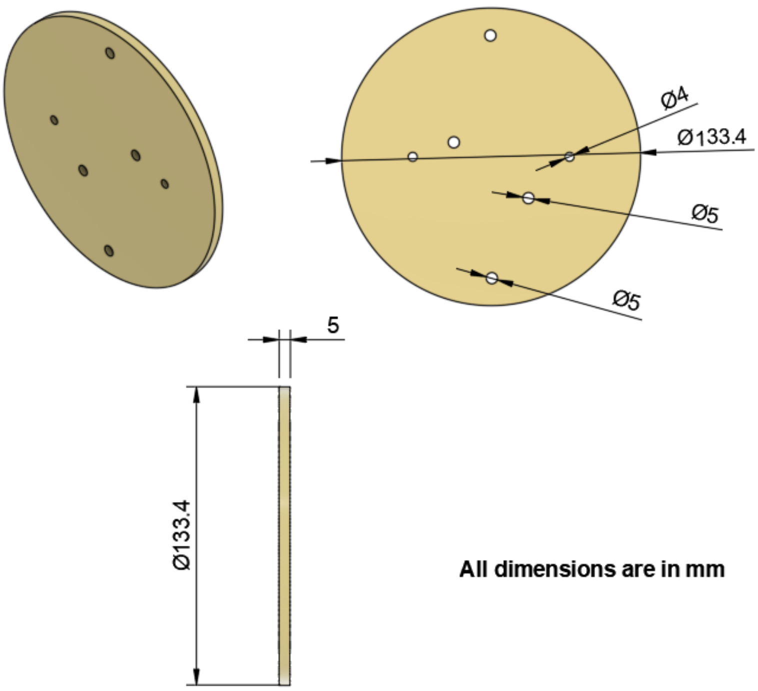


Figure 3.3: Base Plate

Electric Plate:

Purpose: Used for attaching the avionics part of the cansat

Manufacturing: Manufactured from acrylic sheet of thickness 2mm through laser cutting

Placement: Between the base plate and mid-plate

Design Specification
• **Dimensions:** The length of the plate is 170mm the breadth of the plate is 110mm and the thickness is 2mm. • **Holes:** – There are twenty holes of diameter 3mm used for attaching the avionics part of the cansat to the electric plate using M3 nuts and bolts. – There are ten holes of diameter 5mm , out of which 4 pairs are used for attaching the electric plate to the M4 threaded rod using a u clamp. – The two holes of diameter of 5mm near the lower end are used for attaching the electric plate to the base plate using a L-bracket.

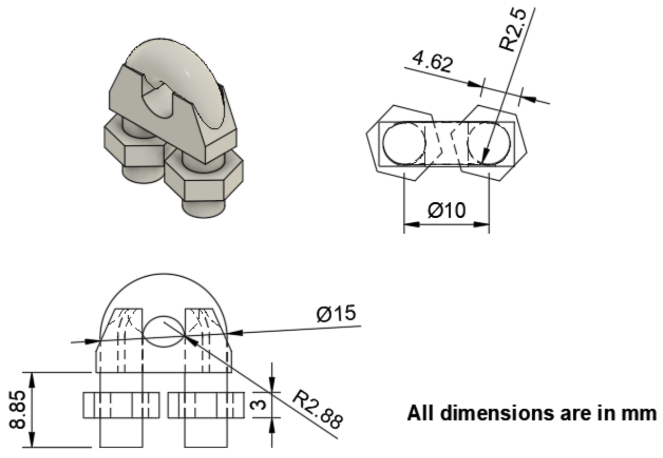


Figure 3.5: U-Clamp

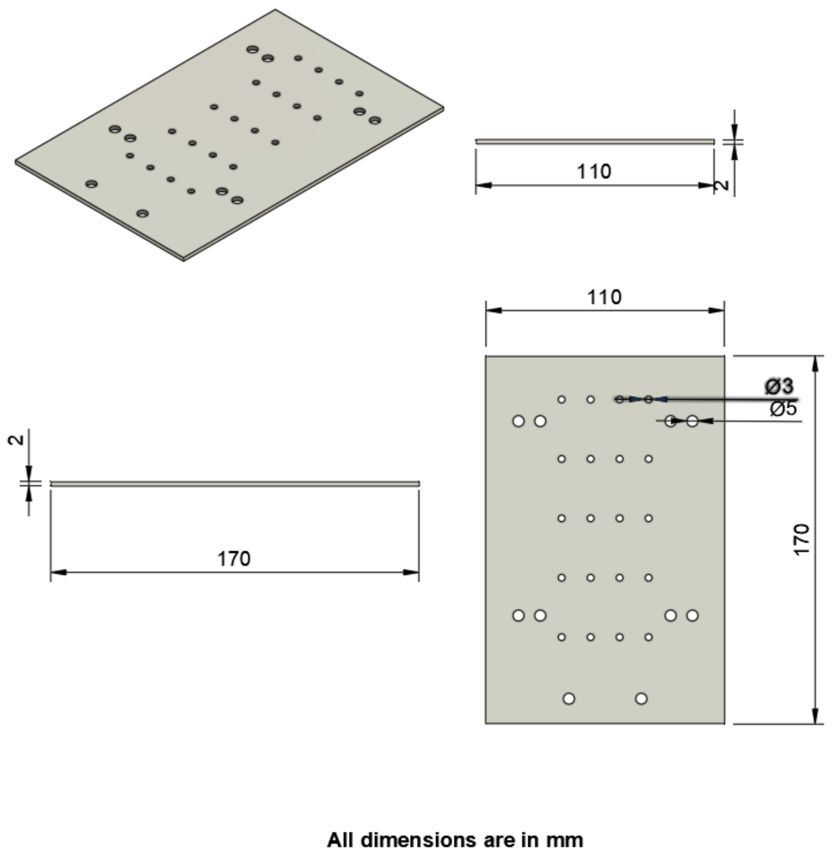


Figure 3.4: Electric Plate

Mid plate

Purpose: It is the middle plate of the cansat for enclosing the avionics part from above.

Manufacturing: Manufactured through laser cutting from an acrylic sheet of thickness of 5mm.

Placement: Outer cover of the CANSAT.

Design Specification
• **Dimensions:** The diameter of the base plate is 133.4mm and the thickness is of 5mm. • **Metal Plate:** It has a metal on the upper surface, this is kept to increase the strength and absorb the forces. • **Holes:** – There are two holes of diameter 4mm used for attaching the M4 threaded rods on which the electric board would be attached. – The two holes of diameter of 5mm near the circumference are used for attaching pvc pipe to the mid plate using a L-bracket.

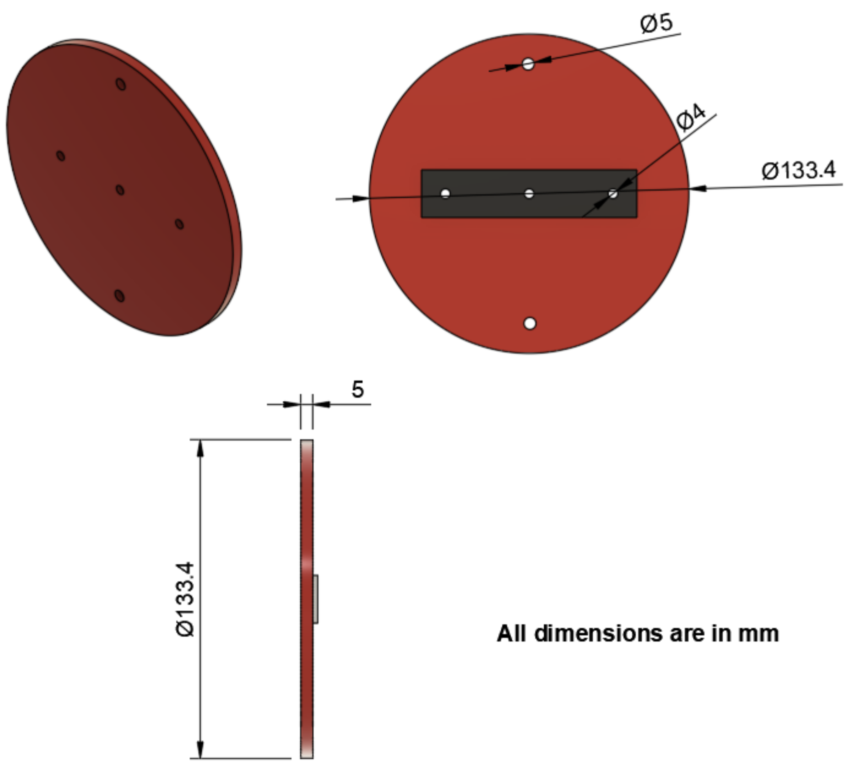


Figure 3.6: Mid Plate

Parachute cup

Purpose: Used to hold the parachute of the CANSAT.

Manufacturing: Manufactured through 3D print using PLA.

Placement: At the top in CANSAT.

Design Specification
• **Outer diameter:** The outer diameter of the parachute cup is 133.4 mm so that it can just fit in the pvc pipe. • **Inner diameter:** The inner diameter of the parachute cup is 125mm. • **Arc cut:** – The radius of cut is 51mm. – The angle of the arc is 45° – There are a total of 8 cuts. – This cut was made so that when the terminal velocity equals 0 and the CANSAT starts to free fall the air flows through the holes and the parachute blooms open. • **Height:** The height of the parachute cup around 55mm • **Holes:** – There are eight 6mm holes, These holes are used for fixing the eye bolt so that parachute chords can be tied to it. – There is one 4mm hole, This is used for the threaded rod which holds the parachute cup in place.

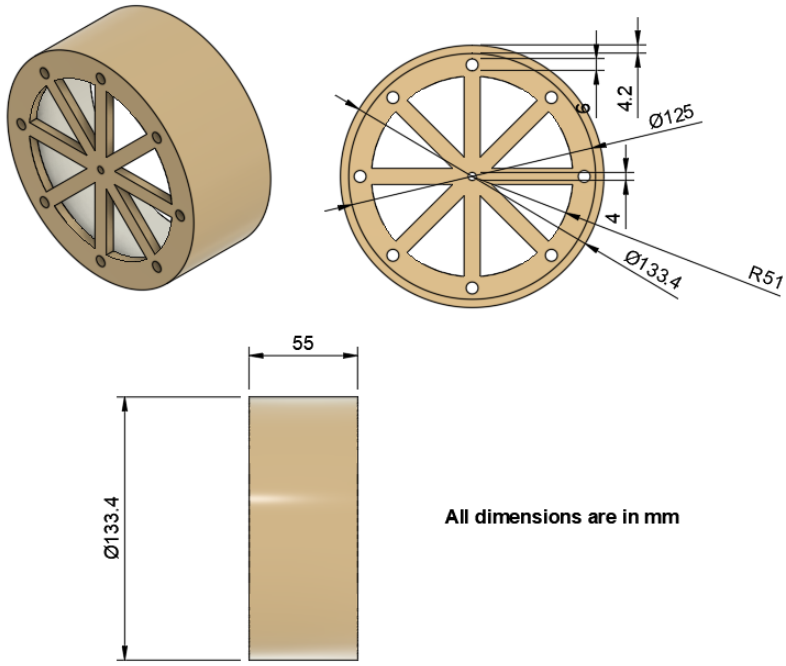


Figure 3.7: Parachute Cup

PVC Pipe

Purpose: Used as an outer cover for the CANSAT to protect the avionics part.

Manufacturing: Manufactured from PVC (PVC pipes).

Placement: Outer cover of the CANSAT.

Design Specification
• **Outer diameter:** The outer diameter of the pvc pipe is 139.7 mm . • **Inner diameter:** The inner diameter of the pvc pipe is 133.4mm so that the parachute cup just fits into it. • **Rectangular cut:** – The radius of cut is 133.4mm. – There are a total of 4 cuts. – The length of these cut is 110mm and the projection of the curved length is 70mm. – This cut was made so that when the terminal velocity equals 0 and the CANSAT starts to free fall the air flows through the holes and the parachute blooms open. • **Height:** The height of the pvc pipe around 400mm • **Holes:** – There are four 5mm holes, These holes are used for fixing the cansat to the pvc pipe, the holes at the end connects the base plate and the holes near the cut connects the mid-plate using the L-bracket.

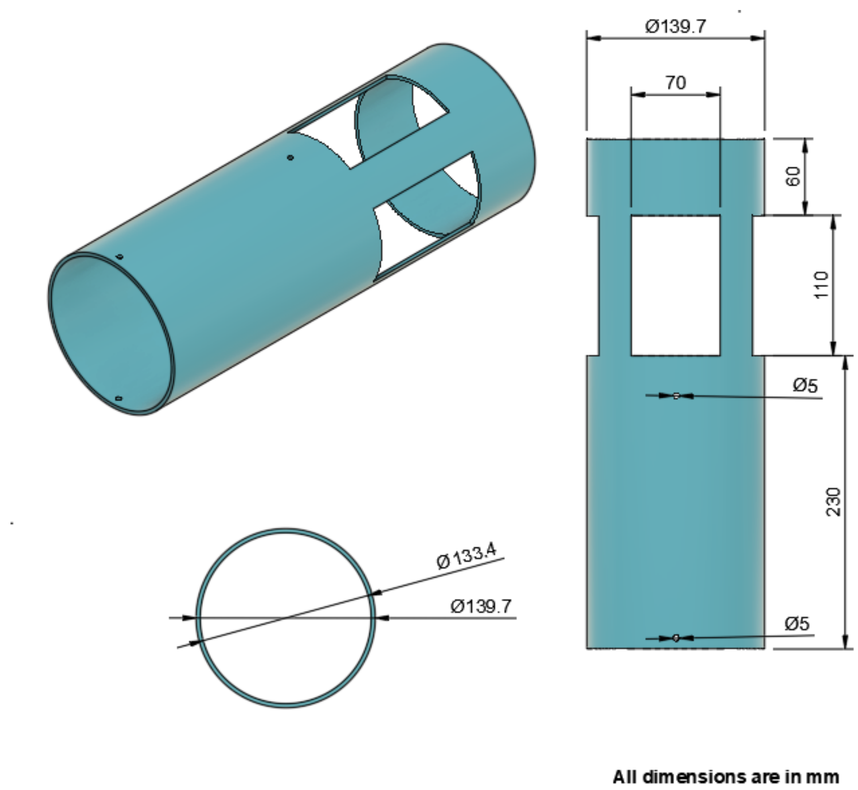


Figure 3.8: PVC pipe

3.1.2 Sensor Subsystem

This contains the list of sensors that are integrated to payload subsystem.

Sensor	Sensor Model	Function
Pressure sensor	BMP280	To measure air pressure
Temperature sensor	BMP280	Measuring air temperature
Altitude sensor	BMP280	Altitude Measurement
Gyroscope	MPU-6050	Rotation Rate
GPS Module	NEO-6M	Navigation
Accelerometer	MPU-6050	Acceleration Rate

Table 3.1

3.1.3 Communication and Data Handling Subsystem

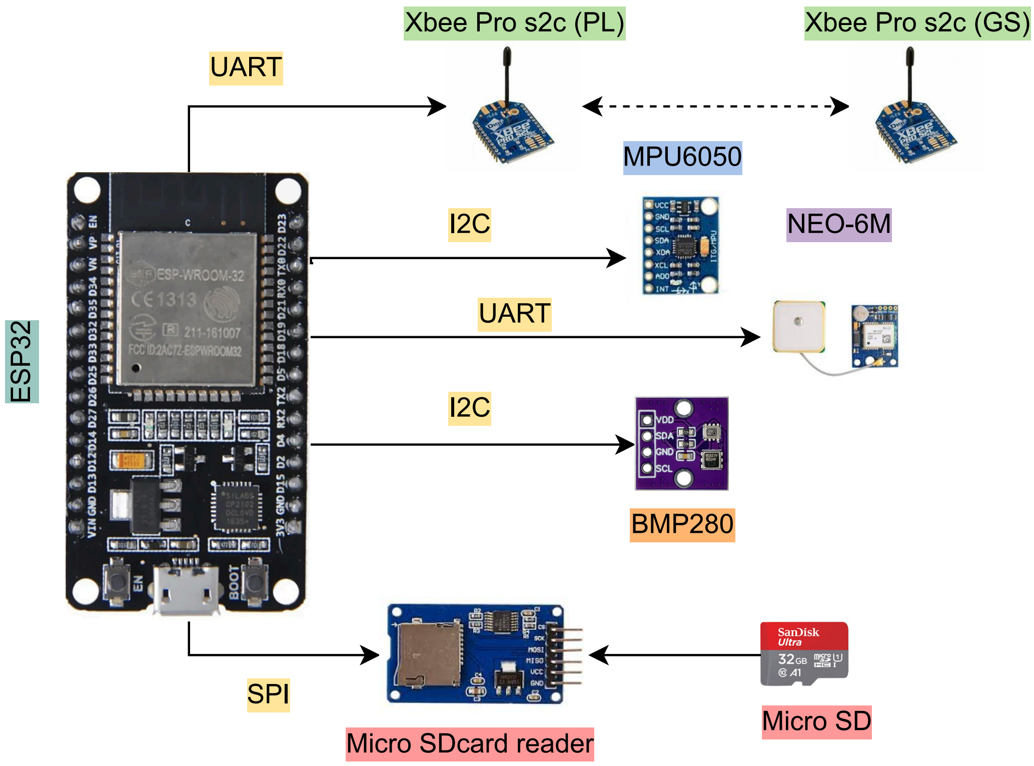


Figure 3.9: Interface diagram for communication and data handling subsystem

3.1.4 Descent Control Subsystem

CANSAT uses a parachute for the descent control. The parachute will be connected to the base of nose cone with the help of a detachable link. This assists the process of parachute deployment for the CANSAT.

3.1.5 Electrical Power Subsystem

Figure 3.10: Electrical power subsystem block diagram showing power supply connections

- Power Source:
  - Battery: Primary power source for components.
  - Umbilical Cable: Power source during testing.
- Control and Monitoring:
  - Mechanical Switch: On/off control.
  - Battery Voltage Sensor: Monitors battery health.
  - RTC: Real-time clock
- Voltage Conversion:
  - 5V Converter: Converts battery voltage to 5V for actuators.
  - 3.3V Converter: Converts battery voltage to 3.3V for microcontroller, sensors, and radio.
- Payload:
  - Sensors: Gather data during flight.
  - Radio: Communicates with ground station.
  - Actuators: Control movement and retrieve module (servos, sound alarm).
- Additional Components:
  - NiCr Cable: Deploys spring mechanism.
  - Pitot Tube: Measures airspeed.
  - Power Switches: Control high-power components.
  - LED: Indicates correct voltage levels.
- Payload Power Architecture:
  - The payload relies on a battery as its primary power source.
  - An umbilical cable can be used to provide external power during testing or ground operations.
  - A mechanical switch allows for manual control of power flow.

  - A voltage sensor continuously monitors the battery voltage to ensure optimal performance.
  - A Real-Time Clock (RTC) provides accurate timekeeping for various payload functions.

- Voltage Regulation:
  - The CANSAT requires different voltage levels for various components.
  - A Low-Dropout Regulator (LDO) is used to provide a stable 3.3V output for low-power components.
  - A DC/DC Boost Converter is used to increase the voltage to 5V for components requiring higher power.

- Core Components of the CANSAT Payload:
  - The MPU6050 and BMP280 sensors collect data on acceleration, angular velocity, pressure, and temperature.
  - The Esp32 microcontroller processes sensor data, controls other components, and communicates with the ground station
  - The XBEE Pro S2C radio module enables wireless communication with the ground station.
  - An LED provides visual feedback on the CANSAT's status.
  - The GPS module determines the CANSAT's location.
  - Servo motors are used to control mechanical components, such as deploying parachutes, controlling fins etc.
  - A buzzer provides audible alerts.

3.1.6 Changes from PDR

The following modifications have been made to the sensor and payload subsystem design since the Preliminary Design Review (PDR):

- **Sensor Upgrades:** The pressure, temperature, and altitude sensor has been updated from BMP390 to BMP280. The BMP280 was selected for its lower power consumption, reduced weight, and sufficient accuracy to meet the mission requirements.
- **Gyroscope and Accelerometer:** The inertial measurement unit has been changed from MPU-6500 to MPU-6050. The MPU-6050 offers adequate performance for measuring rotation rate and acceleration while enabling simpler integration via I^2C.
- **GNSS Module Replacement:** The GNSS module has been changed from PX-1125S to NEO-6M. The NEO-6M is a widely adopted, reliable, and lightweight GPS module that provides sufficient positional accuracy for the mission.
- **Microcontroller Change:** The central processing unit has been updated from PSoC to ESP32. The ESP32 was chosen to enable the use of FreeRTOS for improved task management and real-time control. It also offers higher processing capabilities, integrated wireless communication, and enhanced compatibility with the selected sensors and communication modules.
- **Communication Interface:** The data handling subsystem now utilizes XBee Pro S2C modules for communication on both the payload (PL) and ground station (GS) sides. The updated interface diagram reflects this, showing UART connections for the NEO-6M and XBee modules, I^2C for the MPU-6050 and BMP280, and SPI for

the microSD card.

- **System Simplification and Integration:** The overall electronics architecture has been streamlined to reduce complexity, weight, and power consumption. The updated design consolidates sensor interfacing and data handling onto the ESP32 platform, ensuring better real-time data processing, improved modularity, and increased reliability.

These changes were made to optimize system performance, improve integration, and meet updated mission constraints and requirements.

3.1.7 Changes from PDR

:

- **Base plate:** In PDR the idea of air passing through the perforated plate and inflating the parachute seemed,an unnecessary risk, as irregular air flow could disrupt connections and electrical components and attaching the suspensions to the bottom plate would have proved fruitless, as it does not isolate the electronic plate. Thus, the perforation was removed and a solid base plate was made.
- **Electric Plate:** In PDR there was not enough area for all electronics components, so the height was increased and an electric plate was introduced for better organization of electronic components.
- **Mid plate:** The mid plate was introduced in new so that it can cover the electronic part above because of the arc cuts made in the pvc pipe there is a chance that it may disrupt the electronic connections.
- **Parachute Cup:** The parachute cup was added to keep the parachute in it and so that more air could flow freely through it. The iris opening mechanism was removed because there was a chance that the chords would get stuck in it, interrupting the blooming of the parachute.

3.2 Mechanical/Housekeeping subsystem

This section provides an overview of the mechanical subsystem, detailing its design, CAD models, and layout. 2D-engineering drawing for every component is included in the apendix. The design of the mechanical subsystem is governed by several key constraints, outlined as follows:

3.2.1 Components of the mechanical subsystem:

The mechanical subsystem has the following main components:

Nose Cone

The nose cone is the topmost part of a model rocket. It is designed to minimize aerodynamic drag and protect the rocket during its ascent.

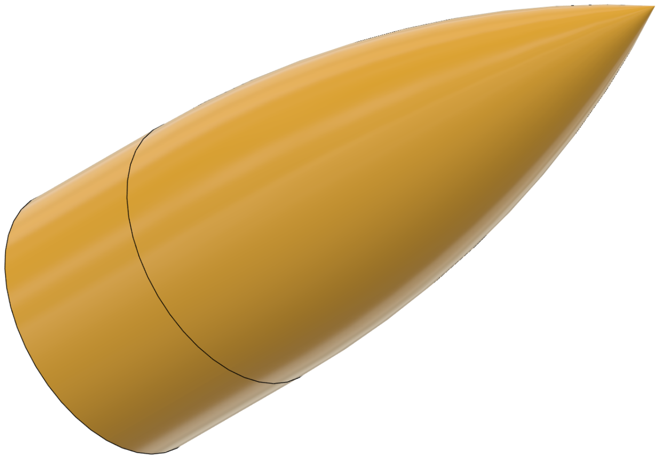


Figure 3.11: 3D image of nose cone

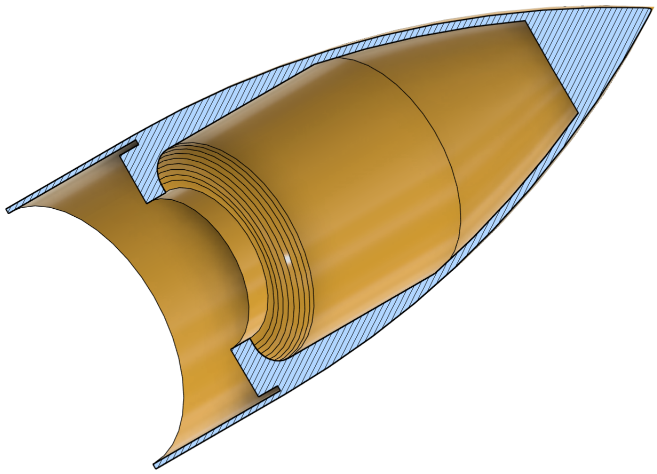


Figure 3.12: 3D section image of nose cone

- **Purpose:** To reduce aerodynamic drag and protect the internal components during flight.
- **Material selection:** The material selected for manufacturing this component is PETG, and its mass will be around 1.8 Kg.
- **Significant changes:** The material changed from balsa wood to PETG because balsa wood has low strength and is not suitable for design. The advantage is that PETG is stronger than Balsa Wood, and the disadvantage is that the mass of the component increased. The length of the nose cone has been decreased from 50 cm to 35 cm to better align with the design. The design has also been further updated to incorporate improved features.

Body Tube

The body tube forms the main structure of the rocket. It houses all other components and ensures aerodynamic stability during flight.

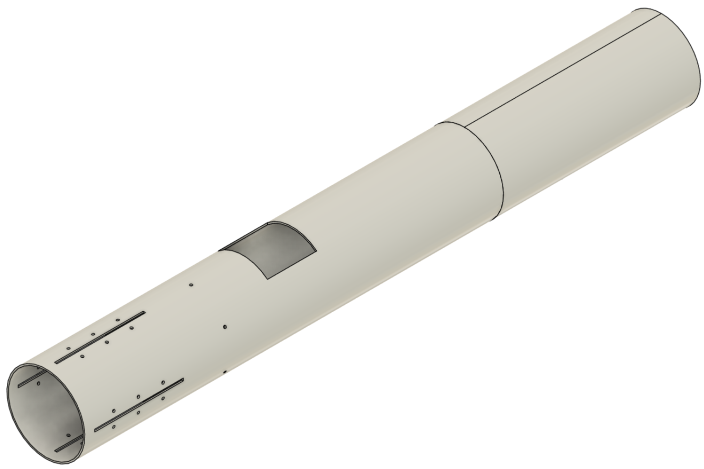


Figure 3.13: 3D image of Body Tube

- **Purpose:** To house various components of the rocket and maintain its structural integrity during flight.
- **Material selection:** The material selected for the body tube is PVC and the mass is around
- **Significant changes:** The material changed from aluminium 2024 to PVC, as after doing analysis, both work well with the design, but PVC has a low price and better availability in the local market, and PVC is easier to work with. The design has also been further updated to incorporate improved features.

Fins

The fins are located at the base of the rocket. They help stabilize the rocket and guide it along a straight trajectory.

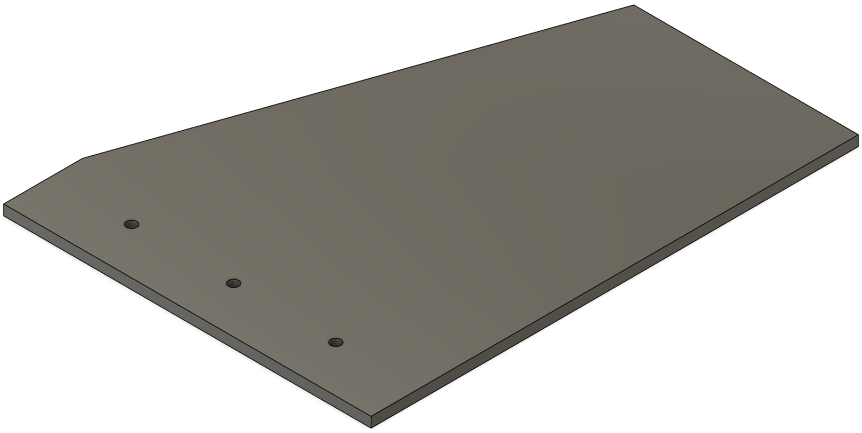


Figure 3.14: 3D image of fins.

- **Purpose:** To maintain the rocket's stability and ensure a straight flight path by counteracting aerodynamic forces.
- **Material selection:** The material selected is polycarbonate, and the mass of the 4 fins is around 0.830 kg.
- **Significant changes:** The material changed from aluminium 2024 to polycarbonate to reduce the mass but keep the design well.

Bulkhead

The bulkhead separates the rocket's internal compartments. It ensures the safety and isolation of critical components, such as the payload and electronics.

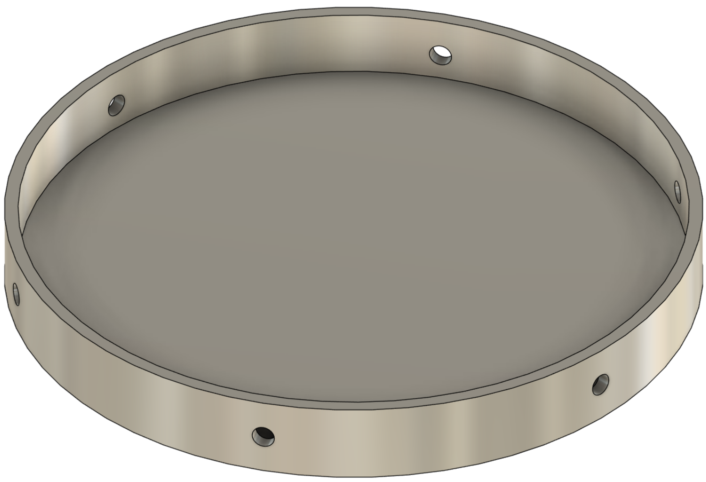


Figure 3.15: 3D image of Bulkhead

- **Purpose:** To create a physical barrier between compartments, ensuring structural stability and protection of components.

- **Material selection:** The material selected is aluminium, and the mass of a bulkhead is approximately 0.210 kg.
- **Significant changes:** The material has been changed from birch plywood to aluminium after analysis to work better with the design, and the design has been further updated to incorporate improved features.

Fin Bracket

The fin bracket is used to securely attach the fins to the body tube. It ensures the proper alignment and stability of the fins during flight.

Figure 3.16: 3D image of Fin bracket

- **Purpose:** To provide a strong and secure connection between the fins and the body tube.
- **Material selection:** The material is selected as aluminium and the mass of four fin brackets for four fins is approximately 0.32 kg.
- **Significant changes:** The fin bracket was not considered in the previous design.

Avionic Bay Access Door

The avionic bay access door is an entry point to the avionics section. It allows easy installation and maintenance of electronics and sensors.

- **Purpose:** To provide convenient access to avionics for installation, maintenance, or data retrieval.
- **Material selection:** The material selected for this component is PVC matching the material of body tube.
- **Significant changes:** This access door was not discussed In previous design.

Shock Cord

The shock cord is an elastic cord used in the recovery system. It absorbs the force of the parachute deployment, preventing damage to the rocket.

- **Purpose:** To connect the rocket sections during recovery and reduce impact forces during the deployment of the parachute.
- **Material selection:** The material selected for shock cord is Nylon.
- **Significant changes:** No significant changes. None

Shock Cord Mount

The shock cord mount secures the shock cord to the rocket body. It ensures that the shock cord stays in place during deployment and recovery.

- **Purpose:** To provide a durable and reliable anchor point for the shock cord.
- **Material selection:** The material selected for shock cord mount is aluminium.
- **Significant changes:** The shock chord mount is same as previous design. None

Launch lugs

The launch lugs is a guiding system used during the rocket's takeoff. It keeps the rocket stable and on course until it gains sufficient velocity.

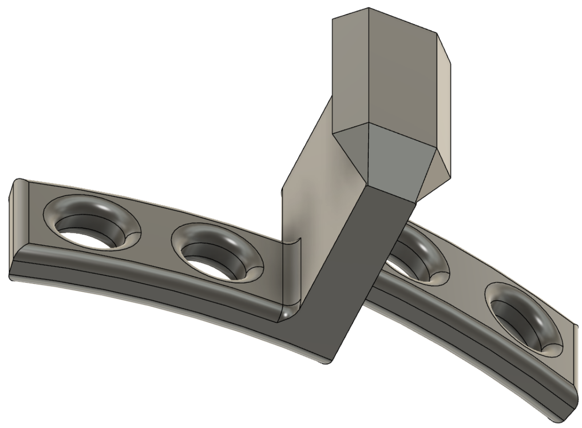


Figure 3.17: 3D image of Launch Lug

- **Purpose:** To guide the rocket during its initial launch phase and ensure a straight ascent.
- **Material selection:** The material selected for this component is aluminium and the mass is approximately 7 grams.
- **Significant changes:** The design has been further improved from the previous design and analysis was done to verify the suitability.

3.3 Avionics

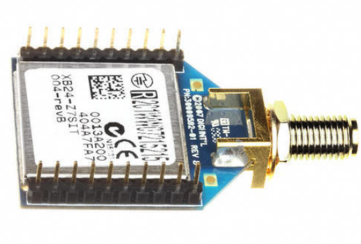
The avionics subsystem acts as the brain of the rocket, responsible for housing and controlling the flight plan from launch to landing. It monitors various flight parameters, transmits data during the flight, and enables the recovery team to locate the rocket post-flight. The avionics subsystem includes hardware and software required to perform the tasks required such as:

- To read and estimate the state of the rocket post-launch.
- To transmit and receive data between rocket and ground station.
- To store data while flight to be retrieved during the recovery of rocket.

3.3.1 Sensor Component Descriptions

Zigbee XBee Pro S2C 802.15.4 Module 63mW 3Km+ 3.2dBi Antenna

A high-performance telemetry module made for wireless communication in the 2.4 GHz ISM band is the Zigbee XBee Pro S2C 802.15.4 Module. In line-of-sight conditions, it has a range of more than 3 kilometers and a maximum output power of 63 mW (18 dBm). With its 3.2 dBi external antenna and compatibility for Zigbee mesh networking, this module makes scalable and dependable communication possible for telemetry and Internet of Things applications. With an operational voltage range of 2.1V to 3.6V and an average transmit current of 250 mA, it has minimal power consumption.



XBEE Pro S2C

GY-BME280-3.3 Precision Altimeter Atmospheric Pressure Sensor Module

A small, highly accurate sensor for determining temperature, humidity, and atmospheric pressure is the GY-BME280-3.3 Precision Altimeter Atmospheric Pressure Sensor Module. The BME280 sensor chip, which is used in this module, may provide extremely precise measurements for devices like indoor navigation systems, weather stations, and altimeters. It communicates using I2C or SPI interfaces and runs at 3.3V, providing flexibility in integrating with different microcontrollers.

BME280 sensor module

MPU6050 6-Axis Attitude Gyro Accelerometer Magnetometer Sensor Module

MPU6050 6-Axis Gyroscope and Accelerometer Sensor Module The MPU6050 6-Axis Gyroscope and Accelerometer Sensor Module integrates a 3-axis gyroscope and a 3-axis accelerometer into a single compact package, delivering a reliable and cost-effective solution for inertial motion sensing. Built around the MPU6050 chip, this module captures precise measurements of angular velocity and linear acceleration, making it suitable for applications in robotics, gesture recognition, balance control systems, and drone flight stabilization. The sensor module supports communication through the I2C interface, allowing seamless integration with a wide range of microcontrollers and embedded platforms.

MPU6050 sensor module

NEO-6M GPS Module

The NEO-6M GPS Module is a versatile and widely used positioning module designed for applications across various domains including navigation, robotics, asset tracking, and DIY electronics. It is based on the powerful u-blox 6 GPS engine, offering robust performance and fast satellite acquisition. This module provides precise global positioning services using the Global Positioning System (GPS), making it suitable for both indoor and outdoor use with clear sky visibility. It supports standard NMEA protocols and communicates easily via UART, allowing seamless integration with microcontrollers such as Arduino,Esp 32, and Bharat Pi. With its compact form factor and onboard ceramic antenna, the NEO-6M is ideal for systems that require reliable global location data. It is particularly suited for real-time navigation, vehicle tracking, time synchronization, and geofencing applications.

NEO-6M GPS Module

3.3.2 Avionics Bay

The avionics system including all the sensors, telemetry and power electronics will be housed in a cylindrical bay. The electronics contained by the PCB circuitry will be Microcontroller, sensors, data handling and communication modules & power electronics circuitry.

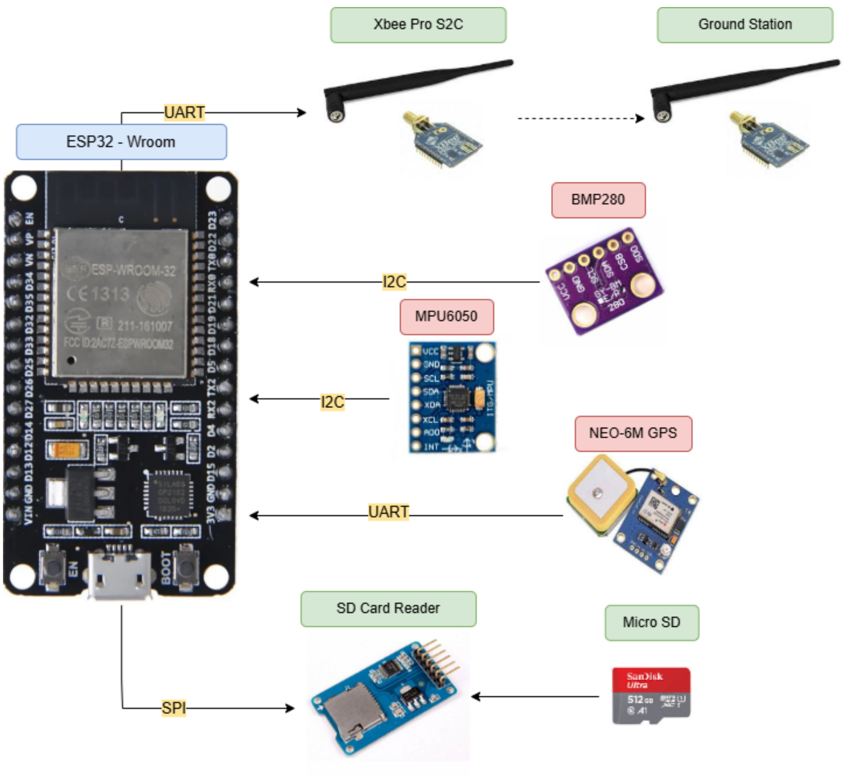


Figure 3.18: Connection diagram for Avionics subsystem

Figure 3.19: Esp32 Wroom 32 micro-controller

The microcontroller used here as a brain to acquire data and transmit/receive depending on necessity and application is Esp32 Wroom 32 microcontroller.

3.3.3 Communication and Data Handling

Design Constraints on the Ground Station

1. Should be XBEE / Zigbee radio series 1/2/pro
2. The XBEE radios shall have their NETID/PANID set to the team number.
3. The XBEE radio can operate in any mode as long as it does not interfere with other XBEE radios.

Configuration of the subsystem

The communication and data handling subsystem is configured in the manner as seen in the Figure 3.20. The Esp32 micro-controller is mainly responsible for the data collection from the sensors, and the data is dumped into a micro SD card, and the same data is transmitted as per the telemetry format (provided later in this report) back to the ground station.

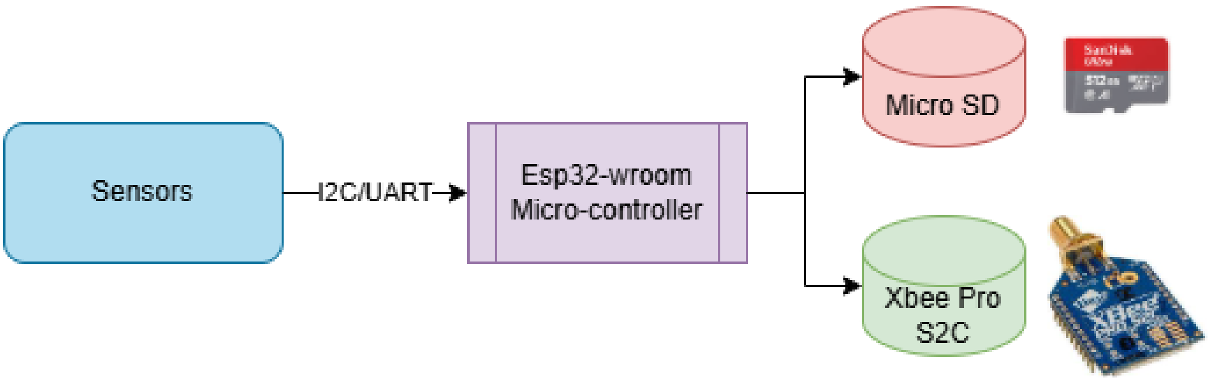


Figure 3.20: Data Handling Flowchart

3.3.4 Electrical Power Subsystem

Design Constraints on the Power requirements

1. Battery capacity to support up to 30 minutes of wait on the launch pad, with additional time for flight operations, shall be ensured.
2. The battery source may be alkaline, Ni-Cad, Ni-MH, or Lithium-ion. Lithium polymer batteries are prohibited. Lithium cells must be manufactured with a metal package similar to 18650 cells.
3. An easily accessible battery compartment must be included, allowing batteries to be installed or removed in less than a minute, without requiring total disassembly of the Rocket/CANSAT mounted on the rocket.
4. Spring contacts shall not be used for making electrical connections to batteries. Care must be taken as the shock forces can cause momentary disconnects of power.

Configuration of the subsystem

The system consists of a 12 V Lithium Ion Battery which is attached to a ON/OFF switch monitored by a voltage sensor. The battery is stepped down to 5V for the Esp32 Microcontroller and its sensors, as well as XBee S2C Module.

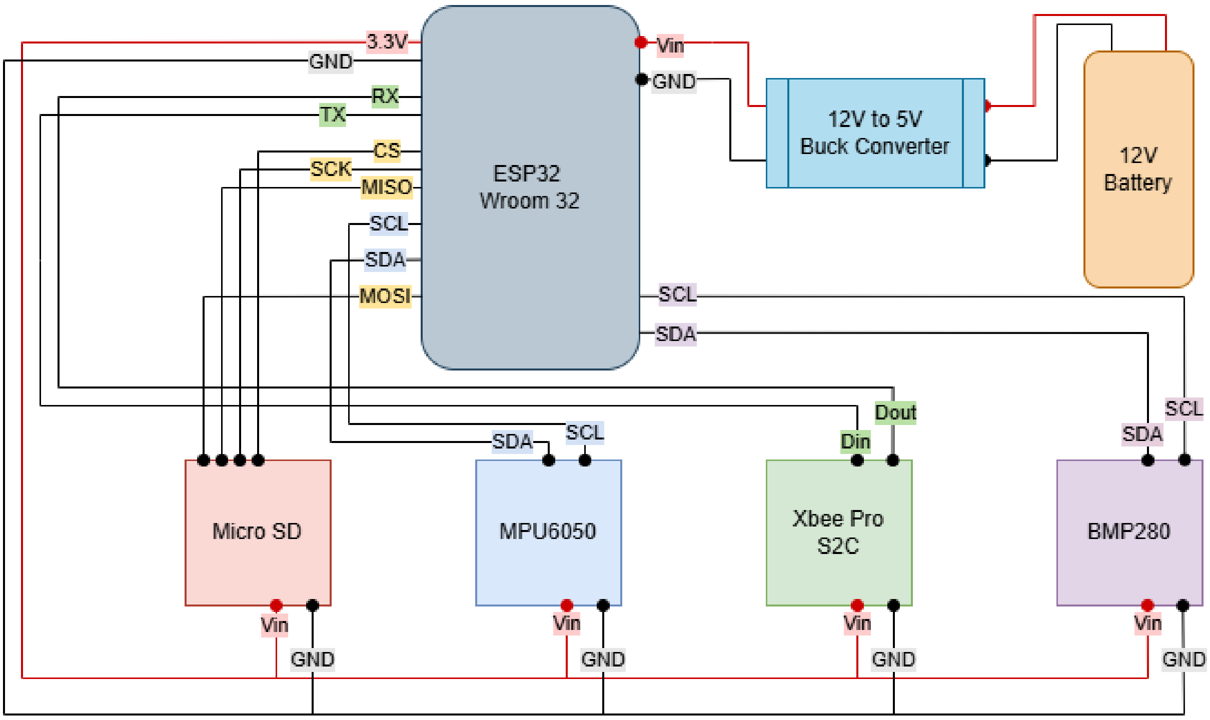


Figure 3.21: Voltage Diagram

3.3.5 Sensor Testing Checklists

During the pre-launch scenario, the following broadly mentioned tests are to be performed with more precise instructions.

Avionics Bay Checklist		
S.No.	Task	Check
1	Tug on wire connectors to ensure they are all firmly connected.	
2	Shake avionics bay and ensure nothing is loose.	
3	Check the connection and integrity of various mounts and antenna.	
4	Ensure the battery is fully charged with a power status tester/monitor.	
5	Make sure the flight system works after POWER ON.	
6	Latch the avionics bay opening firmly with screws during integration with rocket.	
7	Check 'STATE' in ground station GUI after powering on to ensure proper working of telemetry and state estimation during pre-launch.	
8	Check data received in GUI to ensure proper working of sensor data retrieval during pre-launch.	

3.4 Flight Software Algorithm Description

The flight software is responsible for controlling the tasks of the rocket which involve scheduling and timing the launch, the deployment of the CANSAT and the parachute, and ensuring that data communication as well as the data logging.

3.4.1 FSW Tasks Summary

1. Recording of the sensor values and Sensor Calibration.
2. Collect and analyze the commands from Ground station (e.g. to start transmission)
3. Transitioning through Flight software states.
4. Transmission of telemetry packets to the ground station.
5. Restoring telemetry data to a micro SD card.

3.4.2 FSW State Diagram

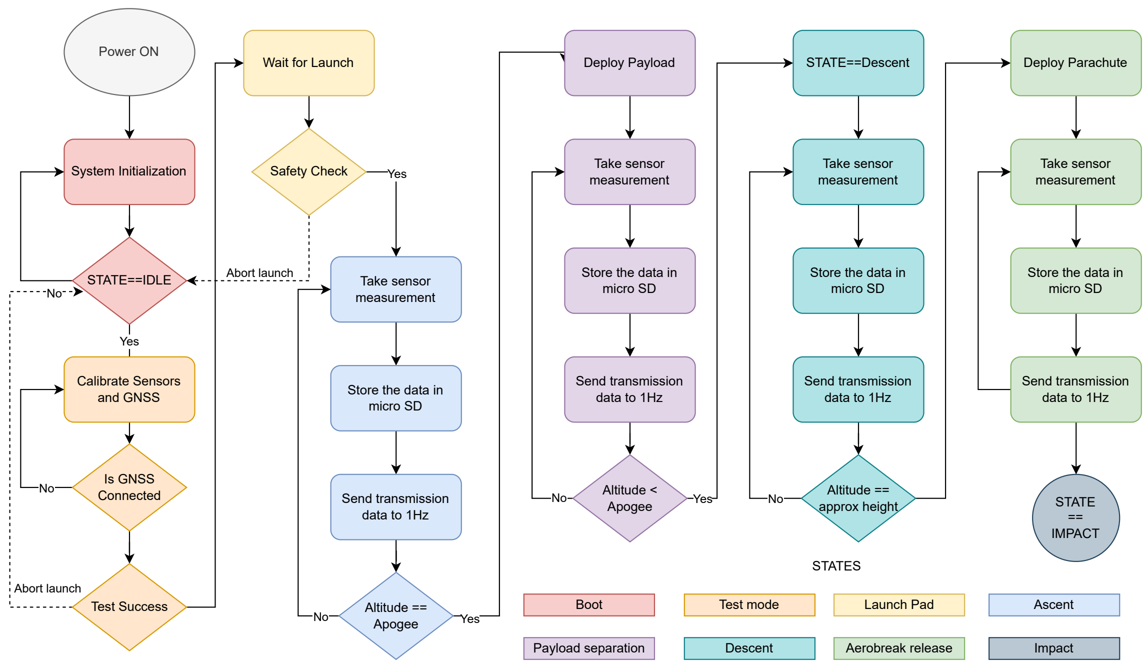


Figure 3.22: FSW State Diagram

3.4.3 Flight Software (FSW) Architecture

The Flight Software (FSW) for this mission is designed as a set of coordinated tasks running on a real-time operating system, rather than as separate application modules. Each task is dedicated to a specific function critical to flight operations and mission success.

Implementation on RTOS

The FSW is implemented using FreeRTOS on the ESP32-WROOM microcontroller. The ESP32-WROOM offers a dual-core architecture with integrated Wi-Fi and Bluetooth and is well-suited for embedded flight systems that require reliable performance and low power consumption.

Using FreeRTOS enables us to precisely manage and schedule multiple tasks, ensuring deterministic real-time behavior. This is crucial for responding to changing flight conditions such as apogee detection, payload deployment, and landing preparation.

Task Structure

The software operates as a set of well-defined tasks, each running under FreeRTOS on the ESP32-WROOM. These tasks work together in a state-driven flow to perform all mission functions reliably and efficiently. The main tasks include:

- **Booting and Calibrating Task**: Responsible for system initialization after power-on. It performs hardware checks, sensor calibration, and ensures GNSS connectivity. The system remains in an idle state until all initial checks pass and a GNSS lock is acquired, ensuring accurate flight data.
- **Sensor Reading Task**: Continuously acquires measurements from onboard sensors such as GNSS, barometer, accelerometer, and other flight instruments. The data collected by this task is shared with other tasks for logging and telemetry purposes.
- **Data Logging Task**: Handles storing all sensor data to the microSD card. This task ensures that detailed flight data is recorded throughout the entire mission, enabling post-flight analysis and verification.
- **Telemetry Transmission Task**: Responsible for formatting and transmitting key telemetry data to the ground station through the XBee communication link at a fixed rate of 1 Hz. This provides real-time insight into the system's state and critical flight parameters during the mission.
- **Payload Dispatch Task**: Monitors flight conditions, particularly altitude, to determine when the vehicle has reached apogee. Upon detection, this task triggers the solenoid mechanism to release the payload. This action is critical for mission objectives such as scientific measurements or experiments conducted after separation.
- **Parachute Deployment Task**: Continuously checks descent altitude during the return phase. When the vehicle reaches approximately 100 meters above ground level, this task commands the parachute deployment mechanism to ensure a controlled and safe landing.

By structuring the software into these focused tasks, we achieve a robust, modular, and deterministic system capable of handling critical mission events precisely and reliably.

Software Framework

In this design, we have deliberately avoided additional frameworks such as KubOS to keep the system lightweight and minimize software overhead. Instead, we directly use FreeRTOS along with the ESP-IDF (Espressif IoT Development Framework) libraries for peripheral control, SD card access, and sensor interfaces.

This approach offers several key advantages:

- **Low complexity and resource efficiency**: Fewer abstractions allow tighter control of hardware resources, essential for power-constrained missions.
- **Deterministic real-time behavior**: FreeRTOS ensures predictable task scheduling and fast response to critical events like payload release or state transitions.
- **Modularity through tasks**: While not separated into distinct applications, individual tasks handle sensing, storage, telemetry, and mission state logic, providing functional separation and easier maintenance.

3.4.4 Data Transmission and Storage Setup

We are using **XBee modules** (configured as a transmitter and receiver pair) for data transmission, utilizing the ZigBee protocol to handle the physical and MAC layers of communication between the onboard system and the ground station.

To structure and manage telemetry data, we use packet-based encapsulation inspired by small satellite protocols (such as the CubeSat Space Protocol), but without directly implementing CSP. Instead, we define our own simple packet structure to package sensor readings and command responses before transmitting them over ZigBee.

Onboard the ESP32-WROOM module, data packets are prepared, queued, and transmitted through the XBee module connected via UART. The ground station receives these packets and decodes them for further analysis or display.

Communication Architecture

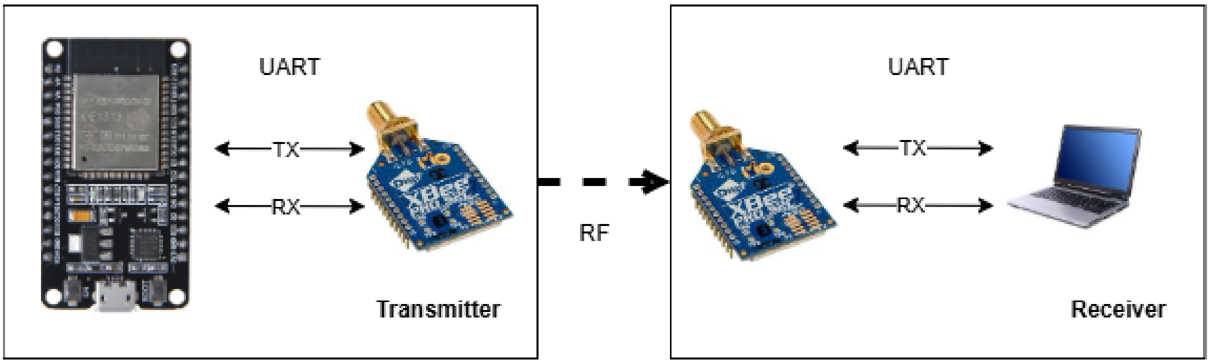


Figure 3.23: Data Transmisson

- **ESP32-WROOM** handles data collection, packet formation, and high-level logic.
- **XBee** (via UART) handles wireless transmission over ZigBee.
- No separate onboard router or stack layers like in CSP; all logic is implemented in firmware on ESP32.

Data Storage

Local data storage is handled using an **SD card**, which is interfaced with the ESP32 using SPI.

The SD card is formatted with the FAT (File Allocation Table) file system, enabling easy file access and compatibility with standard PCs.

We use the **FatFs library**, a lightweight FAT file system module for embedded systems, to handle file operations such as creating logs, saving sensor data, and writing received commands or system states.

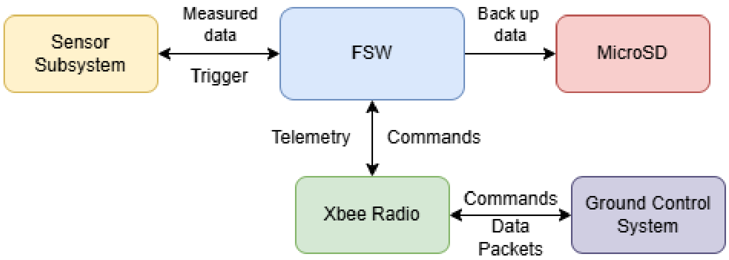


Figure 3.24: FSW Overview

Reasons for Changes

In the revised design, several significant changes were made to the system hardware and software architecture. The reasons for these changes are detailed below.

Change of Microcontroller: STM32 to ESP32-WROOM The microcontroller was changed from STM32 to ESP32-WROOM. This decision was driven by the following factors:

- **Ease of interfacing:** ESP32-WROOM offers significantly easier interfacing with peripherals and modules compared to STM32. Its GPIO handling, simpler driver libraries, and extensive example code base reduce development time and lower overall complexity.
- **Community support and development tools:** ESP32 benefits from extensive community support, easier availability of example codes, and a wide range of readily available libraries.

Change of GNSS Module: Bharat NAVIC to Neo-6M GPS The navigation module was changed from Bharat NAVIC to Neo-6M GPS due to:

- **Compatibility and integration:** Neo-6M GPS modules are more commonly used and offer seamless integration with ESP32, supported by mature software libraries.
- **Availability and reliability:** Neo-6M GPS is readily available and has a proven track record for reliability and accuracy in similar applications.
- **Simplified antenna and hardware requirements:** Neo-6M requires less stringent antenna placement and design constraints compared to NAVIC modules, which helps simplify mechanical integration.

Changes in RTOS Task Structure The task structure of the RTOS was completely redesigned.

- **Improved modularity and robustness:** The new task structure is optimized for ESP32, focusing on clear separation of tasks (such as data acquisition, communication, and logging) to enhance system stability.

- **Removal of software reset loops:** The previous architecture relied on periodic software resets to recover from potential failures. The new design eliminates this dependency by introducing robust error handling and watchdog mechanisms.
- **Discontinuation of KubOS:** The use of KubOS has been discontinued to simplify the software stack and reduce dependencies, thus allowing for a lighter, more efficient custom RTOS implementation tailored to project-specific needs.

3.5 Recovery

The purpose of the recovery subsystem is to control the descent rate of the rocket and ensure recovery of the rocket post touch down. The competition constraint is that the descent rate of the launcher body shall be between 2 and 5 m/s.

3.5.1 Subsystem Details

The recovery subsystem consists of the following :

- A spring-based ejection mechanism triggered by the avionics subsystem to eject the nose cone out of the body tube, deploying the parachute, and allowing the upper section of the body tube to open up.
- Spring-loaded hinges help open the body tube to let the payload drop from the main body.

The main components of the recovery subsystem are

- Spring (for the ejection)
- Rope (to hold the compressed spring and the linear actuator together)
- Linear Actuators (to hold the springs in compressed position)
- Relays (trigger the linear actuators to release the spring)
- Spring Loaded Hinges (push the upper section of body tube outward)
- Parachute (recovery mechanism)
- Controller (flight controller of the avionics subsystem triggers the relays)

The recovery components and their positioning in the rocket are given in the following diagram.

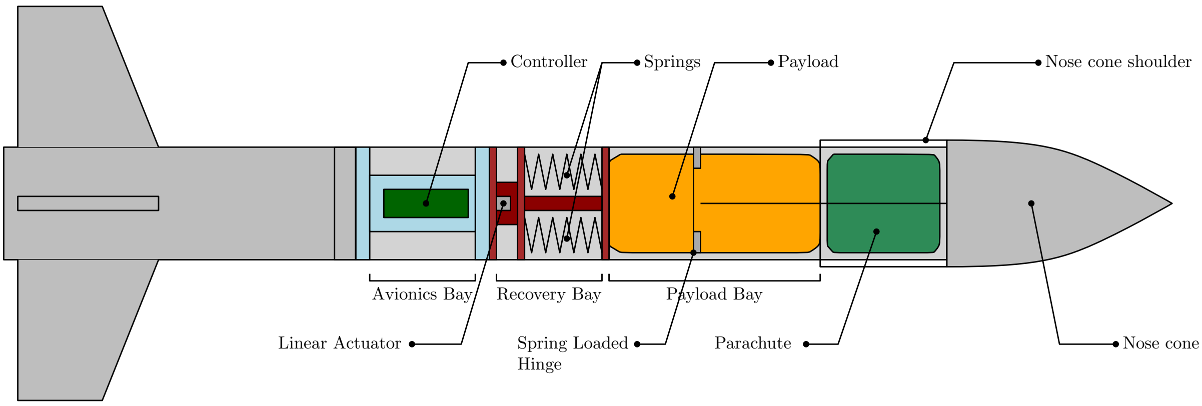


Figure 3.25: Recovery Subsystem of the rocket

The recovery bay is located just above the avionics bay separated by a bulkhead. The upper section (composed of 3 vertical sections) of the body tube is attached to the rest of the bodytube by means of a spring loaded hinges. The nosecone goes on top of this section holding the upper section together. The sequence of events of the recovery subsystem is given below:

1. The spring of the ejection system is compressed and held in the same position by a rope attached to the linear actuators located in the recovery bay. The payload and the main parachute are located on top of the recovery bay.
2. As soon as the desired height is reached, the flight controller module of the avionics subsystem senses it from the altimeter and IMU sensor data.
3. The flight controller sends a signal that triggers the relays, which in turn trigger the linear actuators, which now allow the springs to expand along the body tube.
4. The top of the recovery bay is free to move, pushing the payload and the nosecone.
5. This creates enough pressure to eject the nosecone off the body tube while allowing the upper section to open because of the spring-loaded hinges. The upper section will open like a flower petal, which will help the payload to easily emerge from the rocket.
6. When the nosecone is ejected, the main parachute is deployed and also the payload is ejected from the rocket.
7. The nosecone is attached to the main body tube with the help of the shock cord. The parachute is attached to the shock cord and is fully deployed.
8. The rocket body along with the nose cone is recovered. The payload is recovered by it's own recovery mechanism.

The ejection mechanism triggered by the flight computer undergoes the following process flow,

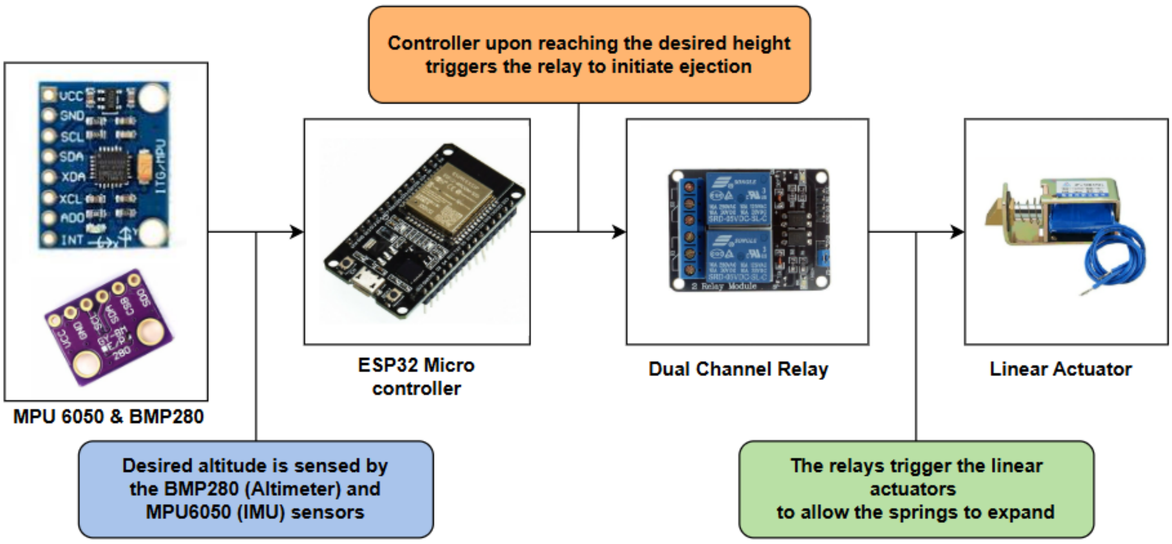


Figure 3.26: Ejection process flow

3.5.2 Design and Prototyping Details

Parachute Calculations

The descent rate of the launcher body should be within 2 to 5m/s. The descent control uses only a single parachute which is in reefed condition just after deployment. Later, as the reefing ring slides down the shroud lines, the parachute becomes unreefed. Since, the apogee is not too high, use of reefing lines and line cutters have been avoided.

For the canopy, toroidal shape was selected as it has the highest drag coefficient. The area of the parachute can be calculated using the drag equation:

$$A = \frac{2mg}{\rho C_d v^2}$$

where:

- A is the parachute area,
- m is the mass of the rocket,
- g is the gravitational acceleration,
- ρ is the air density,
- C_d is the drag coefficient,
- v is the descent velocity.

For toroidal parachutes, the calculation of the area will vary based on its geometry.

Toroidal Parachute Calculation:

Using the drag coefficient for a toroidal parachute $C_d = 2.2$, we calculate the area and diameter.

For a descent rate of $v = 2m/s$:

$$A = \frac{2 \times 12 \times 9.81}{1.225 \times 2.2 \times 2^2} = 30.41m^2$$

$$D = \sqrt{\frac{4 \times 30.41}{\pi}} = 6.22m$$

For a descent rate of $v = 5m/s$:

$$A = \frac{2 \times 12 \times 9.81}{1.225 \times 2.2 \times 5^2} = 4.87m^2$$

$$D = \sqrt{\frac{4 \times 4.87}{\pi}} = 2.49m$$

The parachute will be designed and manufactured in-house although the design itself is inspired by existing designs.

Parachute design

For testing purpose, a small-scale parachute was fabricated using polyester fabric of dimension (180cm × 180cm).

Ejection system calculations

The ejection system requires pushing the nosecone out, which in turn requires pushing the payload, parachute, and nosecone together by a length of atleast 10cm, which is the length of the nosecone shoulder. In the worst-case scenario, the rocket would be upright at the time of ejection, requiring maximum effort from the ejection system. This condition is chosen for the calculations of the required spring constants.

The total mass to push / eject $m_{ejection} = m_{nosecone} + m_{payload} + m_{parachute}$, which is approximately equal to 4kg. Given that the distance to push this total mass is equal to the length of the nose cone shoulder ($L_s = 0.1m$), we have,

$$mgL = \frac{1}{2}kL^2$$

$$k = \frac{2mg}{L}$$

where k is the required spring constant and its value is calculated approximately to be 0.8 N/mm.

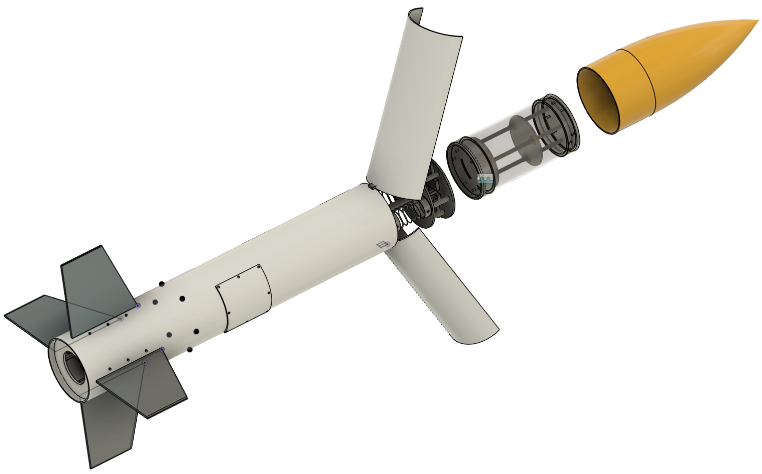


Figure 3.27: Ejection System

Ejection system design

We obtained springs of outer diameter $D_o = 44.3mm$ and inner diameter $D_i = 38.1mm$ and active coils $N_a = 8$ made of brass (shear modulus of elasticity $G \approx 39000N/mm^2$). Using this information, the spring constant can be theoretically calculated using the following relation.

$$k = \frac{dG}{8N_aC^3}$$

Substituting the values, we get the value for k as 0.8047. We will use two of these springs to meet the requirement considering the safety factor. The calculated spring constant was verified with few experiments.

Ejection system CAD

The ejection mechanism, as explained earlier, uses linear actuators to hold the springs in the compressed state. The ejection system was designed in Fusion 360 and an isometric view of the design is given below. The components in the system are as follows,

- Spring Cover (enables attachment of springs to the plates)
- Top Plate (Moves along with the springs, pushing the payload and nosecone)
- Base plate (Stays in place, attached to the bulkhead and contains the linear actuators and latch)
- Linear Actuators (Enables locking the springs in compressed state)
- Latch (Connected to the axle of the actuator, enables locking)
- Springs (Enables ejection)
- Guide rails (to restrict the sideways movement of the spring)
- Guide rail covers (to hold and attach the guide rails to the base plates)
- Rope (to hold the spring in the compressed state)

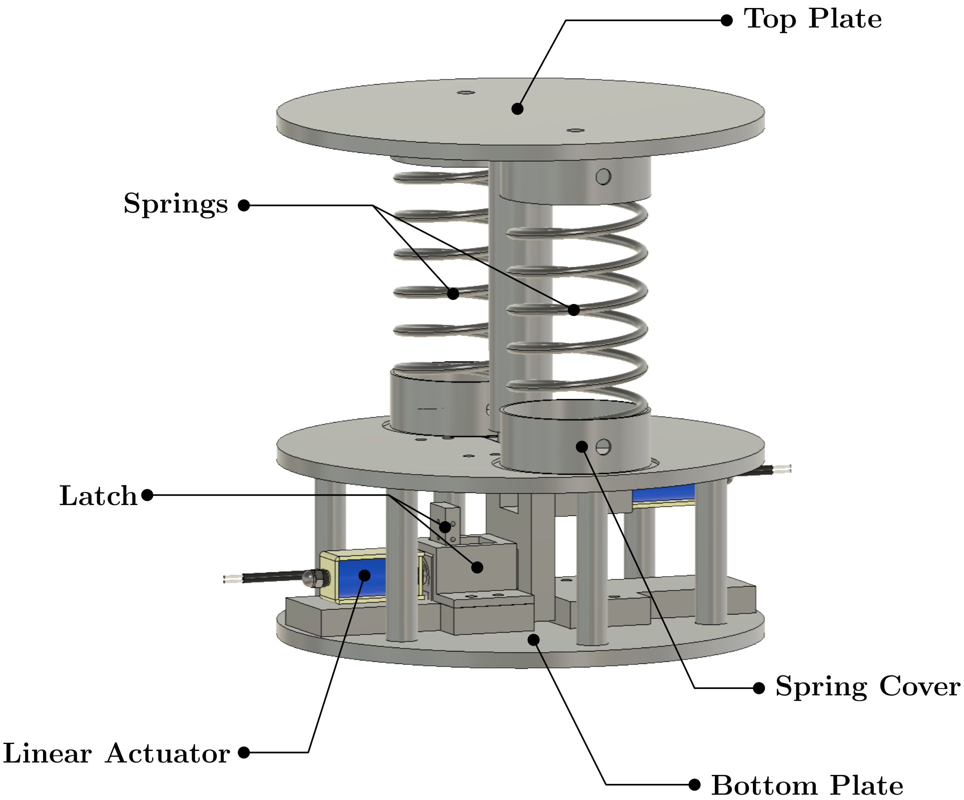


Figure 3.28: CAD Design of the ejection system

Ejection system prototyping

For prototyping, the CAD model was 3D printed and experimented with different scenarios. The results of the experiments are as follows,

- The designed CAD model holds the compressed springs in place by using two latches which are actuated by two linear actuators.
- Although, the springs can be held in place using the designed system. Releasing the springs using linear actuators, is harder. Reduction of friction is required.

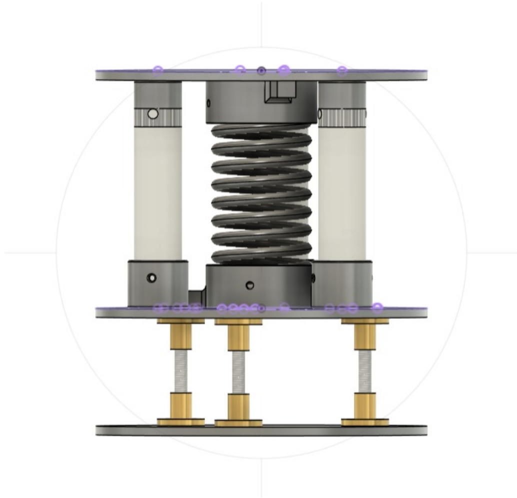


Figure 3.29: CAD Design of the modified ejection system

- The strength of the 3d printed model met the objectives

3.6 Launch Subsystem

The Launch Subsystem encompasses all mechanical and electrical components required to support and execute the launch of the rocket. It comprises two key units: the Launch Pad and the Launch Controller. The design prioritizes safety, modularity, adjustability, and field readiness – ensuring the system is both robust and efficient under operational constraints.

3.6.1 Launch Pad Design

The launch pad serves as the physical interface between the rocket and the ground system, ensuring proper alignment and support during launch. The guiding philosophy behind its design was to simplify rocket loading, allow flexible angular control, and maintain structural integrity during high-thrust ignition.

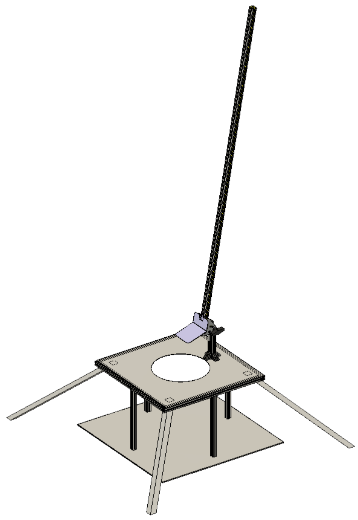


Figure 3.30: Launch Pad

The launch pad is built using a T-slotted aluminium extrusion frame, configured in a rectangular base (2.5 m × 1.8 m) using high-strength L-brackets. The base ensures stable load distribution and acts as an anchor for the hinged guide rail mechanism. A 3.2 m aluminium extrusion serves as the guide rail for the rocket. This rail is attached at the midpoint of one long side of the base via a locking pivot joint, allowing angular adjustment for launch.

To counter the difficulty of vertical rocket loading (given the rocket's 180 cm height), this hinge mechanism allows horizontal mounting followed by tilting the rail up to the desired launch angle – improving both safety and ergonomics.

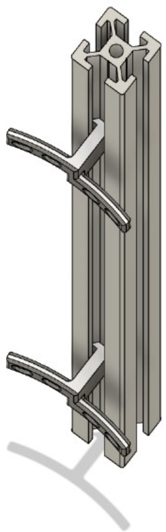


Figure 3.31: Rail Button and Rail

The rocket is equipped with detachable rail buttons, which slide through the T-slot in the extrusion, ensuring aligned and constrained vertical motion during liftoff.

Structural Support Mechanism

A central aluminium cross-beam bisects the base to mount three steel square bracing rods (0.952 m, 1.67 m, and 3.65 m in length). These rods brace the angled guide rail and are connected at predefined positions (0.913 m, 1.6 m, and 3.2 m from the hinge) to support a default 10° inclination. The system allows adjustable angles by sliding the rod bases along the T-slots.

Each steel rod is connected at the bottom to T-type roller wheels, which slide within the aluminium extrusion's T-slots. Once the angle is finalised, these rollers are locked using L-brackets. At the top, the rod uses hinge joints for smooth articulation and angular tolerance.

For toppling resistance, vertical aluminium extrusion is connected from the base to the sides of the angled guide rail. These are fastened using sliding nuts and bolts inserted into the rail's T-slot. Positioned symmetrically at 1.5 m from the hinge, these lateral supports ensure rigidity even under mild wind or vibrations.

Transportability is enhanced by dividing the guide rail into two segments joined by a torque-adjustable hinge, enabling folding and compact packaging. This hinge also provides angular resistance, minimizing unwanted motion during prep.

Material Justification

Component	Material	Justification
Base Frame	Aluminium Extrusions	High strength-to-weight ratio, modular, corrosion-resistant
Guide Rail	Aluminium Extrusion	Compatible with T-slot buttons, easy to customize
Support Rods	Hollow Steel Pipes	Economical, strong under compression
Roller Wheels	Polymer/Steel Hybrid	Smooth sliding, wear-resistant
Brackets and Joints	Mild Steel/Aluminium	Easy to fabricate, readily available

Table 3.2: Launch Pad Material Justification

Pros and Innovations

- **Modular Angle Control:** Adjustable inclination using purely mechanical system – no motors required.
- **Stable Load Transfer:** T-slots and hinge joints ensure stable rocket alignment under load.
- **Ease of Assembly:** Quick field setup with minimal tools.
- **Integrated Safety:** Anti-toppling supports and locking systems.
- **Transport-Friendly:** Foldable design with torque hinges.

Limitations and Fixes

Limitation	Fix
Manual angular control requires effort	Add winch or screw-jack system for mechanical assistance
Load on L-brackets at steep angles may be high	Use dual L-brackets or integrate diagonal cross-bracing
Dust accumulation in T-slots affects movement	Apply T-slot covers or conduct periodic cleaning

Table 3.3: Launch Pad Limitations and Fixes

3.6.2 Launch Controller

The Launch Controller is a simplified electrical system designed to ignite the rocket motor through electric current sent to the ignitor. The controller provides:

- A safe arming mechanism
- Visual feedback via LEDs for circuit readiness
- A push-button trigger that completes the circuit only when armed

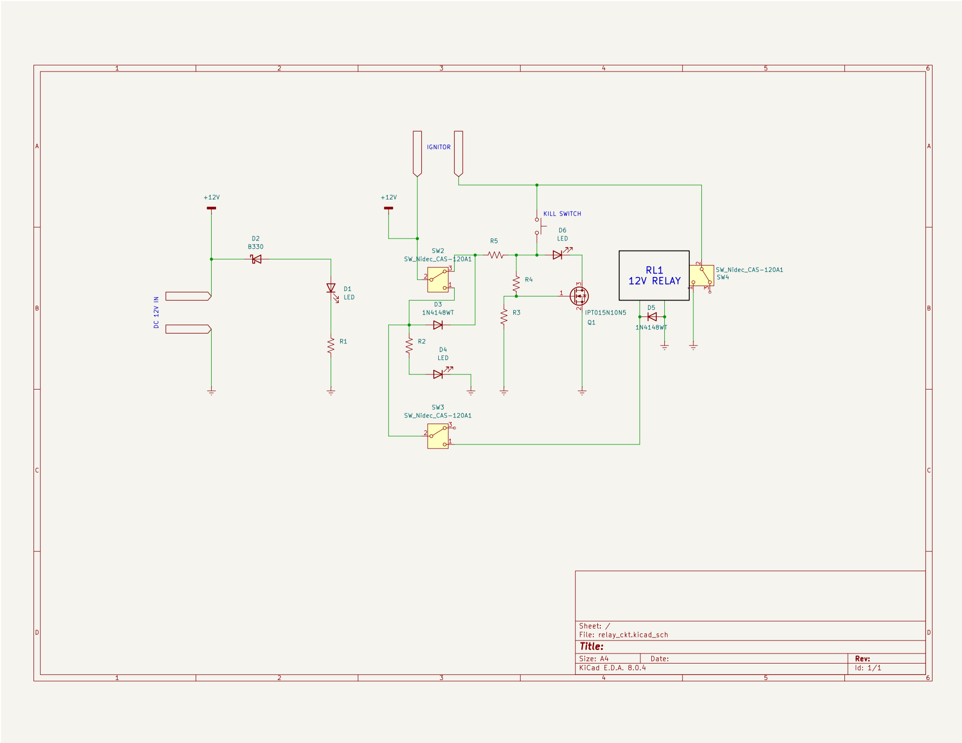


Figure 3.32: Ignitor Schematic

The controller circuit is tested for resistance, reliability, and current output to ensure sufficient energy is delivered to ignite the electric match or nichrome wire within the solid rocket motor.

3.6.3 Conclusion

The Launch Subsystem integrates a mechanically robust and field-friendly pad with a simple and safe ignition system. By combining T-slot aluminium framing, modular steel bracing, and a mechanical angular adjustment system, the design ensures:

- Quick Deployment
- High Safety
- Mechanical Reliability
- Cost-effectiveness

Its modularity allows for future integration of telemetry, payload support, and sensor mounts. Overall, the design stands out for its simplicity, transportability, and mechanical soundness, making it well-suited for repeated launches in variable field conditions.

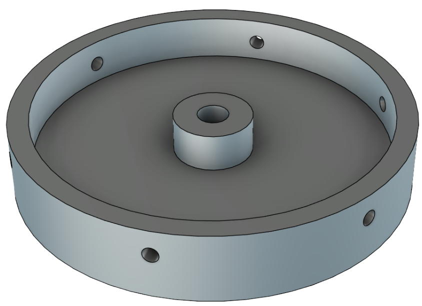
3.7 Propulsion

3.7.1 Major changes from the PDR

1. The total impulse requirement has increased compared to the previous report, primarily due to the rise in overall rocket mass, including the added weight of the motor assembly.
2. Unlike the previous approximation-based method calculation, this report employs actual motor thrust curve data to dynamically compute velocity, altitude, and impulse metrics for improved accuracy.
3. The thrust plate has now been formally identified as the Aeropack, and its detailed design has been incorporated to reflect the actual flight configuration.
4. The centering ring design and material have been updated based on the motor specifications provided by Thrust Tech, ensuring proper integration with the current motor details
5. The component previously referred to as the "retainer" has been renamed as the "thrust plate" in line with motor specifications document. While the earlier report mentioned it as a team-manufactured part, it is now being sourced directly from Thrust Tech.

3.7.2 Components

Aeropack



Purpose:

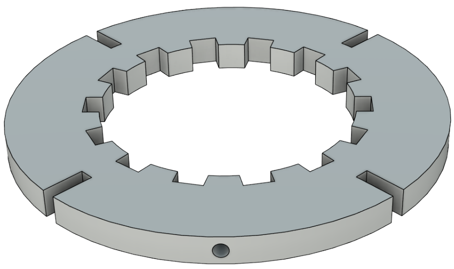
- Securely holds the rocket motor in place with a forward M12 threaded bolt and prevents its rearward movement during thrust generation.
- The Aeropack functions as a motor retention system, ensuring that the motor remains securely attached to the rocket structure post-burnout.

Material: Aluminium 6061 T6 **Weight:** 686.6g
Position: Located at the forward end of the rocket motor.

Design Specifications

Thread Specification: The inner diameter of the smaller inner cylinder is 12 mm and features an M12 $\times$ 1.75 6H internal thread for engagement with the motor's forward bolt.
Thread Engagement: The length of the smaller inner cylinder is 25 mm.
Outer Diameter: 152.4 mm—fits tightly in the airframe and is fixed to the airframe via 6 M6 screws to completely transfer axial thrust loads and flight vibrations.
Aeropack-to-Motor Clearance: 15 mm gap prevents the mechanical interference between the Aeropack and motor.

Centring Ring



Purpose: Provides stability, ensures motor alignment, and damps vibrations of the rocket motor during flight.

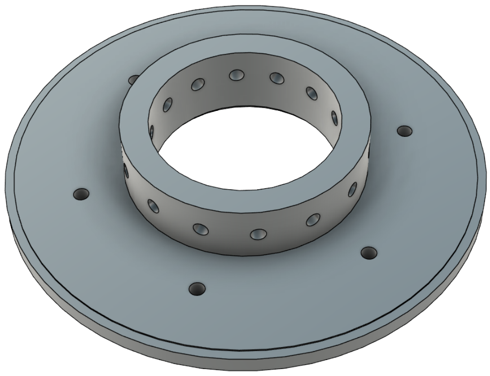
Manufacturing: 3D printed using **PLA (Polylactic Acid)**.

Position: Two centering rings are placed at roughly one-third and two-thirds along the motor's length, with their positioning also optimized to accommodate fin slot alignment without interference. **Weight:** 115.8g each

Design Specifications

- **Outer Diameter:** 152.4 mm—fits into the airframe with minimal clearance; Attached to body tube by epoxy and for more secure connected to the airframe via four M5 screws.
- **Inner Diameter:** 88.5 mm—matches the motor's outer diameter.
- **Inner Slot Profile:** 14 equally spaced slots for M5 bolt clearance:
  - Width: 10 mm
  - Height: 5.76 mm
- **Outer Slot Profile:** 4 slots for fins fitting inside the airframe:
  - Width: 5 mm
  - Height: 14.96 mm
- **Thickness:** 10 mm—chosen to ensure good stiffness and bolt-holding capacity.

Thrust Plate



Purpose:

- Ensures reliable axial load transfer from the motor to the airframe.
- Prevents rearward movement of the motor under high thrust by securely anchoring the motor to the airframe.
- Distributes thrust forces evenly to improve structural stability and safety.

Manufacturing: Designed and manufactured by the Thrust Tech Team using **Aluminium 6061-T6** for its high strength-to-weight ratio and excellent deformation resistance under mechanical/thermal loads.

Positioning: Placed at the rear end of the motor, directly interfacing with the nozzle or rear casing.

Design Specifications

Dimensions:

- Inner diameter (airframe tube): 152.4 mm
- Outer diameter (airframe tube): 158.4 mm

3.7.3 Rocket Engine Subsystem

Rocket Engine Constraints

1. The Rocket must use commercially made model rocket motors.
2. Maximum Total Impulse < 2800 Ns.
3. Rocket Motor must be retained in the rocket by positive mechanical means.

Motor selection and details

This section outlines the rationale behind selecting the rocket motor, supported by simulation data and propulsion requirements. It also provides detailed specifications of the chosen motor and associated structural elements, reflecting recent design updates and supplier information.

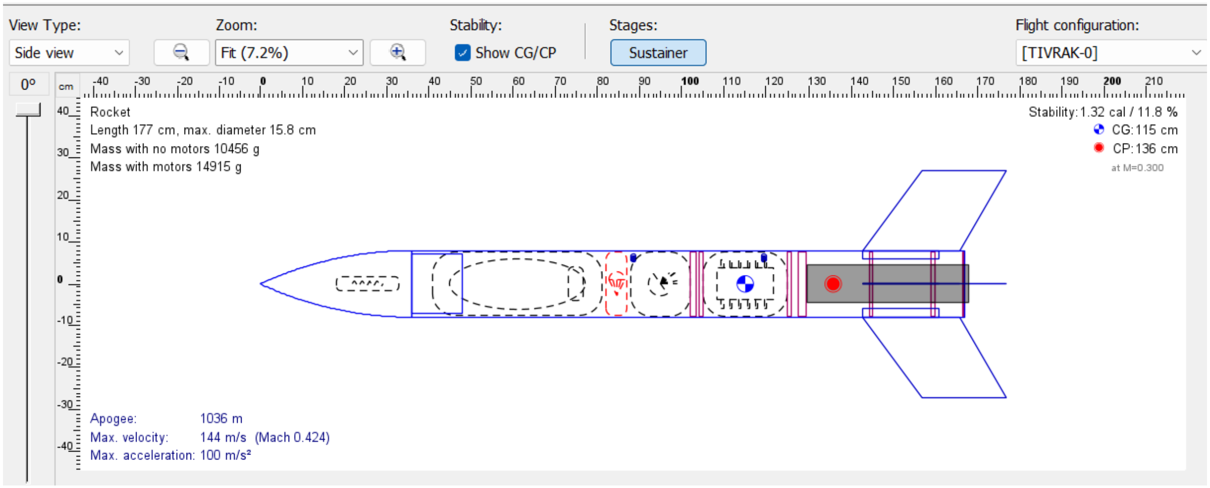


Figure 3.33: OpenRocket simulation output using Motor A thrust curve

The results of the OpenRocket simulation using Motor A(TIVRA K-925)'s thrust curve as shown in the above figure, indicating an apogee of approximately 1036m, a maximum velocity of 144 m/s, and a peak acceleration of 100 m/s^2.

Hence, based on OpenRocket simulations, the apogee achieved by the rocket closely matched the target altitude of 1000m when simulated using Motor A. Therefore, **Motor A (TIVRA K-925)** has been selected as the propulsion unit for the rocket.

Details of Motor A(TIVRA K-925) as provided by the **Thrust Tech**

Name	TIVRA K-925
Motor Diameter	94 mm
Casing Length	383 mm
Casing Material	Aluminium
Pressure Rating	12 MPa
Total Impulse	2500 Newtons-sec
Average Thrust	925 Newtons
Peak Thrust	1550 Newtons
Thrust Duration	2.7 sec
Propellant Weight	2200 grams
Motor Weight	4459 grams
Total Liftoff Weight	15000 grams

Table 3.4: Motor A Specifications (TIVRA K-925)

Performance Analysis of Rocket Ascent Simulation

All the calculations presented below were performed using a custom MATLAB script, which dynamically integrates thrust data, varying mass, atmospheric drag, and gravitational effects to model rocket ascent and compute performance metrics. The following sections provide a detailed breakdown of the process and results.

Objective

This Calculation aims to:

- The motor's thrust curve data was used to dynamically and accurately compute the required performance parameters.
- Compute the **total impulse required** to reach target apogee(1000m) considering gravity and atmospheric drag.
- Evaluate the **actual apogee** achieved based on the thrust curve, mass variation, and aerodynamic drag.
- Quantify Δv **losses** and compare **available vs. required impulse**.

Rocket Parameters and Constants

Parameter	Value
Initial mass	14.915 kg
Propellant mass	2.20 kg
Dry mass	12.715 kg
Rocket diameter (D)	0.1584 m
Frontal area (A)	0.0197 m^2
Drag coefficient (Cd)	0.425
Target apogee	1000 m

Constant	Value
Gravity (g)	9.81 m/s^2
Air density (ρ_0)	1.225 kg/m^3
Standard temp (T_0)	288.15 K
Lapse rate (L)	0.0065 K/m
Gas constant (R)	8.314 J/mol·K
Molar mass (M)	0.029 kg/mol

Thrust Curve Integration

- A CSV file was created from the motor specification's thrust curve and was imported containing time vs. thrust data.

- Total impulse calculated using trapezoidal integration:

$$I_{\text{actual}} = \int_0^{t_{\text{burn}}} T(t)\,dt \approx 2500\,\text{Ns}$$

Dynamic Processes

Mass Reduction

$$\dot{m}(t) = \frac{m_{\text{propellant}}}{I_{\text{actual}}} \cdot T(t)$$

As the rocket burns fuel, its mass decreases over time. Here, $\dot{m}(t)$ represents the rate of mass loss (kg/s), $m_{\text{propellant}}$ is the total propellant mass, I_{actual} is the actual impulse from the thrust curve, and $T(t)$ is the instantaneous thrust.

Atmospheric Density

$$\rho(h) = \rho_0 \left(1 - \frac{Lh}{T_0}\right)^{\frac{gM}{RL}}$$

Air density $\rho(h)$ varies with altitude h, decreasing as the rocket ascends. This equation adjusts drag appropriately at higher altitudes.

Drag Force

$$F_d(t) = \frac{1}{2}\rho(h) \cdot v(t)^2 \cdot C_d \cdot A$$

Drag opposes the rocket's motion and increases with the square of its velocity. Calculating this accurately is crucial for understanding how atmospheric resistance limits the rocket's speed and altitude.

Kinematics and Force Balance

$$\begin{aligned}
F_{\text{net}}(t) &= T(t) - F_d(t) - m(t)g \\
a(t) &= \frac{F_{\text{net}}(t)}{m(t)} \\
v(t+\Delta t) &= v(t) + a(t)\Delta t \\
h(t+\Delta t) &= h(t) + v(t)\Delta t
\end{aligned}$$

These equations form the foundation of the simulation. Net force is used to derive acceleration, then velocity, then altitude — all integrated iteratively over small time steps.

Velocity Losses

$$\Delta v_{\text{gravity}} = \sqrt{2gh} \qquad \Delta v_{\text{drag}} = \int \frac{F_d(t)}{m(t)}\,dt$$

As the rocket climbs, it loses velocity due to gravity pulling it down and drag pushing against it.

Impulse Requirement Calculation

Ideal Velocity for Target Apogee

$$\Delta v_{\text{gravity}} = \sqrt{2gh} = \sqrt{2 \cdot 9.81 \cdot 1000} = 140\,\text{m/s}$$

Add Drag Loss

$$\Delta v_{\text{total}} = 140 + 35.72 = 175.72\,\text{m/s}$$

Total Required Impulse

$$I_{\text{required}} = m_{\text{initial}} \cdot \Delta v_{\text{total}} = 14.915 \cdot 175.72 = 2620.86\,\text{Ns}$$

Apogee and Output Metrics

- **Apogee:** $h_{\max} = h(t)$ when $v(t) = 0$
- **Max velocity:** $\max(v(t))$
- **Total impulse from thrust curve:** $I = \int T(t)\,dt$
- **Impulse required for target apogee:** $I_{\text{required}} = m_{\text{initial}} \cdot (\Delta v_{\text{gravity}} + \Delta v_{\text{drag}})$
- **Velocity losses:** integrated over time using Δv_{drag}

Final Results

Output	**Value**
Target Apogee	1000.00 m
Achieved Apogee	984.25 m
Max Velocity	140.28 m/s
Total Impulse (from thrust curve)	2500 Ns
Required Impulse (computed)	2620.86 Ns
Max Drag Force	98.54 N
Time to Apogee	15.04 s
Δv lost to gravity	140 m/s
Δv lost to drag	35.72 m/s
Total Δv loss	175.72 m/s

Conclusion

Based on the calculations, the rocket reaches an apogee of **985.25 m**, slightly below the **1000 m** target. The motor provides **2500 Ns** of total impulse, but **2620 Ns** was required. Gravity and drag losses are the primary contributors.

Chapter 4

Ground Station

The ground station helps in real-time telemetry monitoring, transmission of commands and logging of the data into SD card.

4.1 System Architecture for Ground station

- Laptop running the PyQT5 GUI.
- Zigbee XBee Pro S2C 802.15.4 module with antenna connected to laptop using USB serial port.
- The GUI is coded in Python using the libraries matplotlib for graph plotting and pyserial for communication between serial ports.
- The GUI framework is made using PyQT5 with the PIL library for adding image

4.2 Working of GUI

In the avionics subsystem, the readings from sensors which are connected to ESP32 will be transmitted to the groundstation in packets after UTF-8 encoding through the Zigbee XBee Pro. The transmitted data is picked up by the receiver XBee connected to the groundtation Laptop. The data is decoded and parsed by the GUI and displayed while being simultaneously stored in the SD-card.

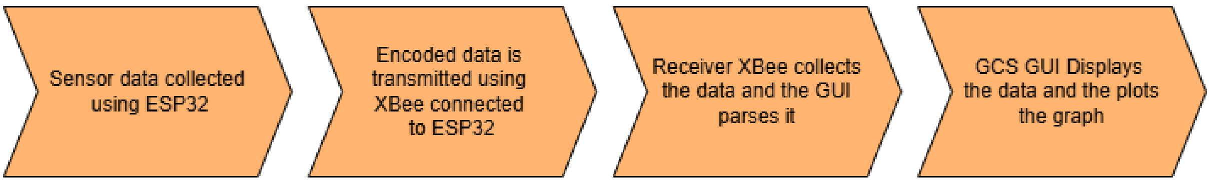


Figure 4.1: Flowchart of data transmission

4.3 Format of Telemetry data packets

S No.	TM Parameter	Function	Resolution or Format
1	`<TEAM ID>`	Team Number	2025-ASI-
2	`<TIME STAMPING>`	Time since the initial power	Seconds
3	`<PACKET COUNT>`	Count of transmitted packets	-
4	`<ALTITUDE>`	Altitude in units of meters and must be relative to ground	0.1 meters
5	`<PRESSURE>`	Measurement of atmospheric pressure	1 pascal
6	`<TEMP>`	Temperature in Celsius	0.1 degree Celsius
7	`<VOLTAGE>`	Voltage of the power bus	0.01 V
8	`<GNSS TIME>`	Time generated by the GNSS receiver	Seconds
9	`<GNSS LATITUDE>`	Latitude generated by the GNSS receiver	0.0001 degrees
10	`<GNSS LONGITUDE>`	Longitude generated by the GNSS receiver	0.0001 degrees
11	`<GNSS ALTITUDE>`	Altitude generated by the GNSS receiver	0.1 meters
12	`<GNSS SATS>`	GNSS satellites connected	integer
13	`<ACCELEROMETER DATA>`	Data received from the gyroscopic sensor i.e. acceleration and roll & pitch parameters	m/s^2
14	`<GYRO SPIN RATE>`	Spin rate of Mechanical Gyro	deg/s
15	`<FLIGHT SOFTWARE STATE>`	Operating state of the software	(boot, idle, launch etc.)

Table 4.1: TM Parameters

4.4 GUI and testing

Ground station checklist			
S.no	**Task**	**Compliance**	**Deviation**
1	Ensure the ground station correctly receives telemetry data packets from the flight computer.	Yes	No
2	Check whether ground station correctly parses telemetry packets.	Yes	No
3	Check the maximum range at which telemetry data can be reliably received.	No	Should be tested after RTOS integration
4	Ensure all data fields are correctly displayed on the GUI.	Yes	No
5	Test the entire communication chain under field conditions before launch.	No	Future test
6	Ensure telemetry logs match the recorded flight data.	No	To be tested after integrating SD card using RTOS in flight computer

4.4.1 GUI Functionality Tests

GUI telemetry data display test

Objective: To verify that the GUI displays the received telemetry data correctly in real time.

Testing and result: After passing the telemetry data as a packet, the GUI is able to parse it successfully and displays each of the data types as given in Table 4.1.

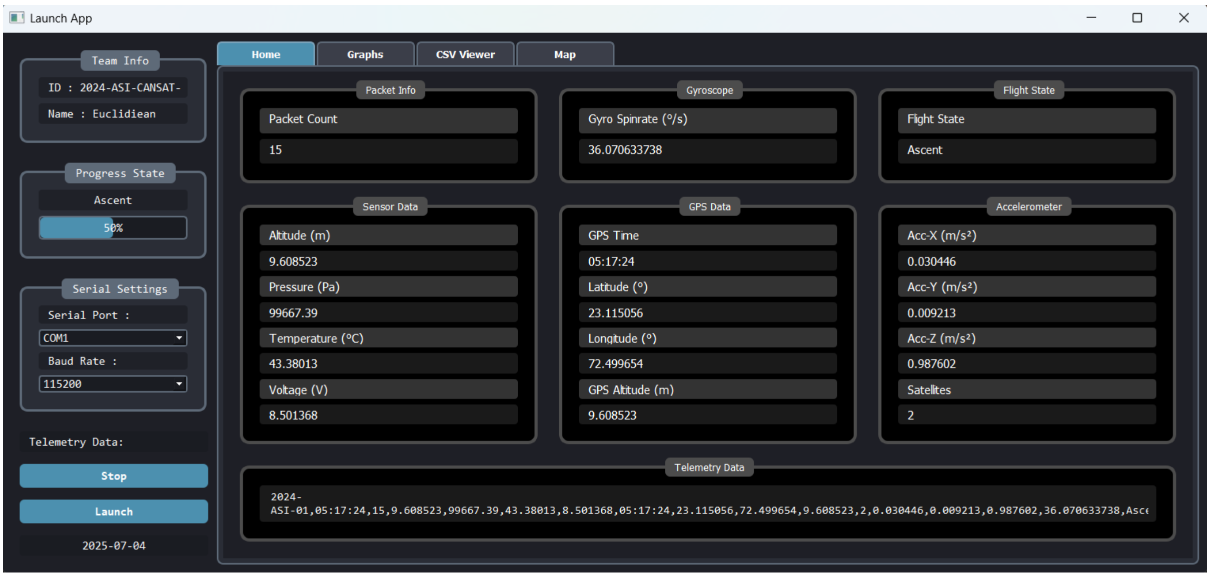


Figure 4.2: Updated GUI front end showing parsed telemetry data

Real-time mapping test

Objective: To verify the performance of the GUI in displaying location updates (latitude and longitude) on a map in real time.

Testing and result: Upon receiving changing GPS coordinates from the telemetry packets, the GUI successfully updates the map interface and marks the new location dynamically.

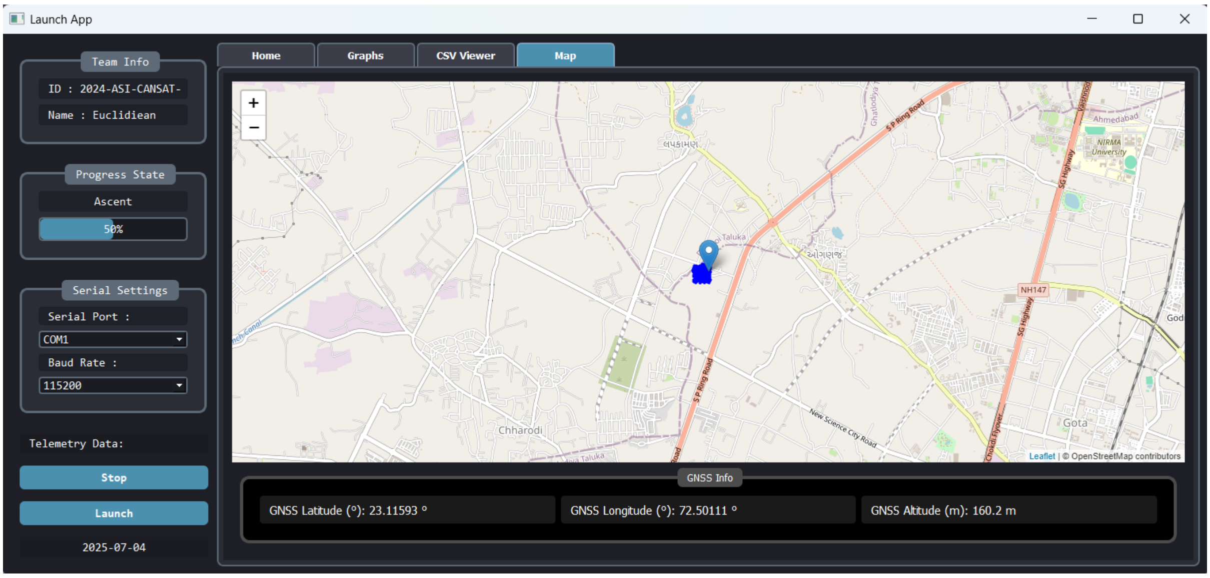


Figure 4.3: Real-time location update on GUI map

Real-time graph plotting test

Objective: To verify the performance of the GUI in plotting telemetry parameters on real-time updating graphs.

Testing and result: The GUI is able to continuously update the graphs for the telemetry parameters such as altitude, velocity, and temperature as new packets are received.

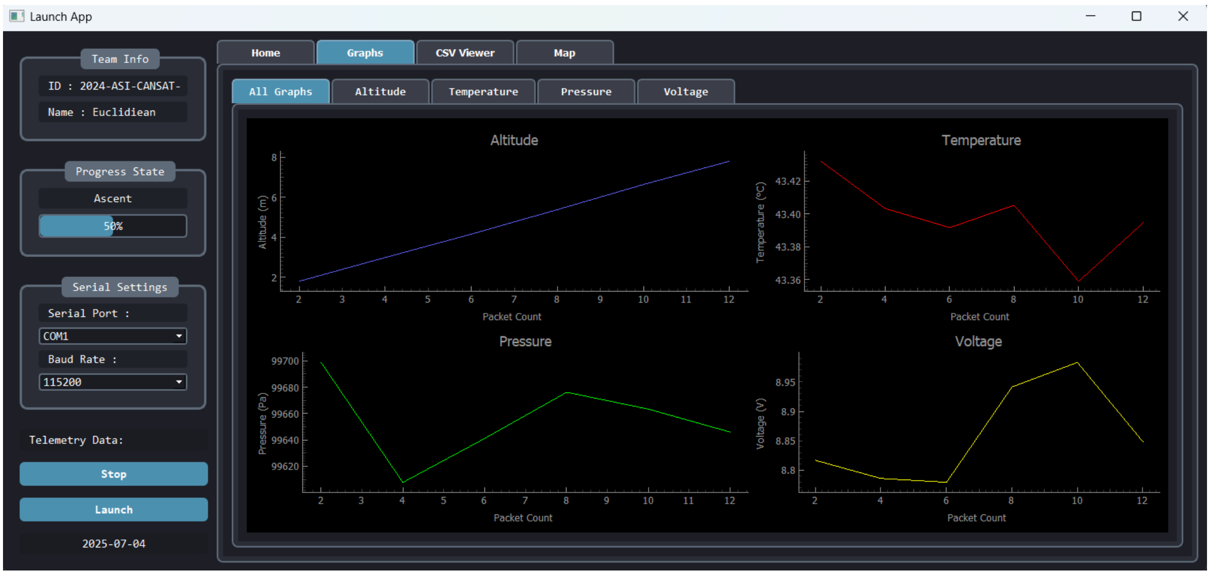
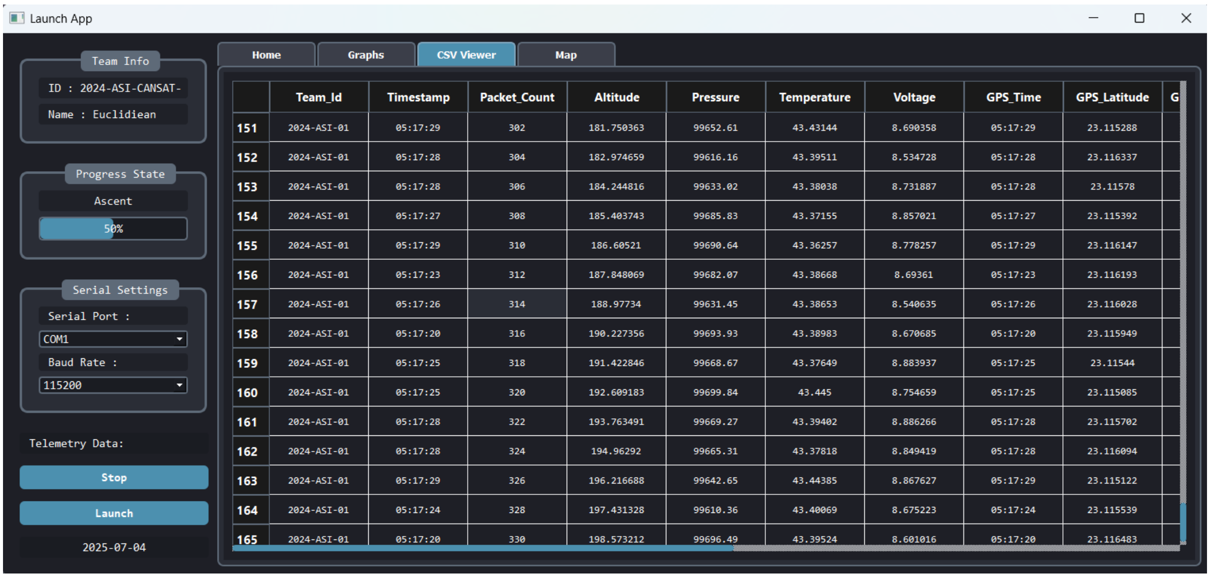


Figure 4.4: Live telemetry graph plotting in GUI



	Team_Id	Timestamp	Packet_Count	Altitude	Pressure	Temperature	Voltage	GPS_Time	GPS_Latitude	G
151	2024-ASI-01	05:17:29	302	181.750363	99652.61	43.43144	8.690358	05:17:29	23.115288	
152	2024-ASI-01	05:17:28	304	182.974659	99616.16	43.39511	8.534728	05:17:28	23.116337	
153	2024-ASI-01	05:17:28	306	184.244816	99633.02	43.38038	8.731887	05:17:28	23.11578	
154	2024-ASI-01	05:17:27	308	185.403743	99685.83	43.37155	8.857021	05:17:27	23.115392	
155	2024-ASI-01	05:17:29	310	186.60521	99690.64	43.36257	8.778257	05:17:29	23.116147	
156	2024-ASI-01	05:17:23	312	187.848069	99682.07	43.38668	8.69361	05:17:23	23.116193	
157	2024-ASI-01	05:17:26	314	188.97734	99631.45	43.38653	8.540635	05:17:26	23.116028	
158	2024-ASI-01	05:17:20	316	190.227356	99693.93	43.38983	8.670685	05:17:20	23.115949	
159	2024-ASI-01	05:17:25	318	191.422846	99668.67	43.37649	8.883937	05:17:25	23.11544	
160	2024-ASI-01	05:17:25	320	192.609183	99699.84	43.445	8.754659	05:17:25	23.115085	
161	2024-ASI-01	05:17:28	322	193.763491	99669.27	43.39402	8.886266	05:17:28	23.115702	
162	2024-ASI-01	05:17:28	324	194.96292	99665.31	43.37818	8.849419	05:17:28	23.116094	
163	2024-ASI-01	05:17:29	326	196.216688	99642.65	43.44385	8.867627	05:17:29	23.115122	
164	2024-ASI-01	05:17:24	328	197.431328	99610.36	43.40069	8.675223	05:17:24	23.115539	
165	2024-ASI-01	05:17:20	330	198.573212	99696.49	43.39524	8.601016	05:17:20	23.116483	

Figure 4.5: Live CSV veiwer in GUI

4.4.2 Changes from the PDR

The GUI is made in much more concrete terms using PyQt5 rather than Python Tkinter.Which is easily Modular and Easily Upgradable.

Chapter 5

Rocket Integration and Testing

5.1 Payload

5.1.1 Testing done

1. **Modal Analysis:** Modal analysis for the cansat was done in ANSYS. The analysis was performed for varying frequency replicate the frequency of wind which caused the vibrations leading to the maximum deformation of 1985.3 mm at 112.22 Hz.

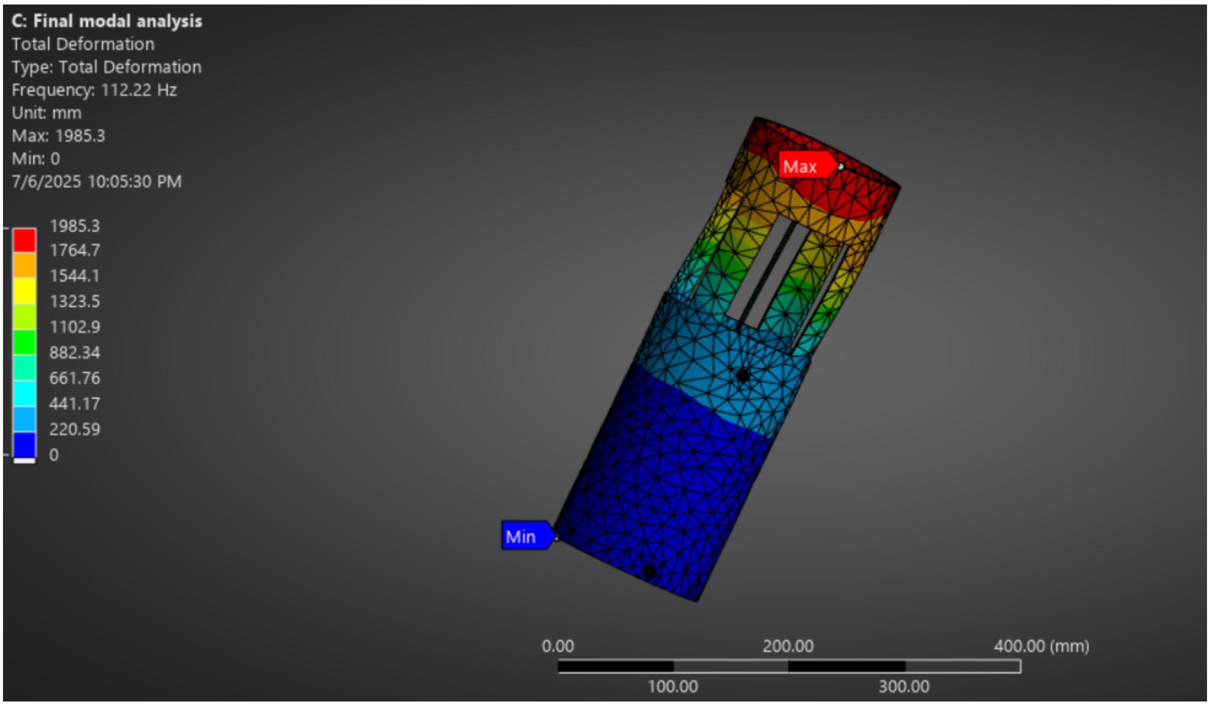
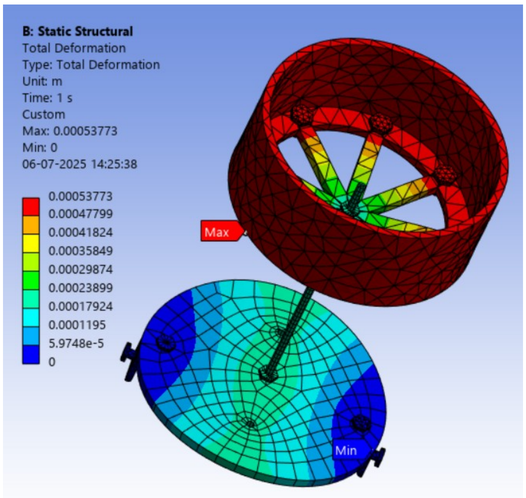
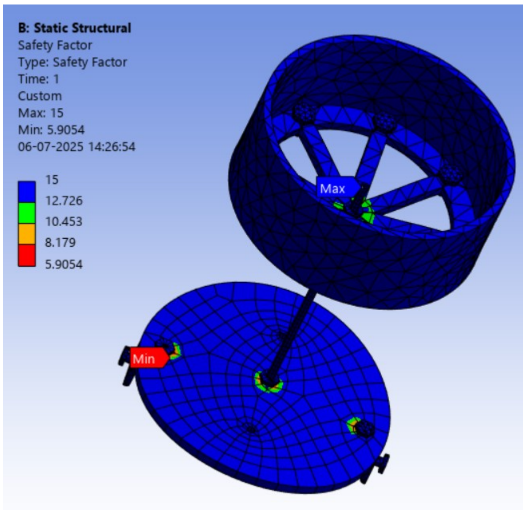


Figure 5.1: modal analysis

2. **Parachute Inflation:**

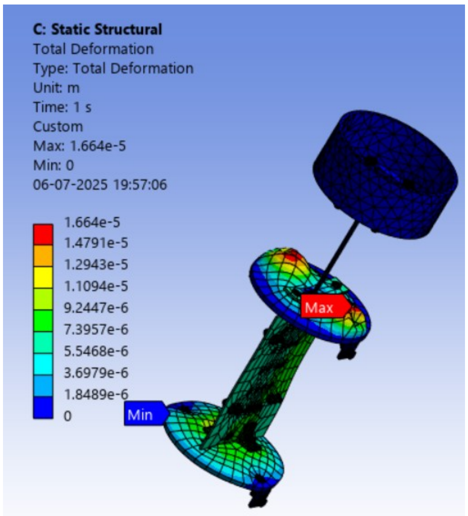


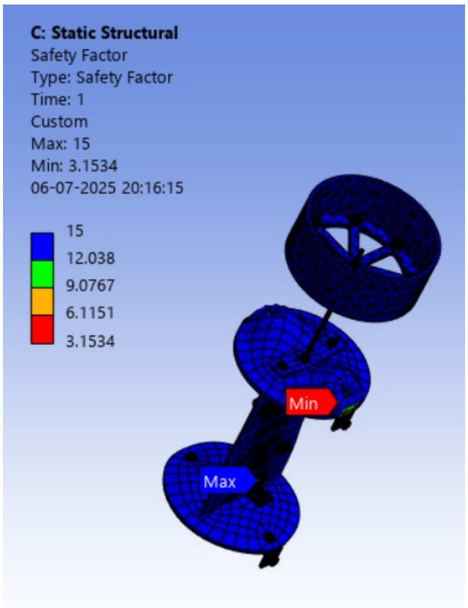


Parachute inflation impact

Condition	Value
Acceleration	g (9.81 m/s^2)
Force	4 kgf
Support	Parachute cup
Min SF	5.9054
Deform.	0.538 mm

3. **Ejection Force:**





Ejection force impact

Condition	Value
Acceleration	g (9.81 m/s^2)
Force	40 N
Support	Base Plate
Min SF	3.1534
Deform.	0.017 mm

5.1.2 Assembly

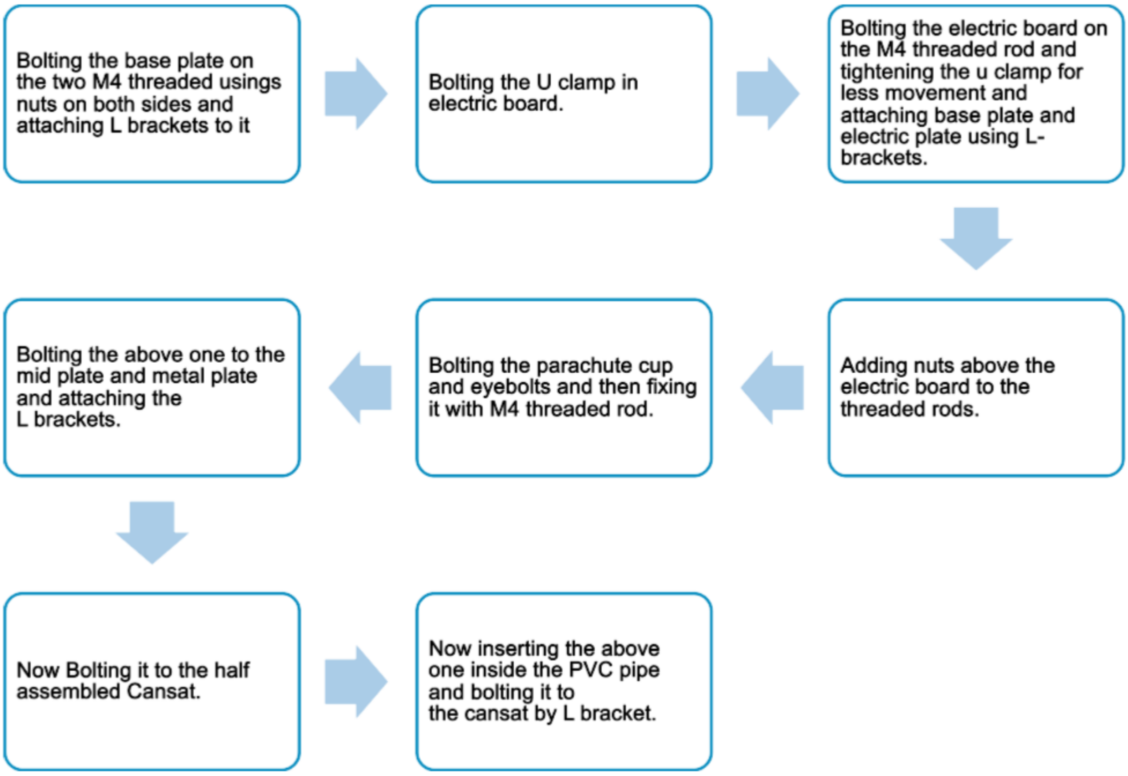


Figure 5.4: Assembly Process

5.2 Avionics and Flight Software

5.2.1 Assembly and Integration

The below shown KiCAD schematic provides with the information on how the connection are made roughly for the required pins/ports.

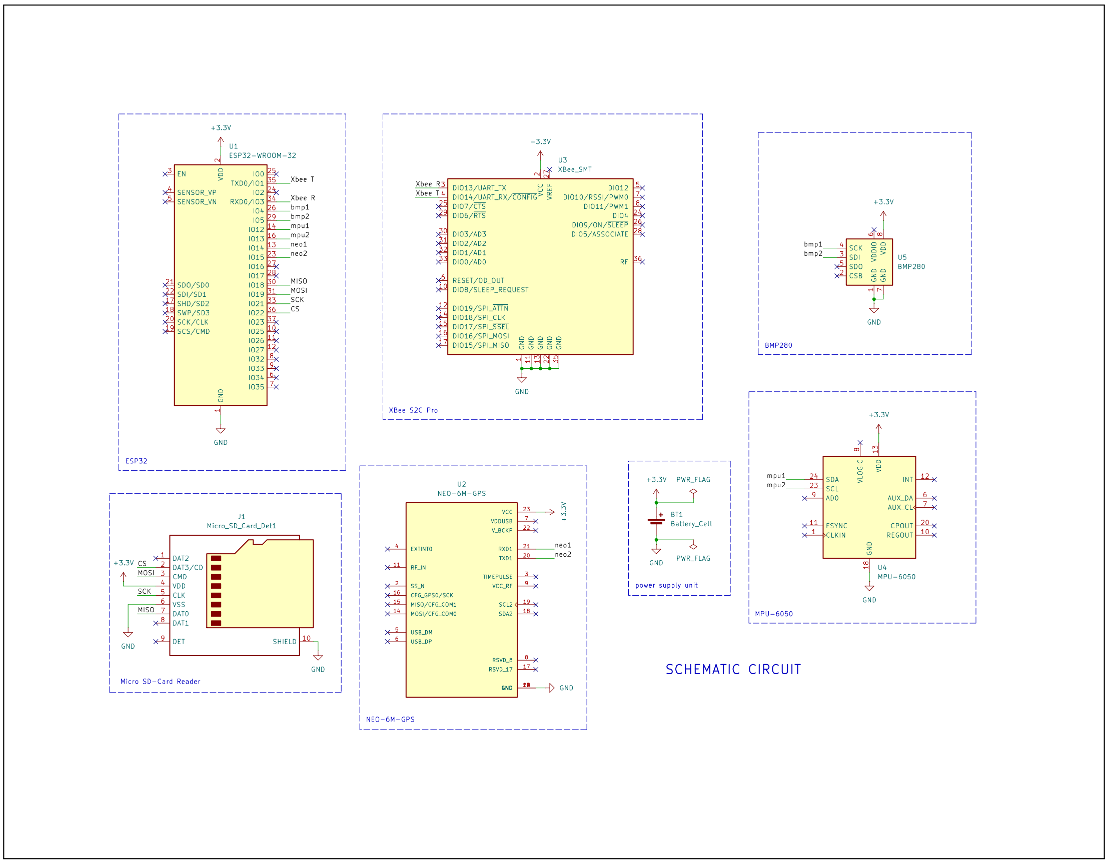


Figure 5.5: Schematics for Avionics subsystem connections

The PCB containing the required circuitry will be attached using screws in the provided screw holes shown in the 3D model of Avionics Bay. The bay will be 3D printer using PLA. The 3D model of the Avionics Bay is shown below:

Figure 5.6: Model of Avionics Bay

5.2.2 Testing

1. AT001 - This test requires ensuring proper integration of the telemetry system, including short range, long range, and moving tests, with the rocket for reliable data transmission.
2. AT002 - This test involves validating the barometric altitude sensor through static, dynamic, and calibration tests to ensure accurate altitude measurements.
3. AT003 - This requires testing the Inertial Measurement Unit (IMU) for static alignment, dynamic motion, and integration with other subsystems to verify motion tracking accuracy.
4. AT004 - This involves testing the GNSS module for signal acquisition, dynamic positioning, and accuracy during simulated flight conditions.
5. AT005 - This test validates the microcontroller functionality, load handling, and seamless integration with all avionics components.
6. AT006 - This involves testing the power subsystem through battery discharge tests, power distribution checks, and thermal performance assessments.
7. AT007 - This involves testing the data logging system for write speed, data integrity during retrieval, and stress conditions for long-duration logging.
8. AT008 - This test validates the voltage sensor for accuracy, load monitoring, and integration with the telemetry and microcontroller systems.
9. AT009 - This test involves verifying sensor data logging, including integration with telemetry, real-time monitoring, and timestamp synchronization.
10. AT010 - This involves combining telemetry with data logging systems, ensuring simultaneous operation, data consistency, and fault tolerance during simulated failures.
11. AT011 - This requires conducting a full system test, including pre-launch checks,

simulated flight tests, and post-flight data analysis.

12. AT012 - This involves assembling the avionics bay, conducting fit and alignment checks, vibration tests, and environmental performance assessments.

5.2.3 FSW Testing

1. FT001 - Integrate the sensors (Pressure - BME280, IMU - MPU6050, Neo-6M GPS Module) in FSW and validate the communication (Xbee Pro S2C) between sensors and FSW.
2. FT002 - Perform field tests under realistic conditions to ensure that the software responds correctly to sensor activation and telemetry transmission.
3. FT003 - Implement and Perform checks on Data Storage for potential errors or issues and test to verify independent functionality.
4. FT004 - Tests on Data Retrieval from Backup registers in case of power failure.
5. FT005 - Perform an overall evaluation of the software such as timing analysis and memory usage.

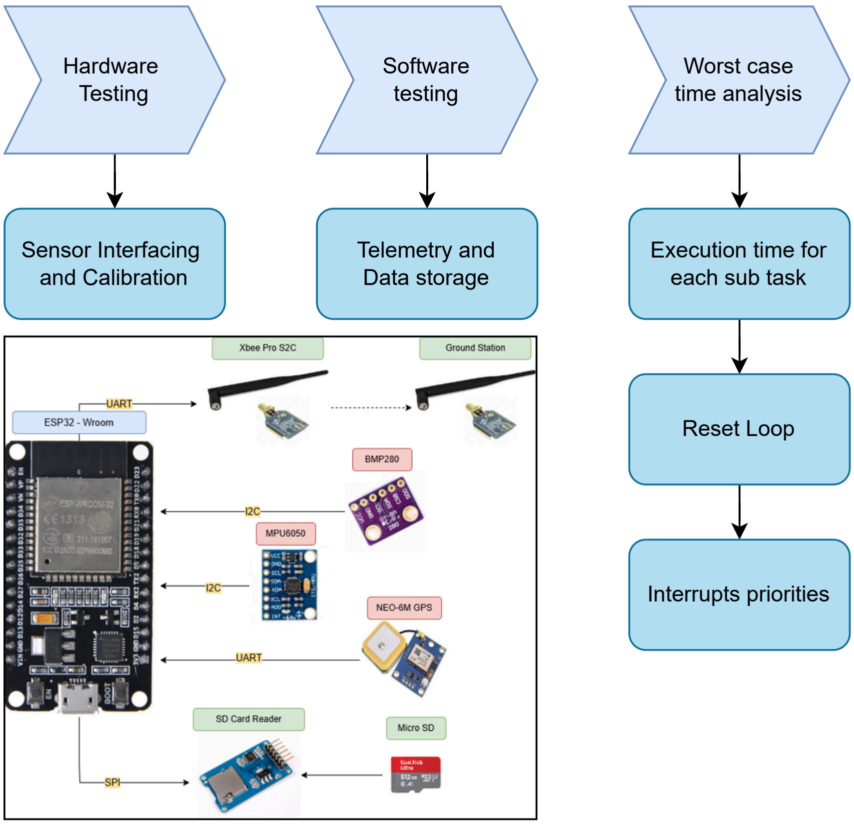


Figure 5.7: FSW testing

5.3 Recovery

5.3.1 Assembly/Configuration

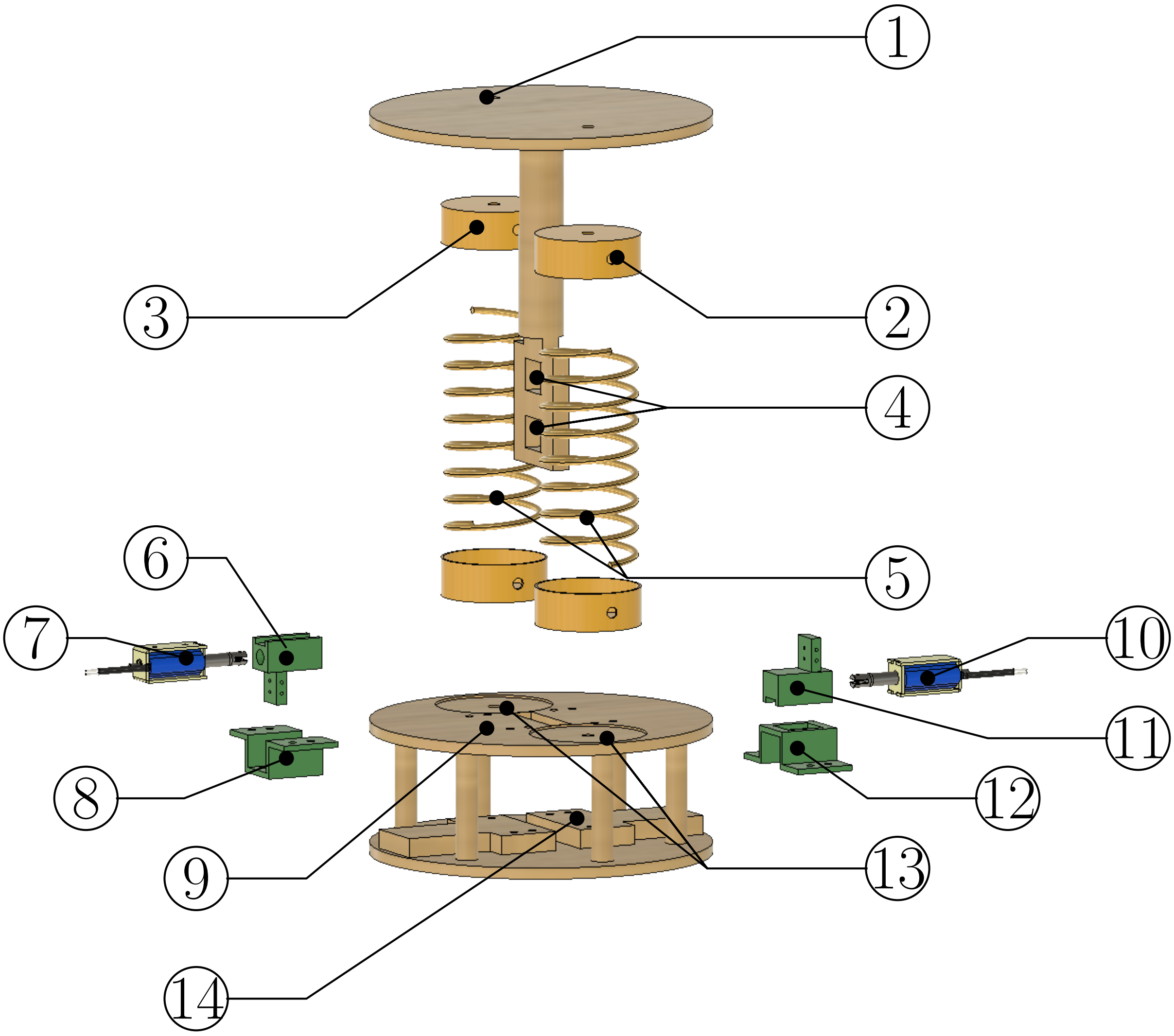


Figure 5.8: Ejection system - Exploded view

The subsystem configuration and integration are given below.

- The top plate (1) is attached to the spring covers (3) by means of nuts and bolts
- The spring covers (3) are attached to springs (5) by means of friction fit and also the screws along the sides of the spring cover.
- The latches (6) and (11) hold the springs in compressed position along with the top plate by means of the latch holes (4) where they lock into
- The springs are attached to spring covers at the bottom also and they get attached to screw holes on the bottom plate (13). The spring covers are to ensure straight alignment of the springs to the top and bottom plate surfaces.
- The latches are covered by latch covers (8) and (12).

- The linear actuators (7) and (10) are attached to the latches by friction fit and adhesive.
- The latch covers are attached to the bottom plate by means of the screw holes (9) and (14).

Component Number	Component Name
1	Top Plate
2	Screw Hole - Spring Cap
3	Spring Cap
4	Latch Holes
5	Springs
6	Latch - 1
7	Latch Cover - 1
8	Linear Actuator - 1
9	Screw Holes - Latch 1
10	Latch - 2
11	Latch Cover - 2
12	Linear Actuator - 2
13	Spring Attachment
14	Screw Holes - Latch 2

Table 5.1: Components listed in the exploded view

5.3.2 Testing

1. RT001 - This test requires ensuring proper integration of the ejection system with the rocket body in the CAD design.
2. RT002 - This test involves the acquisition of components for building the ejection system prototype, testing them for any flaws, measurements and comparison to CAD model
3. RT003 - This requires testing the acquired springs used in the ejection system for compliance with the designed system reqquirements
4. RT004 - 3D print the CAD model and test the strength of the system along with checking if the design can withstand the force due to compressed springs w.
5. RT005 - This involves integrating the mechanical system with the electrical system, involving proper attachment of the electronic components.
6. RT006 - This involves building the entire ejection system that will be used for the actual rocket, along with testing the ejection of CANSAT (or 1kg dummy mass) and nosecone.
7. RT007,RT008 - This involves acquisition and testing of all electrical components individually.
8. RT009 - This involves verification the circuit consisting the solenoid locks and the manufactured battery pack
9. RT010 - Integration of the circuit system with the 3D printed model to ensure proper fit of all the components
10. RT011 - This involves building the whole ejection system, integration with electrical components and testing of the complete system

11. RT012 - This involves acquisition components for building a small parachute which include fabric, parachord, hooks and swivels.
12. RT013 - This involves manufacture of the parachute and testing the design for the parachute
13. RT014 - This involves static test of the parachute, where the manufactured parachute is tested for proper deployment in wind.
14. RT015,RT016 - This involves integration of the parachute with ejection system. The parachute will be connected to the shock cord, placed on top of the CANSAT / dummy payload, and tested for parachute deployment (static test).

5.4 Launch

5.4.1 Testing

1. LT001 - Acquisition of components to build the lauch pad and circuitry
2. LT002 - Strength test of the Extrusion rod for deformations
3. LT003 - Test to ensure that the launch pad stays in the same angle
4. LT004 - Testing the circuit
5. LT005 - Integration of launch pad and circuit
6. LT006 - Test with rocket

5.5 Mechanical

5.5.1 Assembly/Configuration

5.5.2 Testing

1. MT001: Ensure the structural integrity of the rocket body through simulations and stress analysis in the CAD design.
2. MT002: Conduct material testing for components individually such as the nosecone, body tube, and fins to verify strength and durability.
3. MT003: Test the aerodynamic performance of the fin design.
4. MT004: Manufacture and test-fit the fins, ensuring proper alignment and secure attachment to the rocket body.
5. MT005: Assemble the rocket body and verify the alignment of all components, including the nosecone and motor mount.
6. MT006: Conduct a static load test to evaluate the rocket's ability to withstand forces experienced during flight.
7. MT007: Test the functionality and fit of the motor retention system to ensure secure housing of the propulsion system.
8. MT008: Evaluate the balance and stability of the rocket using the center of gravity (CG) and center of pressure (CP) calculations, followed by practical testing.
9. MT009: Conduct a dry assembly of all mechanical components to confirm proper integration and fit before final assembly.
10. MT010: Perform a vibration test to simulate launch conditions and identify any potential issues with mechanical connections.
11. MT011: Test the assembly process for disassembly and reassembly efficiency to

ensure ease of maintenance and repair.

12. MT012: Verify the alignment and proper operation of the launch lug/rail buttons with the launch system.
13. MT013: Integrate the mechanical components with the recovery and propulsion systems, ensuring seamless interaction.
14. MT014: Conduct a final pre-launch assembly and inspection to confirm all mechanical components are in place and ready for flight.

5.5.3 Testing done

Nose Cone

- **Finite Element Analysis:** Static structural test was done for the nose cone in ANSYS. Load of 700 N was applied. Pressure of 0.5 MPa was applied. Fixed support was given. Earth gravity was applied globally. The minimum safety factor for sheer stress was found at 7.8246. Maximum deformation was found to be 0.12459 mm.

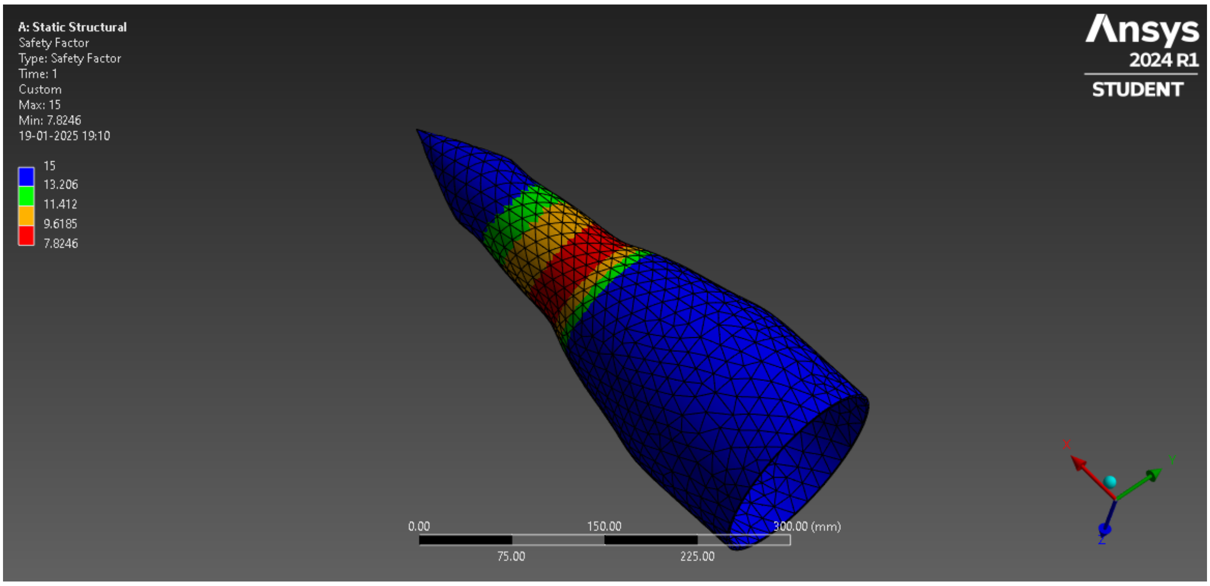


Figure 5.9: Safety factor Analysis of nose cone

Body Tube

- **Finite Element Analysis:** Static Structural analysis was done on the body tube to check the structural integrity of it. Fixed support was given on the lower end of it. 2600 N load was applied axially on the joint between thrust plate and body tube to consider load from rocket motor. Another 150 N load was applied axially to simulate the load of other components. Another 100 N load was applied perpendicular to the axis line on the surface to simulate external force on it. Gravity was applied globally. The minimum safety factor was found to be 2.9095. Maximum deformation was found to be 2.2384 mm.

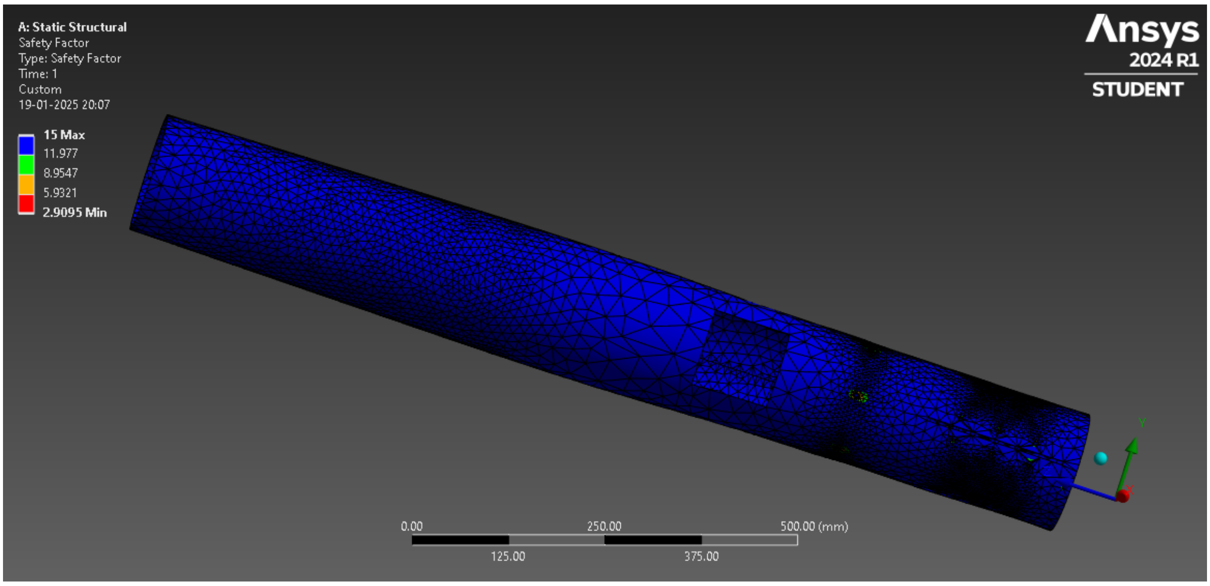


Figure 5.10: Safety factor analysis of bodytube

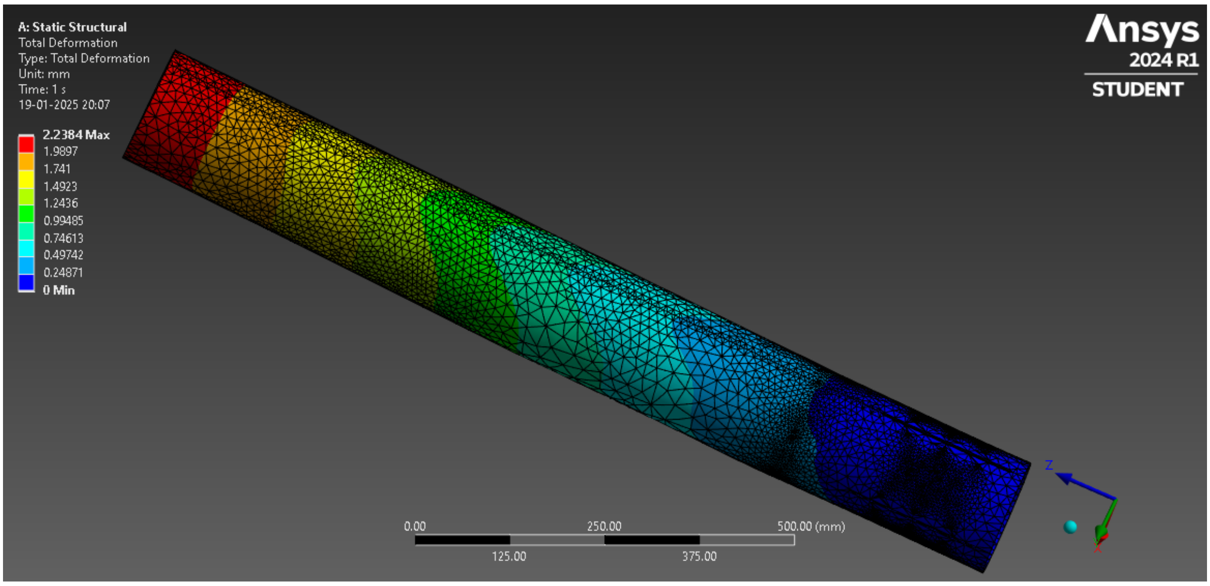


Figure 5.11: Total deformation analysis of bodytube

- **Static load test:** Static load were applied on the body tube to verify the result of the analysis in real world. Static load of 600 N was applied perpendicular to the axis line. In another test, static load of 1000 N was applied along axis line to verify the result.

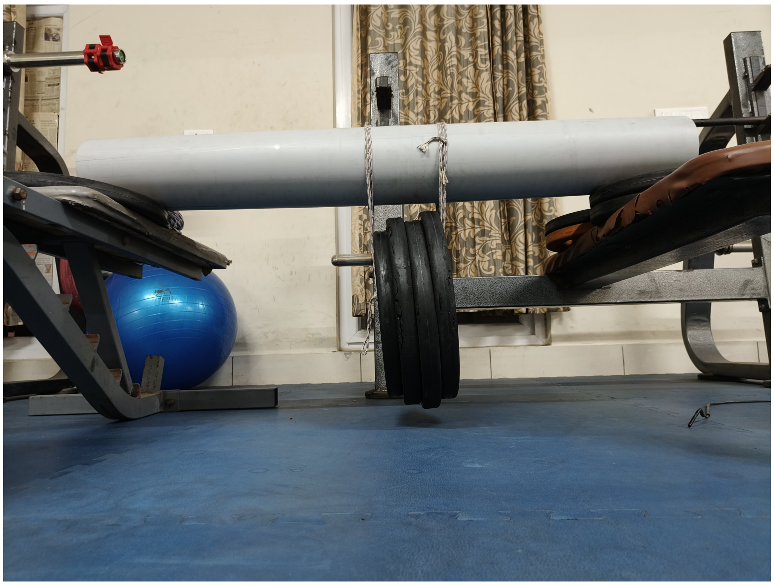


Figure 5.12: Static Load of 600 N applied perpendicular to axis

Figure 5.13: Static Load of 1000 N applied along the axis

Rocket Fins & Fin bracket

- **Finite Element Analysis:** Static structural analysis was done on the integration of fin bracket and fins to check the structural integrity. Standard earth gravity was applied globally. The end face of the body tube was fixed. 250 N force was applied on the fin vertically downward and 50 N force was applied perpendicular to fin as well. Minimum safety of factor was found to be 1.392 at the joint.

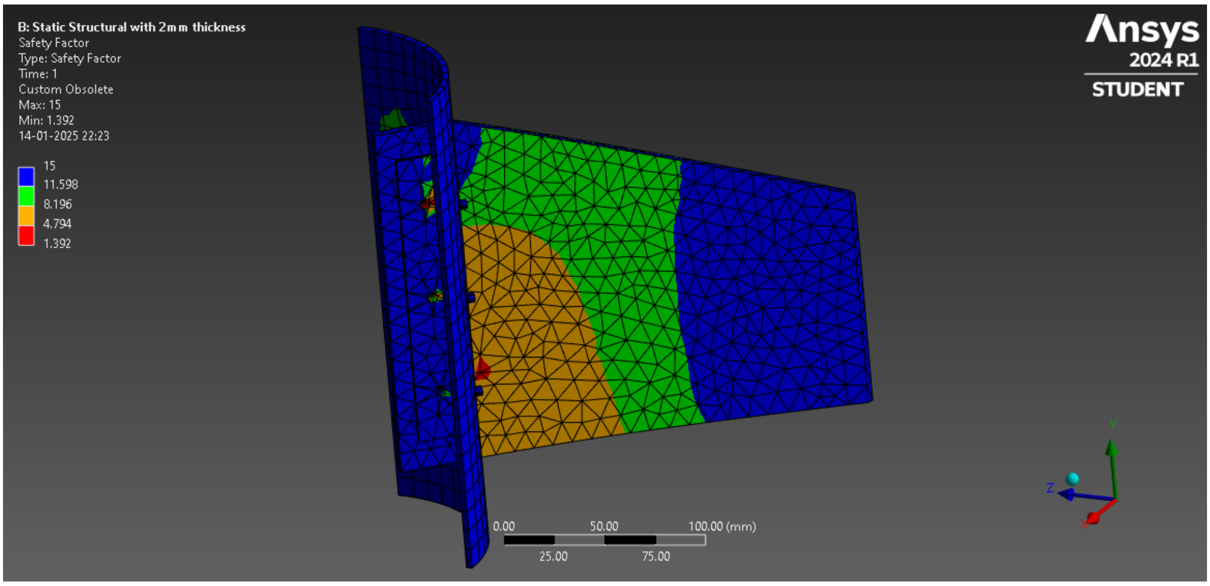


Figure 5.14: Safety factor analysis of fins and fin bracket

Bulkhead

- **Finite Element Analysis:** Static structural analysis was done on bulkhead to verify the structural integrity. Standard earth gravity was applied globally. The model was fixed at the joint between the bulkhead and the body tube. 1200 N force was applied on the bulkhead to simulate the weight of the components above placed on the bulkhead at maximum acceleration. The minimum safety factor was found to be 7.8812. The maximum deformation was found to be 0.2145 mm.

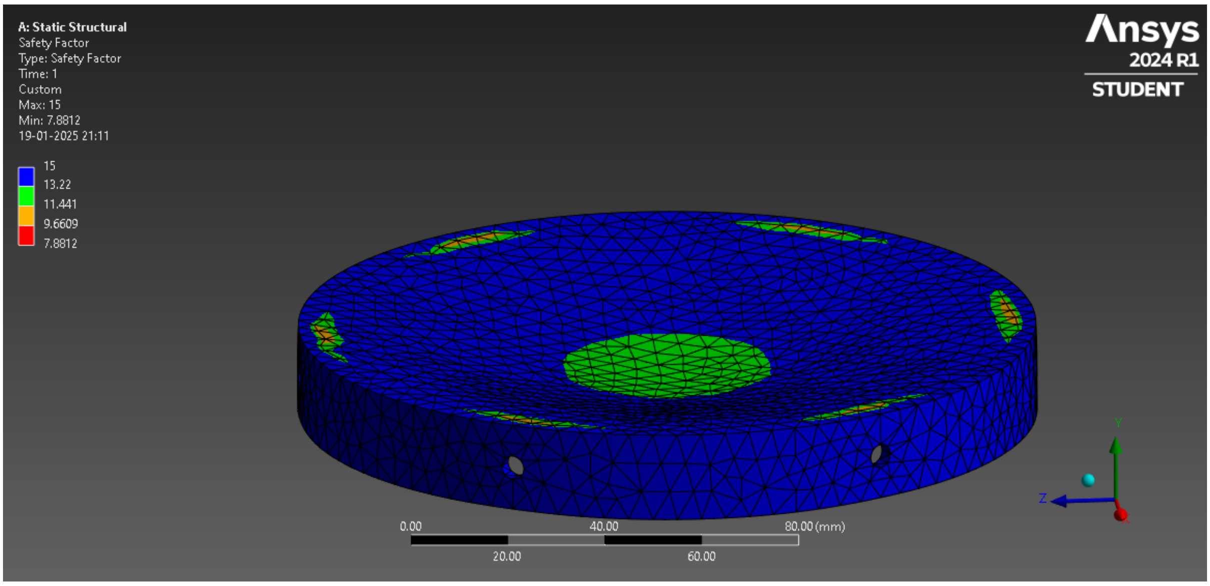


Figure 5.15: Safety factor analysis of the bulkhead.

Launch lugs

- **Finite element analysis:** Static structural analysis was done on launch lugs to verify the structural integrity. Standard earth was applied globally. Fixed support was applied at the joint between the launch lugs and the body tube. 200 N force was applied vertically to simulate the body weight of model rocket on the launch lug. 50 N force was applied along the lugs to simulate the friction force. The minimum safety factor was found to be 7.3773. The maximum deformation was found to be 6.9175e-003 mm.

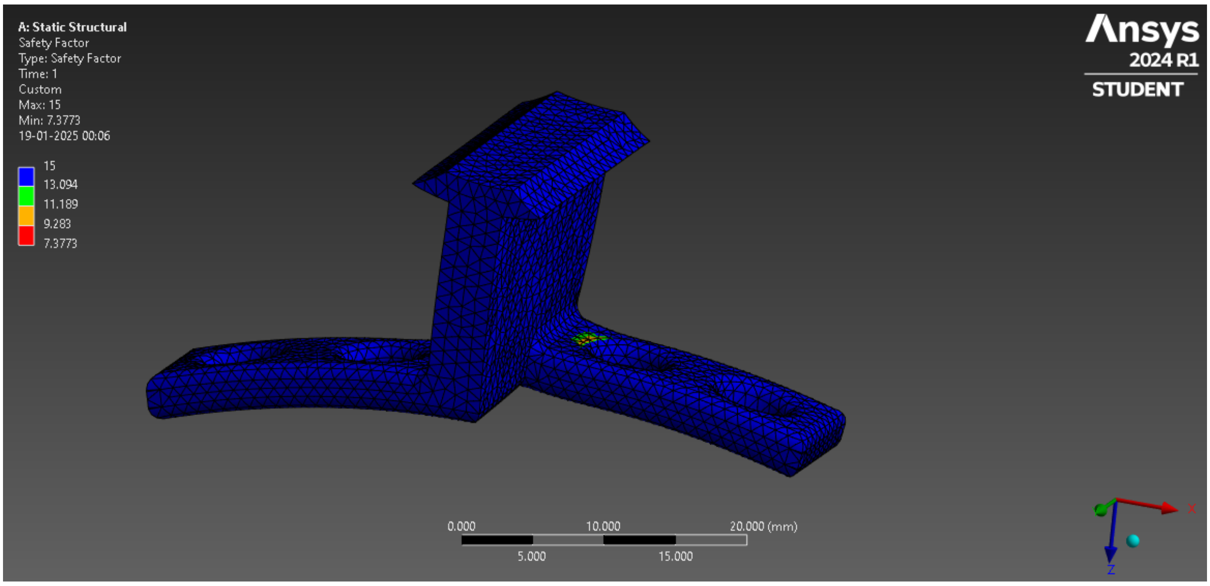
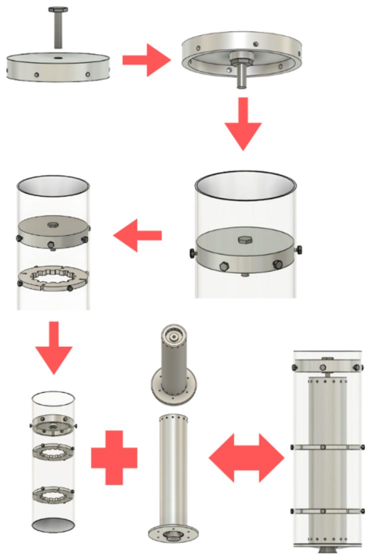


Figure 5.16: Safety factor analysis of launch lug.

5.6 Propulsion

5.6.1 Full Motor Assembly



1. **Preparing the parts:** Screw the M12 bolt(of length 70mm) into the centre of the aeropack. Drill holes at proper positions in the body tube.

2. **Mount the Aeropack:** Position the Aeropack against the body tube shoulder approximately 395mm from open end of body tube considering the motor length and clearance, aligning its six M6 holes with those on the tube.

3. **Attach the Centering Rings:** Slide the first centering ring over the tube and is attached to the body tube using epoxy and for more safety screw it using four M5 bolts and follow it with the second centering ring.

4. **Attach the Thrust Plate:** Align the thrust plate with the rear flange of the rocket motor. Insert fourteen M5 bolts and snug them alternately so the plate sits squarely against the motor.

5. **Insert the Rocket Motor:** Take the motor–thrust-plate subassembly and guide it into the open end of the body tube. Thread the motor onto the protruding M12 bolt by hand until the thrust plate makes firm contact with the body tube.

6. **Inspect:** Check that all M5 and M12 fasteners are tight, evenly seated, and free of gaps.

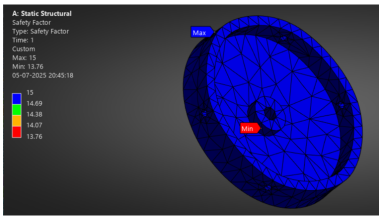
Note: The correct positioning of the Aeropack and selection of the appropriate M12 bolt length are crucial to ensure proper fitting of the motor and thrust plate, for effective thrust transfer to the rocket structure.

5.6.2 Individual Components Testing

Aeropack

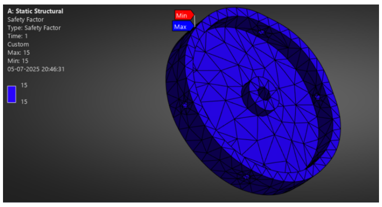
This section presents the results of structural analysis conducted on Aeropack, under the most extreme loading conditions in Ansys mechanical.

Test Results Summary



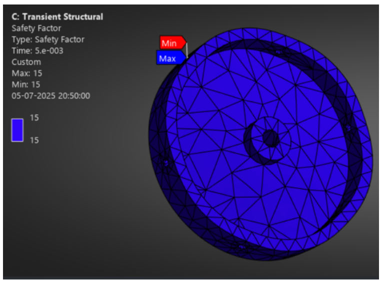
Static test

Condition	Value
Force applied	1600N
Fixed Support	6 holes of aerpack
Min Safety factor	13.76
Max.deformation	0.025 mm



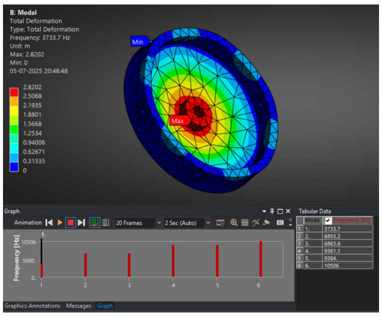
Static test

Condition	Value
Acceleration	15g (147.15 m/s^2)
Fixed Support	6 holes of aerpack
Min Safety factor	15.0
Max.deformation	0.0004mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Fixed Support	6 holes of aerpack
Min Safety Factor	15
Max. deformation	0.000004 mm



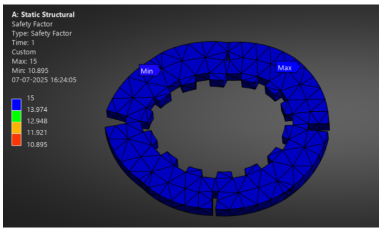
Modal analysis

Condition	Value
Fixed Support	6 holes of aerpack
Mode-1	3733.7 Hz
Mode-2	6855.2 Hz
Mode-3	6863.6 Hz
Mode-4	9361.1 Hz
Mode-5	9384 Hz
Mode-6	10506 Hz

Centring Ring

This section presents the results of structural analysis conducted on Centring Ring, under the most extreme loading conditions in Ansys mechanical.

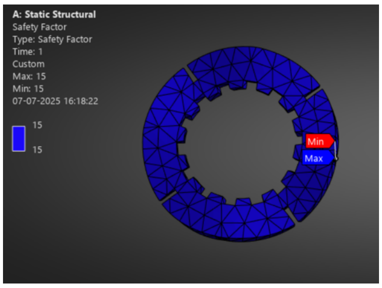
Test Results Summary



Static test

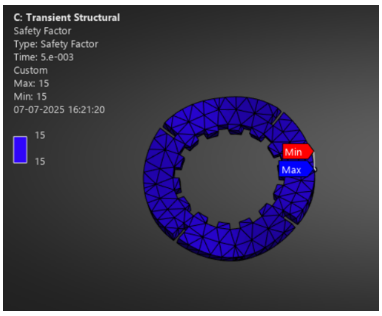
Note: This test was done just in any case the motor tilts a bit and gives some force on centring ring

Condition	Value
Force applied	500N(on half side of inner surface)
Fixed Support	4 holes of Centring ring
Min Safety factor	10.89
Max.deformation	0.055 mm



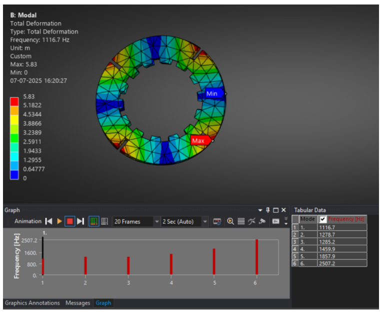
Static test

Condition	Value
Acceleration	15g (147.15 m/s^2)
Fixed Support	4 holes of Centring ring
Min Safety factor	15.0
Max.deformation	0.0029mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Fixed Support	4 holes of Centring ring
Min Safety Factor	15
Max. deformation	0.0025 mm



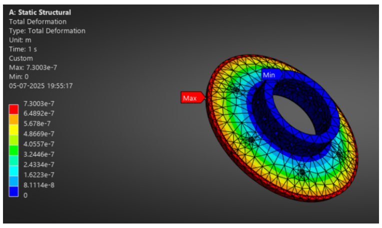
Modal analysis

Condition	Value
Fixed Support	4 holes of Centring ring
Mode-1	1116.7 Hz
Mode-2	1278.7 Hz
Mode-3	1285.2 Hz
Mode-4	1459.9 Hz
Mode-5	1857.9 Hz
Mode-6	2507.2 Hz

Thrust plate

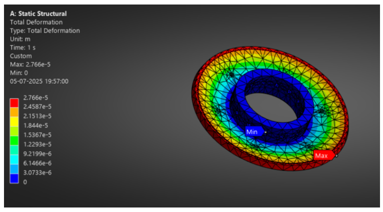
This section presents the results of structural analysis conducted on Thrust plate, under the most extreme loading conditions in Ansys mechanical.

Test Results Summary



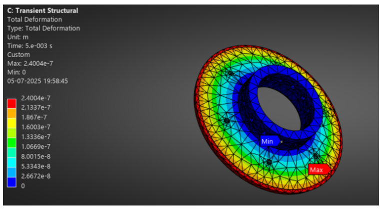
Static test

Condition	Value
Force applied	1600N
Fixed Support	14 holes of thrust plate
Min Safety factor	15
Max.deformation	0.0007 mm



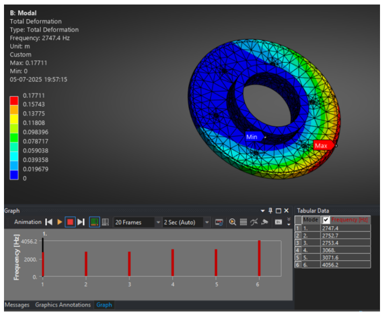
Static test

Condition	Value
Acceleration	15g (147.15 m/s^2)
Fixed Support	14 holes of thrust plate
Min Safety factor	15.0
Max.deformation	0.002mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Fixed Support	14 holes of thrust plate
Min Safety Factor	15
Max. deformation	0.00024 mm



Modal analysis

Condition	Value
Fixed Support	14 holes of thrust plate
Mode-1	2747.4 Hz
Mode-2	2752.7 Hz
Mode-3	2753.4 Hz
Mode-4	3071.6 Hz
Mode-5	3071.6 Hz
Mode-6	4056.2 Hz

5.6.3 Sub-assembly/Joints structural analysis

Imp Note: In the individual component simulations , the minimum safety factor was observed to be in the range of 10 to 15, indicating a high margin of structural integrity. However, during the sub-assembly level tests the observed minimum safety factor reduced to around 1.5 in certain regions at extreme conditions.

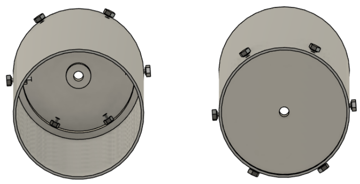
This lower value is not indicative of a design flaw but rather a result of simulation boundary conditions, particularly the application of fixed supports. In these assembly-level analyses, the fixed support constrains the upper section of the body tube completely, which introduces unnaturally rigid conditions. This causes components like the aeropack and the bolted joint to behave as if they're being peeled apart, especially near the bolt holes, resulting in high localized stresses and lower reported safety factors.

Furthermore, the lowest safety factor regions are extremely localized, usually confined to small areas around bolt holes due to stress concentration, while the majority of the assembly consistently shows safety factors above 4, 6, or even 10.It is important to note that in the actual rocket, no such fixed support exists. The components are free to deform slightly and redistribute loads naturally through the structure.

Therefore, the design remains structurally sound and safe under real-world conditions, and the simulation outputs should be interpreted with an understanding of their constraint-based limitations.

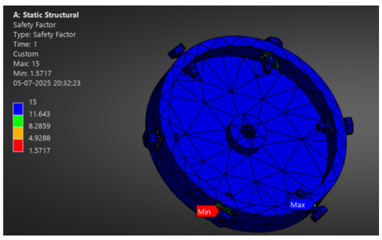
Aeropack with body tube

This section presents the results of structural analysis conducted on Sub-assembly of aeropack attached to the body tube using 6 M6 bolts, under the most extreme loading conditions in Ansys mechanical.



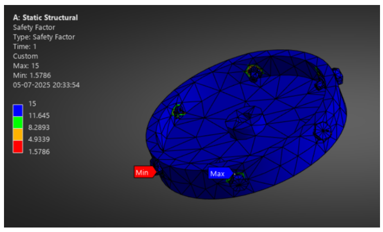
CAD model showing Aeropack with and body tube assembly

Test Results Summary



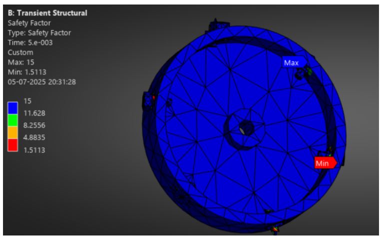
Static test

Condition	Value
Force applied	1600N(on Aeropack hole inner surace)
Contact Surfaces	Rough
Fixed Support	Bottom surafce of body tube
Min Safety factor	1.57
Max.deformation	0.02 mm



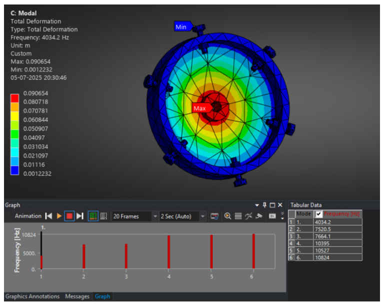
Static test

Condition	Value
Acceleration	15g (147.15 m/s^2) to all bodies
Contact Surfaces	Rough
Fixed Support	Bottom surafce of body tube
Min Safety factor	1.57
Max.deformation	0.06mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Contact Surfaces	Rough
Fixed Support	Bottom surafce of body tube
Min Safety Factor	1.51
Max. deformation	0.07 mm



Modal analysis

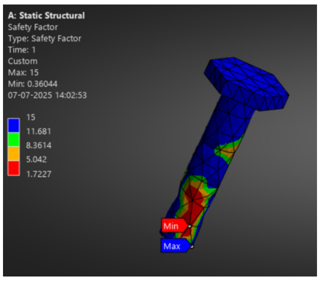
Condition	Value
Fixed Support	Bottom surafce of body tube
Contact Surfaces	Rough
Mode-1	4034.2 Hz
Mode-2	7520.5 Hz
Mode-3	7664.1 Hz
Mode-4	10395 Hz
Mode-5	10527 Hz
Mode-6	10824 Hz

M12 (Forward bolt) testing

This section presents the results of structural analysis conducted on Sub-assembly of aeropack attached to the Top interference of motor using M12 forward bolt, under the most extreme loading conditions in Ansys mechanical.

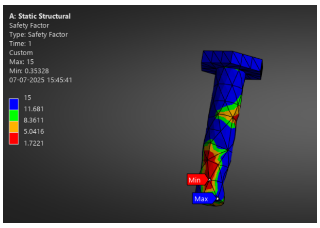
CAD model showing Aeropack with Top Interference Assembly

Test Results Summary



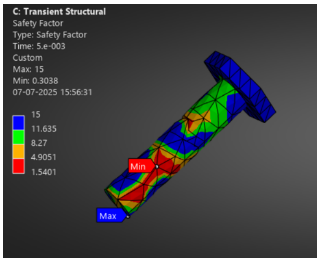
Static test

Condition	Value
Force applied	1600N(on Top interference's bottom surface) and 50N on bolt surafce as motor weight
Contact Surfaces	Rough
Fixed Support	14 holes of top interference
Min Safety factor	1.72
Max.deformation	0.44 mm



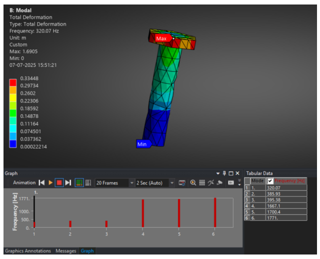
Static test

Condition	Value
Acceleration	15g (147.15 m/s^2) to all bodies
Contact Surfaces	Rough
Fixed Support	14 holes of top interference
Min Safety factor	1.72
Max.deformation	0.44mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Force	50N on bolt surafce as motor weight
Contact Surfaces	Rough
Fixed Support	14 holes of top interference
Min Safety Factor	1.51
Max. deformation	1.5 mm

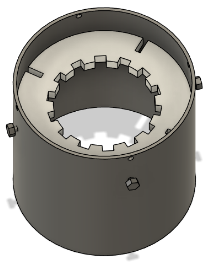


Modal analysis

Condition	Value
Fixed Support	14 holes of top interference
Contact Surfaces	Rough
Mode-1	320.07 Hz
Mode-2	385.93 Hz
Mode-3	395.38 Hz
Mode-4	1667.1 Hz
Mode-5	1700.4 Hz
Mode-6	1771 Hz

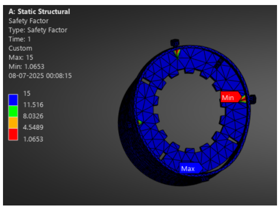
Centring ring with body tube testing

This section presents the results of structural analysis conducted on Sub-assembly of Centring ring connected to body tube with 4 M5 bolts, under the most extreme loading conditions in Ansys mechanical. **Note:**The centering rings actually are bonded to the body tube using epoxy as the primary attachment method, with four M5 bolts provided as a mechanical backup for added reliability.



CAD model showing centering ring and body tube assembly

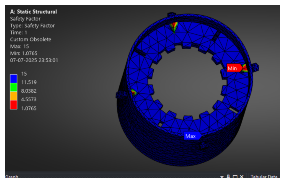
Test Results Summary



Static test

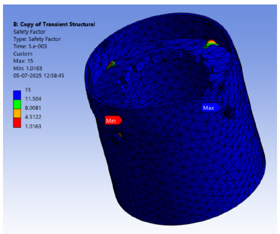
This test was done just in any case the motor tilts a bit and gives some force on centring ring

Condition	**Value**
Force applied	500N(on inner surface of ring -radial)
Contact Surfaces	Rough
Fixed Support	Bottom surface of the body tube
Min Safety factor	1.06
Max.deformation	0.019mm



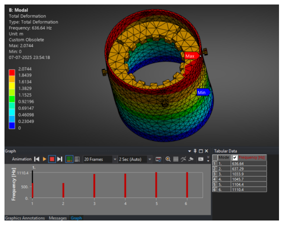
Static test

Condition	**Value**
Acceleration	15g (147.15 m/s^2) to all bodies
Contact Surfaces	Rough
Fixed Support	Bottom surface of the body tube
Min Safety factor	1.07
Max.deformation	0.08mm



30g Shock Test

Condition	Value
Acceleration(for 1ms)	30g (295.3 m/s^2)
Contact Surfaces	Rough
Fixed Support	Bottom surface of the body tube
Min Safety Factor	1.01
Max. deformation	0.09mm



Modal analysis

Condition	Value
Fixed Support	14 holes of top interference
Contact Surfaces	Rough
Mode-1	636.64 Hz
Mode-2	637.29 Hz
Mode-3	1033.9 Hz
Mode-4	1045.7 Hz
Mode-5	1104.4 Hz
Mode-6	1110.4 Hz

Chapter 6

Operations Plan and Quality Control

6.1 Avionics and Flight Software

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
AT001	Integration of the telemetry system, including short range, long range, and moving tests with the rocket for reliable data transmission	Yes	None	None
AT002	Validation of the barometric altitude sensor through static, dynamic, and calibration tests	Yes	None	None
AT003	Testing the IMU for static alignment, dynamic motion, and integration with subsystems	Yes (Verified accuracy under various conditions)	None	None
AT004	GNSS module testing for signal acquisition, dynamic positioning, and accuracy in simulated flight conditions	Yes	None	None
AT005	Validation of microcontroller functionality, load handling, and integration with avionics	Yes (Tested under simulated load conditions)	None	None
AT006	Testing the power subsystem, including battery discharge, distribution checks, and thermal assessments	No (Pending)	-	-
AT007	Validation of data logging system, including write speed, data integrity during retrieval, and stress tests	No	System shows slow write speeds during stress conditions	Optimize firmware, ensure buffer management
AT008	Voltage sensor testing for accuracy, load monitoring, and integration with telemetry	Yes	None	None
AT009	Verification of sensor data logging, real-time monitoring, and synchronization	Yes	None	None
AT010	Telemetry and data logging combined test ensuring simultaneous operation and fault tolerance	Yes (Operational under normal conditions)	Minor faults observed during high interference	Implement shielding and software error correction
AT011	Full system testing, including pre-launch checks, simulated flight tests, and post-flight analysis	No (Pending)	-	-
AT012	Avionics bay assembly, fit checks, vibration and environmental testing	No	Alignment issues detected during fit checks	Redesign mounting points for better fit

Table 6.1: Avionics - System Testing Requirements

ID	Requirements	Compliance	Deviation	Rectification
FT001	Sensor Integration and Calibration	Yes	No	No
FT002	Real time Data Transmission	No	While UART data transmission is done between STM to PC, it used GPOS though.	Yet to figure out implementing Wireless communication on Xbee modules using RTOS.
FT003	Real time Data Storage	Yes	No	No
FT004	Data Retrieval from backup registers	Yes	No	No
FT005	Timing Analysis	No	Telemetry sub task is not yet implemented on RTOS.	Test by introducing reset loops and priority faults in software.

Table 6.2: Testing Plans for Flight Software

6.2 Mechanical subsystem

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
MT001	Ensure structural integrity through CAD simulations and stress analysis.	Yes	None	None
MT002	Test materials for nosecone, body tube, and fins for strength and durability.	Yes (Partial)	None	None
MT003	Test aerodynamic performance of the fin design.	Yes	None	None
MT004	Manufacture and test-fit fins, ensuring proper alignment.	No (Pending)	-	-
MT005	Assemble rocket body and verify alignment of components.	No (Pending)	-	-
MT006	Conduct static load test for flight force evaluation.	No (Pending)	-	-
MT007	Test motor retention system for secure fit of propulsion system.	No (Pending)	-	-
MT008	Evaluate balance using CG/CP calculations and practical testing.	Yes	None	None
MT009	Perform dry assembly to verify integration and fit.	No (Pending)	-	-
MT010	Conduct vibration test to simulate launch conditions.	No (Pending)	-	-
MT011	Test assembly process for ease of disassembly and maintenance.	No (Pending)	-	-
MT012	Verify alignment of launch lug/rail buttons with launch system.	No (Pending)	-	-
MT013	Integrate mechanical components with recovery and propulsion systems.	No (Pending)	-	-
MT014	Perform final pre-launch assembly and inspection.	No (Pending)	-	-

Table 6.3: Testing Plan for Mechanical Subsystem

6.3 Recovery System

6.3.1 Ejection System - Mechanical

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
RT001	CAD design for the model rocket	Yes	None	None
RT002	Acquire components for building the ejection system	Yes	None	None
RT003	Springs that suffice the requirement of the ejection system to push CANSAT and nosecone out	Yes (Tests were done to ensure the same)	None	None
RT004	3D printed CAD model that is durable to hold the compressed springs in place and ease release while ejection	No	The designed model needs changes to ensure the ease of release	Reduce friction. Add multiple actuators to reduce load on each
RT005	Integration with electrical components of ejection system prototype	Yes (Electrical component integration can be achieved)	None	None
RT006	Testing ejection system	No (Pending)	-	-

Table 6.4: Recovery - Ejection system - Mechanical

6.3.2 Ejection System - Electrical

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
RT007	Acquire circuit components	Yes	None	None
RT008	Test components individually	Yes	None	None
RT009	Circuit verification with battery pack	Yes	None	None
RT010	Integration with 3D printed prototype	Yes	None	None
RT011	Ejection system testing	No (Pending)	-	-

Table 6.5: Recovery - Ejection system - Electrical

6.3.3 Parachute

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
RT012	Acquire components for a smaller scale parachute	Yes	None	None
RT013	Manufacture the small parachute	Yes	None	None
RT014	Static test of the small parachute	No (Pending)	-	-
RT015	Design and manufacture actual parachute	No (Pending)	-	-
RT016	Test parachute	No (Pending)	-	-
RT017	Integrate with ejection system and test ejection	No (Pending)	-	-

Table 6.6: Recovery - Parachute

6.4 Launch System

ID	Requirement	Compliance (Additional Comments)	Deviation	Rectification
LT001	Acquire components for launch pad	No (Pending)	-	-
LT002	Manufacture and strength test	No (Pending)	-	-
LT003	Launch pad elevation positioning	No (Pending)	-	-
LT004	Circuit Testing	No (Pending)	-	-
LT005	Integration of launch pad and electrical circuit	No (Pending)	-	-
LT006	Test with rocket	No (Pending)	-	-

Table 6.7: Lauch pad testing

The following table provides the Requirements Compliance Matrix, where each requirement is listed along with its compliance status and any deviations.

Table 6.8: Requirements Compliance Matrix

S. No	Requirement	Compliance (Yes/No)	Deviation / Notes
1	The lift off rocket mass must be within +/-5% of the design value. The overall length of the rocket as measured from the lowest to the highest points of the airframe structure (including fins) in launch configuration, shall be less than 180cm.	Yes	-
1.1	Aluminum body mass (including Motor) shall not exceed 15Kg, Cardboard body 10Kg, and PVC body 11.5Kg. Motor mass around 3Kg.	Yes	-
1.2	Provision for Bulkhead / Integration of Motor Compartment should be made available in the rocket body.	Yes	-
1.3	Teams must design their own launch pads, with a launch angle between 80°-85°.	Yes	-
1.4	All parts of the rocket must descend tethered together using parachute recovery.	Yes	-
1.5	The rocket must be powered by commercially-made motors and must not exceed 2800 N-s of total impulse.	Yes	-
1.6	Motors must be retained by positive mechanical means (clip, hook, screw-on cap, etc.), not friction fit.	Yes	-

Continued on the next page

S. No	Requirement	Compliance (Yes/No)	Deviation / Notes
1.7	Payload separation mechanism should be developed by the teams for activation at the desired altitude.	Yes	-
1.8	The body of the rocket must be painted with fluorescent colors (pink, red, or orange).	Yes	-
1.9	The rocket must contain necessary sensors to provide real-time datasets: Position data, altitude, pressure, temperature, orientation, power data, and system status.	Yes	-
1.10	Flight software must record data and save it into an onboard SD card in case of telemetry connection loss during flight.	Yes	-
2.1	Rockets must contain and enclose a CAN-Sized satellite (0.15m diameter, 0.40m length, 1Kg +/- 0.05Kg).	Yes	-
2.2	The CANSAT (Payload) must be separated and deployed at 1000m +/- 100m altitude.	Yes	-
2.3	The vehicle (rocket body and CANSAT) shall return safely to the ground using a deployable parachute.	Yes	-
2.4	CANSAT shall contain an altimeter and accelerometer to measure altitude and acceleration levels.	Yes	-
3.1	The vehicle structure must survive 15g launch acceleration and 30g shock.	Yes	-

Continued on the next page

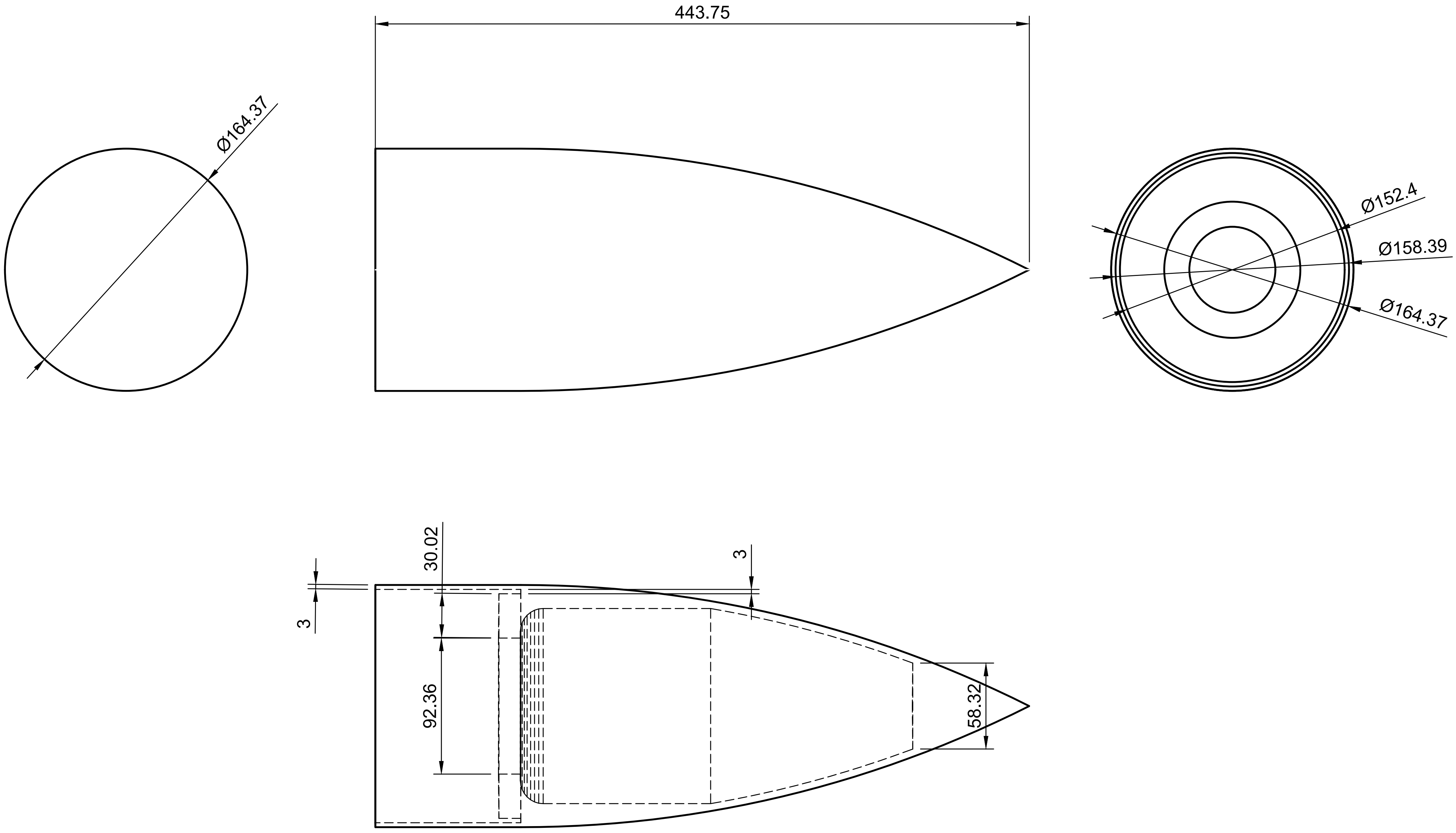
S. No	Requirement	Compliance (Yes/No)	Deviation / Notes
3.2	Team number, email, and phone number must be placed on the structure in English, Hindi, and the regional language of the launch state.	Yes	-
4.1	All electronics must be enclosed and shielded from the environment except for sensors.	Yes	-
4.2	The battery must support 30 minutes of wait on the launch pad and flight operations.	Yes	-
4.3	Lithium-ion or NiMH batteries must be used, but LiPo batteries are prohibited.	Yes	-
4.4	Rocket communication must use XBEE/Zigbee radios with the NETID/PANID set to the team number.	Yes	-
5.1	Teams must develop their own ground station, displaying telemetry in real-time during launch and descent.	Yes	-
6.1	Telemetry must be transmitted at a 1 Hz sample rate or better, in CSV format as per the provided format.	Yes	-
7.1	The rocket shall use parachutes for descent control, with a descent rate of 2 to 5 m/s (+/- 0.5 m/s).	Yes	-
7.2	The descent control mechanism must survive 30g shock at launch and separation.	Yes	-

Chapter 7

Appendix

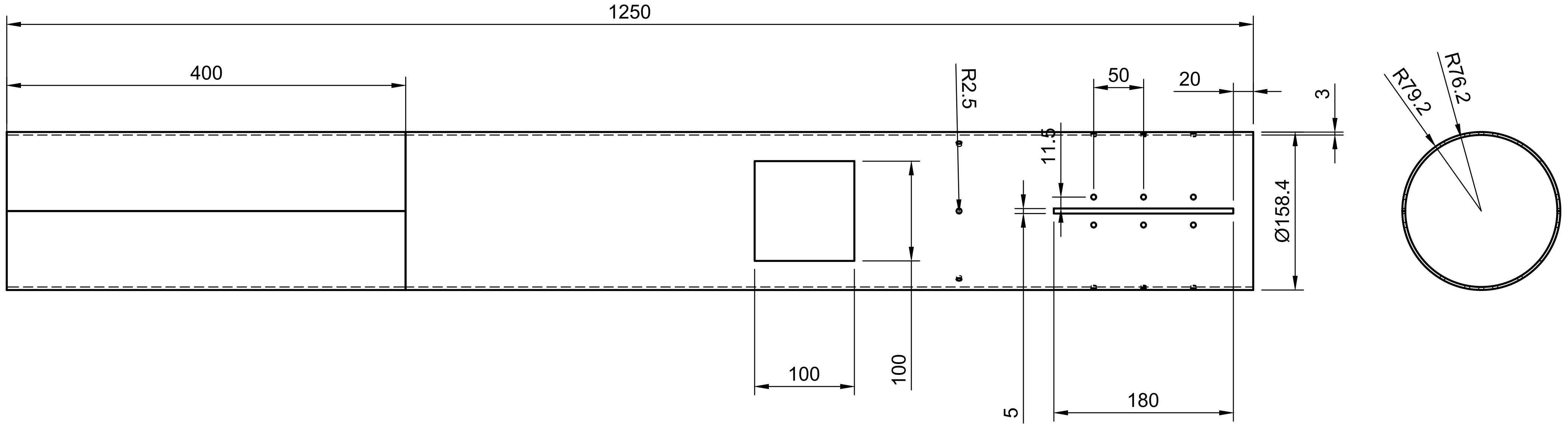
7.1 Engineering Drawings

7.1.1 Nose Cone Drawing

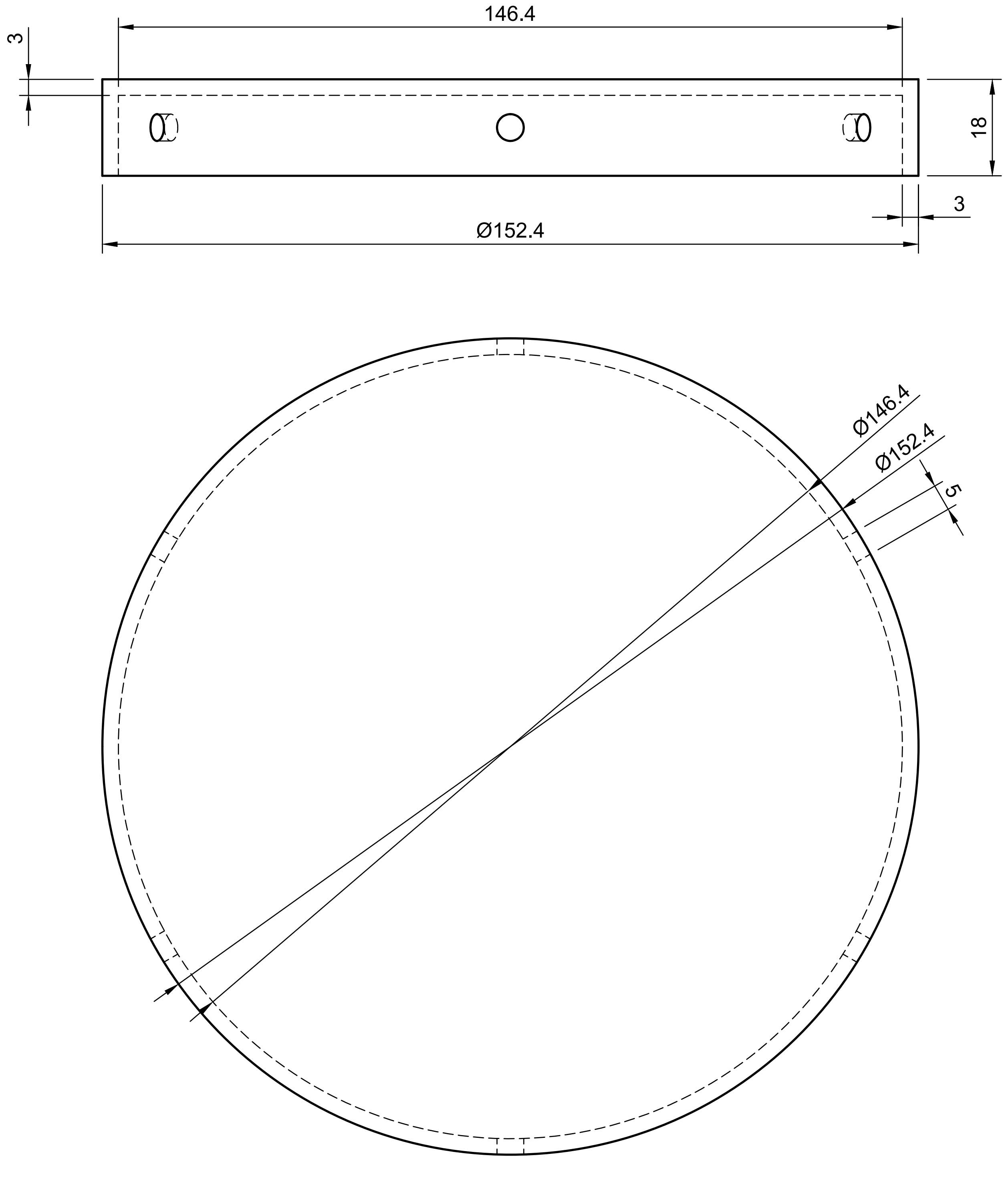


443.75
Ø164.37
Ø152.4
Ø158.39
Ø164.37
30.02
3
3
92.36
58.32

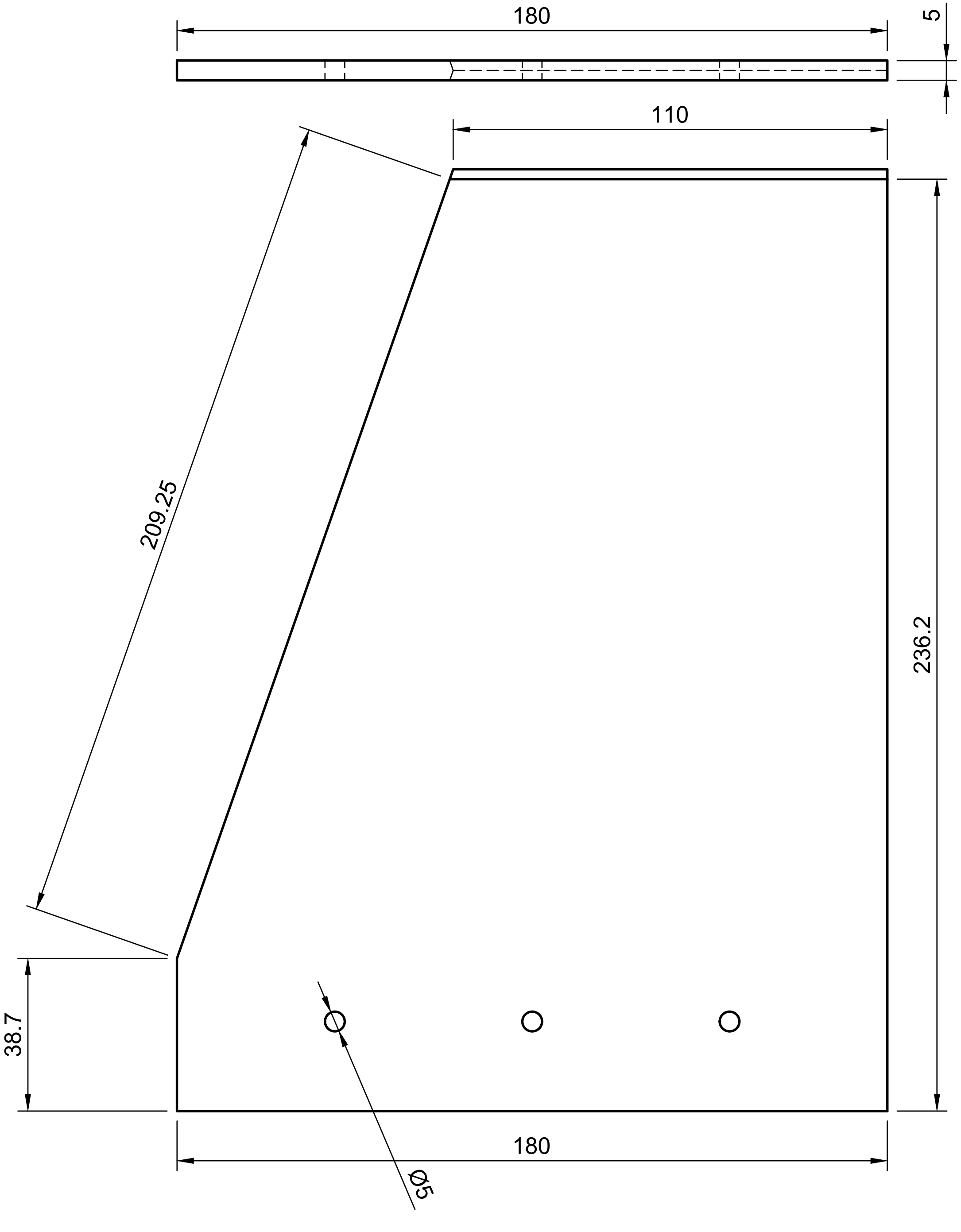
7.1.2 Body Tube Drawing


1250
400
R2.5
50
20
3
R79.2
R76.2
11.5
Ø158.4
100
100
5
180

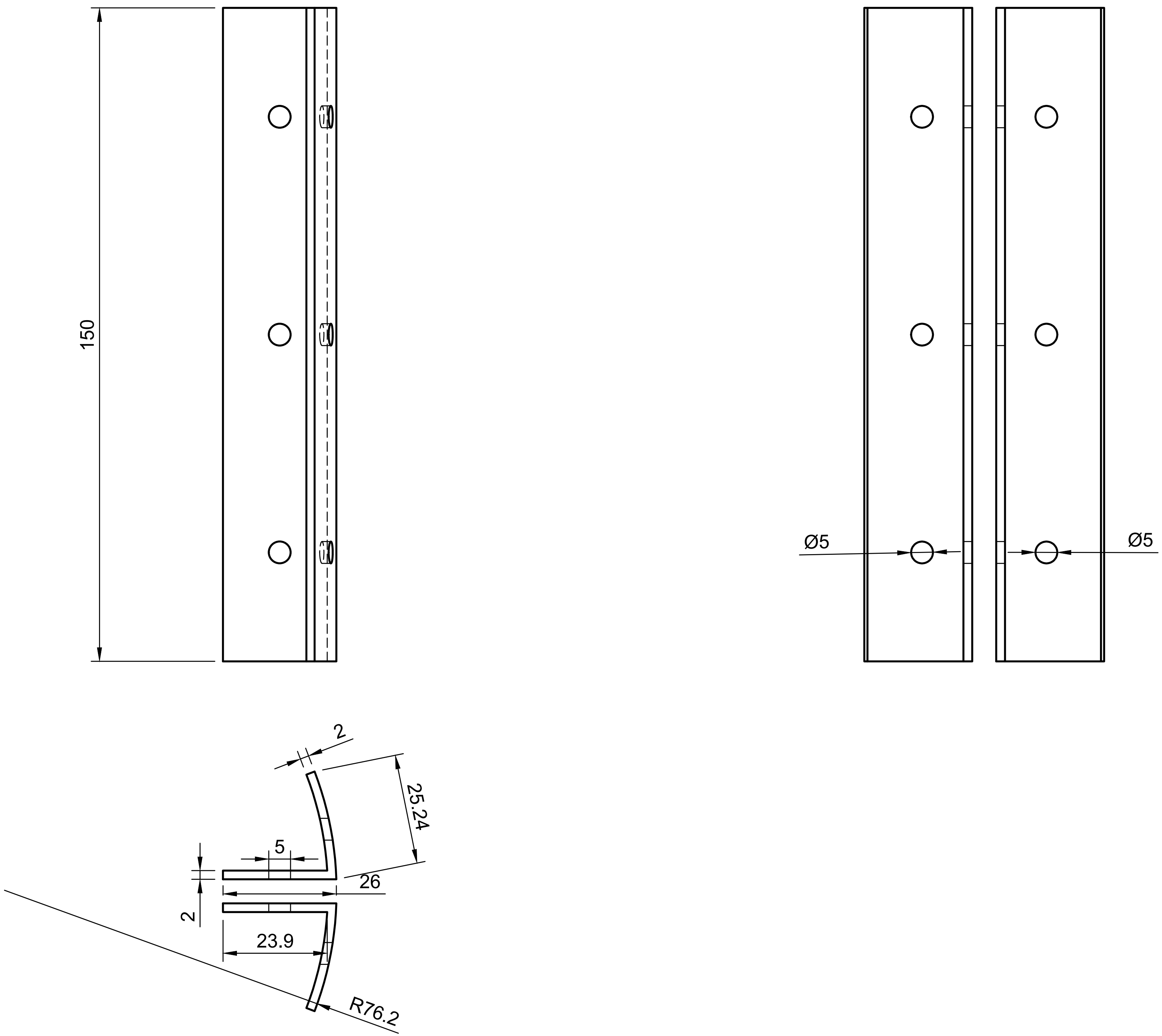
7.1.3 Bulkhead Drawing


146.4
3
18
3
Ø152.4
Ø146.4
Ø152.4
5

7.1.4 Fins Drawing

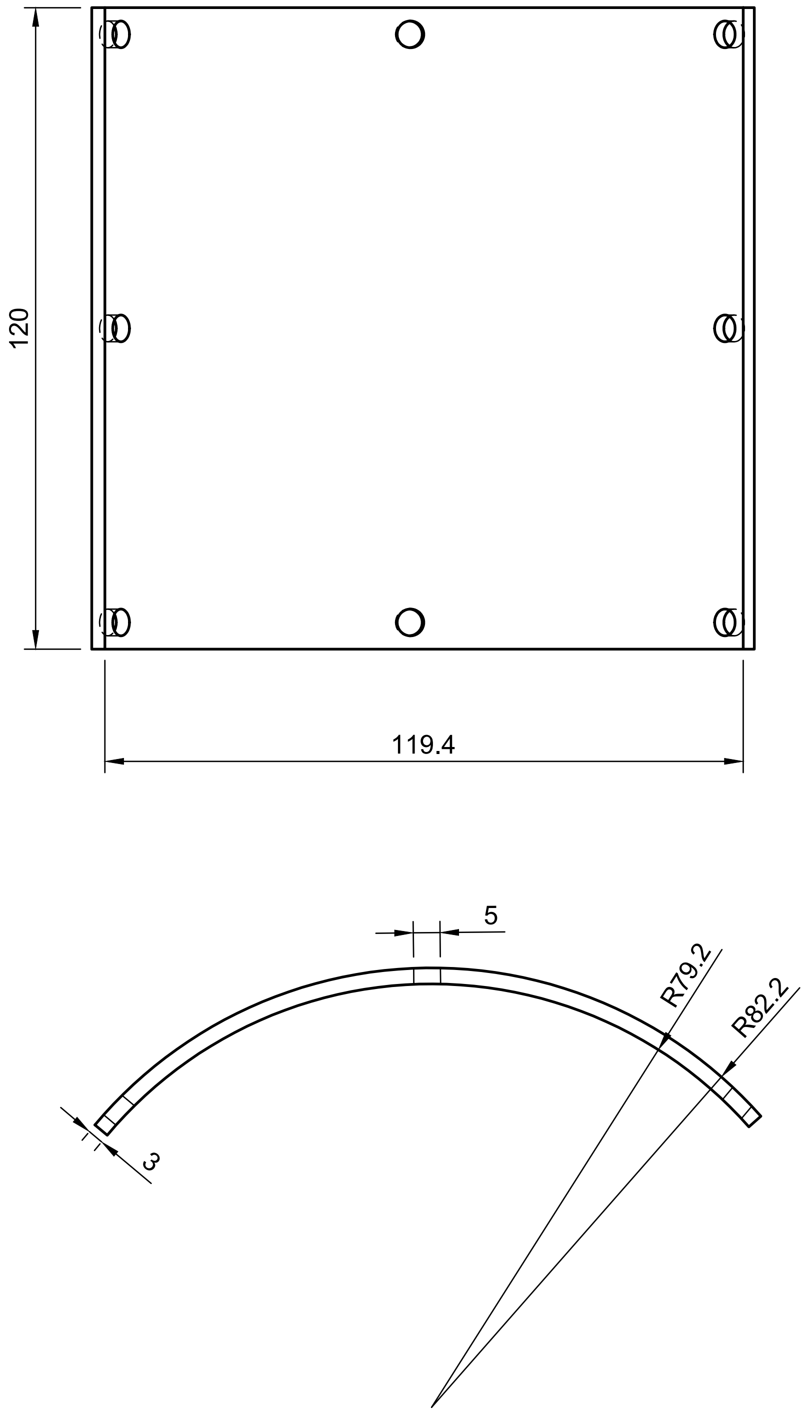

180
5
110
209.25
236.2
38.7
180
Ø5

7.1.5 Fin Bracket Drawing

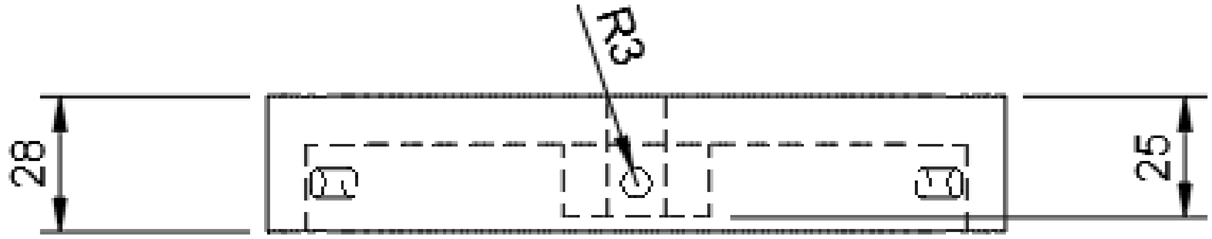


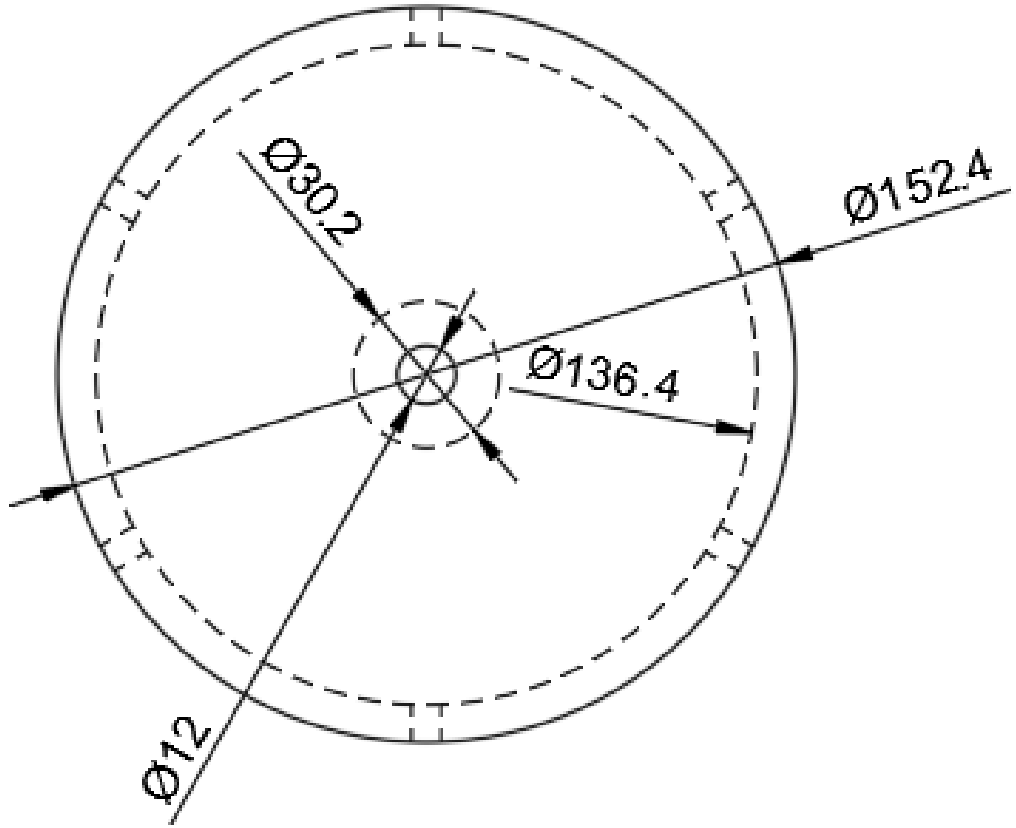
150
Ø5
Ø5
2
25.24
5
2
26
23.9
R76.2

7.1.6 Flight Computer Door Drawing

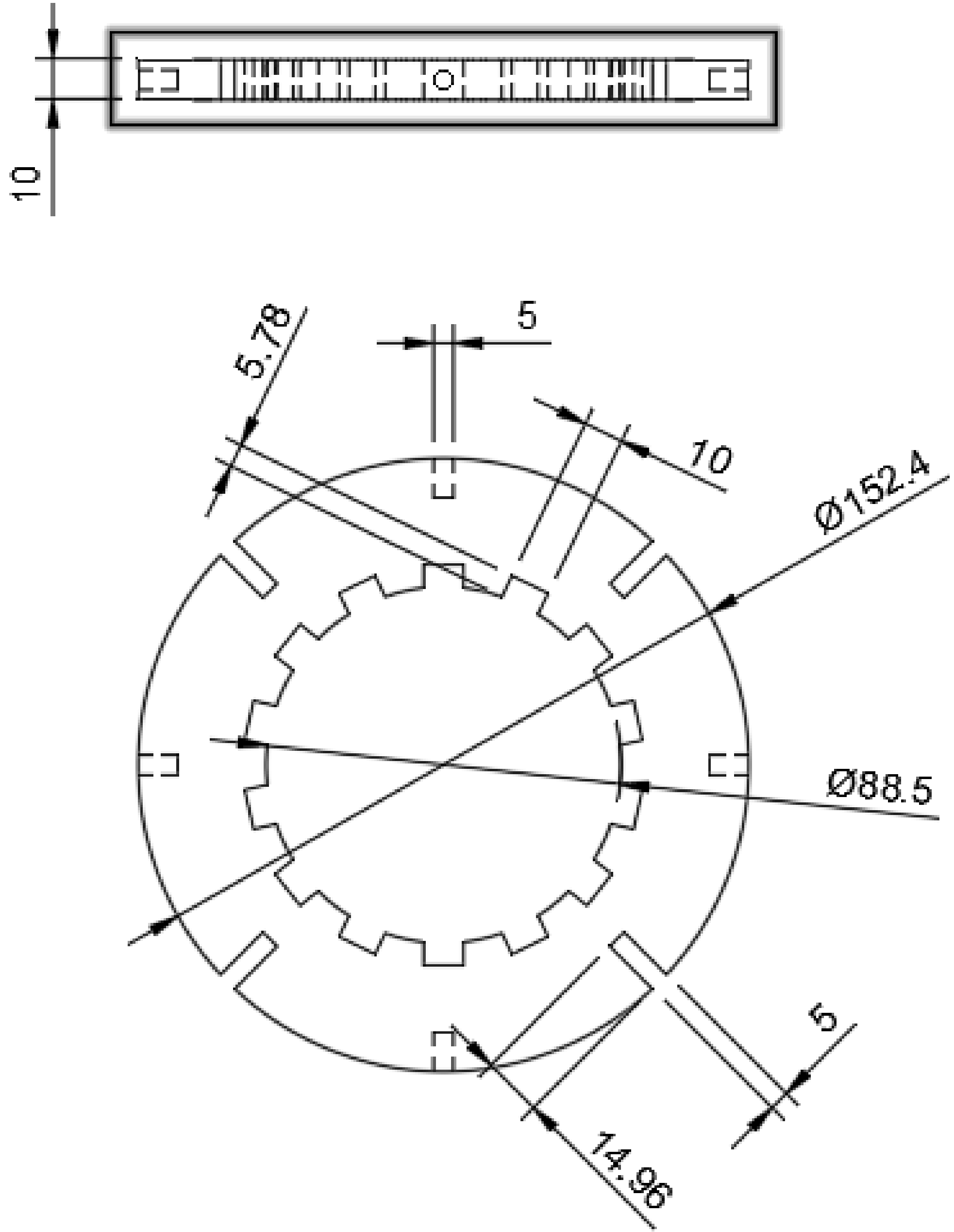

120
119.4
5
R79.2
R82.2
3

7.1.7 Aeropack Drawing

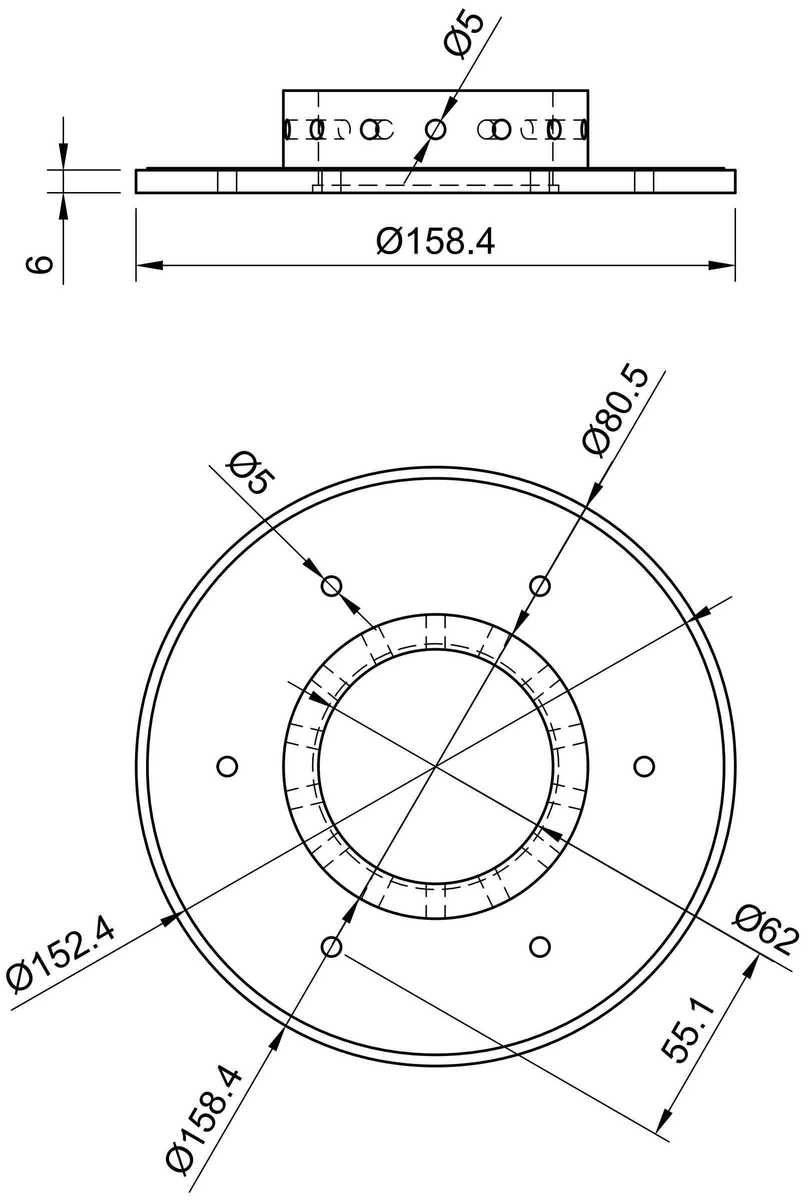

R3
28
25


Ø30.2
Ø152.4
Ø136.4
Ø12

7.1.8 Centering Ring Drawing


10
5.78
5
10
Ø152.4
Ø88.5
5
14.96

7.1.9 Thrust Plate Drawing



Ø5
6
Ø158.4
Ø80.5
Ø5
Ø152.4
Ø62
55.1
Ø158.4

7.2 Bill of Materials

7.2.1 Avionics

S.No.	Name of Component	Purpose	Justification	Cost (INR)	Quantity	Net Cost (INR)
1	STM32F407 Discovery Kit	Flight controller	This controller supports RTOS which is essential for the project.	3,146	1	3,146
2	Zigbee XBee Pro S2C 802.15.4 Module 63mW 3Km+ 3.2dBi Antenna	Telemetry	Min 2km range required, specified by competition organisers.	2,145	2	4,290
3	GY-BME280-3.3 Precision Altimeter Atmospheric Pressure Sensor Module	Altimeter, Pressure, and Temp sensor	Accurate altimeter to convert pressure data into altitude with 1.5 cm accuracy.	40	1	40
4	MPU9250 9-Axis Attitude Gyro Accelerometer Magnetometer Sensor Module-(Made in India)	Attitude sensor	Required for measuring orientation, made in India as per competition guidelines.	816	1	816
5	Spark-Fun XBee Explorer USB	XBee to PC adapter	Connect the receiver XBEE with the PC (Ground Station) through this connector.	2,498	1	2,498

S.No.	Name of Component	Purpose	Justification	Cost (INR)	Quantity	Net Cost (INR)
6	NavIC GPS	GNSS with NavIC	India-made GPS module to produce position data using NavIC.	1,500	1	1,500
7	Li-ion 3S2P 11.1V 4000mAh battery	Power	Li-ion battery selected for light weight and 30 minutes of power before launch.	1,299	1	1,299
8	ZB2L3 18650 Li-ion Lithium Battery Capacity Tester	Power status	Measure power status and relay it to the control unit.	225	1	225
9	Micro SD Card Reader Module	Store Data in SD card	Reliable module to log data during flight.	29	1	29
10	IRNSS L1 & L5 Antenna for NavIC GPS Tracker	GNSS Antenna	Obtain IRNSS data regarding the position of the rocket reliably.	750	1	750
11	LWC-CA-SMA-JACK-BH-ST-UFL-1.13mm RF Cable Assemblies-15cm	UFL connector	Standard connector for RF Module.	69	1	69
12	DC-DC 12V to 3.3V 5V 12V Power Module Multi Output Voltage Conversion	Voltage converter	Required to supply power to recovery (12V) and avionics (3.3V) subsystems.	39	1	39

S.No.	Name of Component	Purpose	Justification	Cost (INR)	Quantity	Net Cost (INR)
13	SanDisk V30 32GB High Endurance Video MicroSDHC Card with Adapter	SD card	Standard and reliable SD card brand.	719	1	719
14	High Speed Micro SD Card Reader	SD Card Reader	Reliable module for reading data to laptop.	59	1	59

7.2.2 Recovery and launch

SNo	Item	Estimated Min Cost (INR)	Estimated Max Cost (INR)
1	T-slotted Aluminium Extrusions	18.36	18.36
2	T-slot cover	83.49	249.47
3	Corner Brackets	167	417.45
4	12V Power Supply (1.2A)	834.9	1,252.35
5	12V Dual Channel Relay	1,252.35	2,086.25
6	12V Relay	417.45	834.9
7	Igniters	167	417.45
8	Alligator connectors	41.75	125.23
9	Wires	8.35	41.75
10	Fabric for parachute	417.45	1,252.35
11	Button Head Screws, Nuts, Bolts	4.17	41.75
12	Pivot Bracket with handle	834.9	1,669.80
13	Aluminium Base Plate	1,669.80	4,174.53
14	Rail Cap	167	417.45
15	Panel Mount Bracket	417.45	1,252.35
16	T-slot cover (duplicate)	83.49	249.47
17	Springs	83.49	249.47
18	Solenoid Locks	1,669.80	3,339.60
19	Another 12V power supply	834.9	1,252.35
20	Mechanical emergency switch	417.45	1,252.35
	Total	**9590.55**	**20594.68**

Table 7.2: Bill of Materials(Recovery and Launch)

7.2.3 Mechanical Subsystem

S.No.	Item	Quantity.	Amount (Rs.)	Purpose
1	Polycarbonate Filament	2 Kg	6000	Nose Cone
2	PVC Pipe	6 kg	1000	Body tube
3	Polycarbonate sheet	4	2000	Fins
4	SS M5 screw, length = 30 mm	6	100	body tube
5	SS M12 bolt, length = 30 mm	2	50	Rocket motor
6	ALuminum Block of 8 inch diameter and 1.5 cm height	3	2000	bulkhead & Thrust Plate
7	Primer Spray	2	500	painting
8	Paint spray (color =)	2	500	painting
9	Duct Tape	2	300	fixing
10	Painter tape	2	100	painting
11	Epoxy Adhesive	1	250	fixing
12	Feviquick	2	50	fixing
13	Centring ring	4	500	Centring ring
	Total		13350	