COMPETITIONS

NATIONAL ROCKETRY CHAMPIONSHIP 2024-25

Critical Design Review

TEAM EXODUS

NATIONAL ROCKETRY CHAMPIONSHIP

UKSEDS

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UKSEDS COMPETITIONS

UKSEDS National Rocketry Championship Critical Design Review

Guidance

The Critical Design Review details the team's final rocket design and discusses how the team arrived at their design. Minor alterations to your design may be made after the CDR but it is expected that the majority of design work is complete and the manufacturing and test phases have started.

This template has been provided as a guide, but its structure can be altered to better reflect the team's work. **The section headings provided in the template are required as a minimum**. Reports are limited to no more than **30 pages total including the template** (you may delete this page). Appendices are optional and could contain background or contextual information that is not essential to the project but they will not be marked and do not count towards the page count. References are included in the page count.

The deadline for the submission of this report is **23:59 GMT on the 21st of February 2025**. Please submit this through the CDR submission portal on our website on the submissions page.

Please contact rocketry@ukseds.org if you have any further questions.

UKSEDS National Rocketry Championship Critical Design Review

2024 - 2025

Team Exodus

Issued by (Project Lead): Mikaal Amini
University: University of Surrey

Table of Contents

1 Introduction

Our team is a relatively amateur but highly motivated group of students aspiring to compete in the **National Rocketry Championship (NRC) by UKSEDS**. This project represents our commitment to developing fundamental engineering skills, problem-solving abilities and hands-on experience in rocketry.

We have designed a model rocket that fully complies with the National Rocketry Championship requirements, integrating a **CPD** and **RPD**.

RPD shall act as **data logger** and also process flight data in real-time to detect landing, ensuring accurate event tracking.

1.1 Mission Statement

This model rocket shall achieve a stable launch to an apogee of 2200 feet, deploy a parachute for safe recovery & ground hit velocity of 10.6 m/s, and carry a Customer payload and Rideshare payload that collects location, altitude, and vibration data.

1.2 Objectives

- **Stable launch** and minimal deviation from the intended trajectory.
- **Successful landing and recovery** with all critical components intact.
- **Accurate data logging** to capture essential flight parameters for analysis.
- **Minimal structural and functional damage** upon landing
- **Rapid assembly & disassembly** to facilitate efficient pre-flight preparation and post-flight analysis.
- **Reliable software** ensuring seamless operation of avionics and telemetry systems.
- **Automated landing notification** to promptly update the recovery team on the rocket's location.
- **Robust structural integrity** capable of withstanding launch and landing forces.

2 Project Management

2.1 Team Members

Include a table of team members and their assigned roles. A team picture would be nice!

Name	Role	Year/Course
Caitlin Doutch	Vice Lead	Placement Year Aerospace Engineering
Parshva Patel	Avionics Lead	Year 1 Aerospace engineering
Aryan Sharda	Avionics	Year 1 Aerospace engineering
Mikaal Amini	Team Leader	Year 1 Aerospace Engineering
Thakshanth Ramesgumar	Recovery Lead	Year 1 Aerospace Engineering
Rohan Rajput	Aero & Structure	Year 1 Aerospace Engineering
Avinash uthayakumar	Recovery	Year 1 Aerospace Engineering

2.2 Financial Budget

Based on rough estimation we allocated £120 for structural components, £50 for the payload & avionics, and set aside £30 as a buffer. However it can be varied accordingly.

Bill of Materials (BOM)

Note : This excludes the cost of PCB, Epoxy and Plywood.

Component	Price per unit (£)	Number of units	Total cost of component
Micro SD Adapter	**0.99**	**1**	**0.99**
Barometer (BMP 280)	**1.49**	**1**	**1.49**
Eyenut(M8)	**2.99**	**2**	**5.98**
Micro SD (16GB)	**3**	**1**	**3**

IMU (MPU6050)	**3.45**	**1**	**3.45**
HC-12 Communication Board	**3.9**	**2**	**7.8**
Coupler Tube (54mm short)	**4.1**	**1**	**4.1**
Microcontroller (PI Pico)	**4.75**	**2**	**9.5**
Pack of Nut (M3)	**6.08**	**1**	**6.08**
Battery (2000mah 103450)	**8.45**	**2**	**16.9**
Blast shield(12")	**9.1**	**1**	**9.1**
GPS Module	**9.9**	**1**	**9.9**
Pack of Bolt (M8x18)	**10.52**	**1**	**10.52**
29mm Estes Compatible Motor Retainer	**10.66**	**1**	**10.66**
Parachute (15")	**11.04**	**1**	**11.04**
Threaded rod (M3)	**13.5**	**1**	**13.5**
Body Tube (54mm)	**18.95**	**1**	**18.95**
PETG filament (750g)	**23.4**	**1**	**23.4**
All Components			**166.36**

Transportation cost is excluded from project finance.

2.3 Project Risks and Mitigations

The risk matrix provided below identifies potential risks associated with the major aspects of the project, including risks related to Project Management, Avionics, Structural, Manufacturing and Recovery. The matrix assesses the impact and likelihood of these risks and outlines mitigation plans.

Risk Matrix

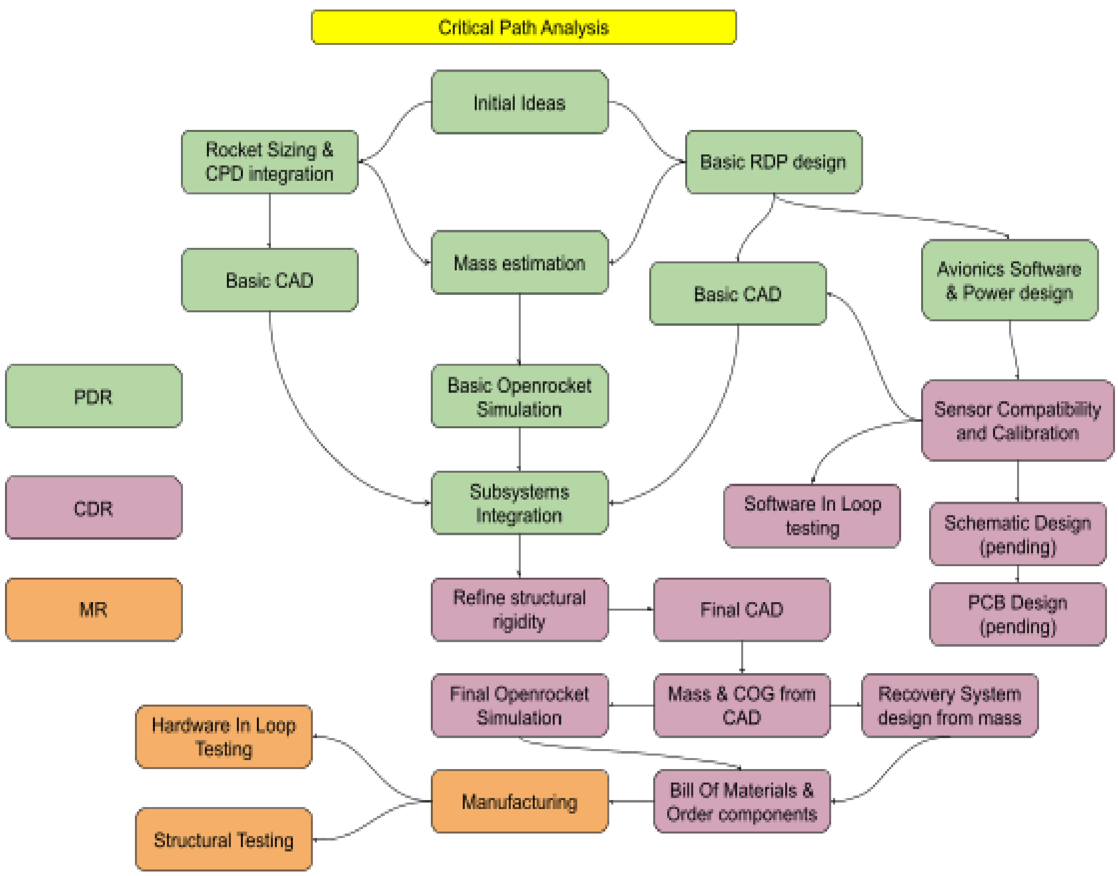
2.4 Project Plan

NRC Gantt Chart

The Gantt Chart provided is based on the initial rocket design based on a 48.7mm **diameter body tube**. However, as of **February 11, 2025**, body tubes of this size became unavailable, necessitating a **shift to a 54mm diameter design**. This change required significant overhaul of the design.

Due to time constraints, we regret that we are unable to provide an updated **Chart** at this stage. However, the version submitted reflects the exact design **path followed until mid-February.**

Critical Path Analysis up to MR



2.5 Work Breakdown Structure

Work Breakdown structure has been prepared for up to Manufacturing review.

Phase	Task number	Task Description	Aero	Work load taken (%)	Structure	Work load taken (%)2	Recovery	Work load taken (%)3	Avionics	Work load taken (%)4
Preliminary Design Phase	1	Mass & Financial budget planning	Assigned	3	Assigned	3	Assigned	3	Assigned	91
	2	Payload proposal	Assigned	5	Assigned	5	Not Assigned	5	Assigned	85
	3	Hardware Sizing	Assigned	5	Assigned	5	Not Assigned	0	Assigned	90
	4	Basic OR model	Assigned	3	Assigned	3	Assigned	3	Assigned	91
	5	Sensor testing and software development	Not assigned	0	Not Assigned	0	Not Assigned	0	Assigned	100
	6	OR model to CAD	Assigned	0	Assigned	0	Assigned	0	Assigned	100
	7	Presentation	Assigned	0	Assigned	0	Assigned	0	Assigned	100
		Recovery design	Not Assigned	2	Not Assigned	2	Assigned	2	Not Assigned	94

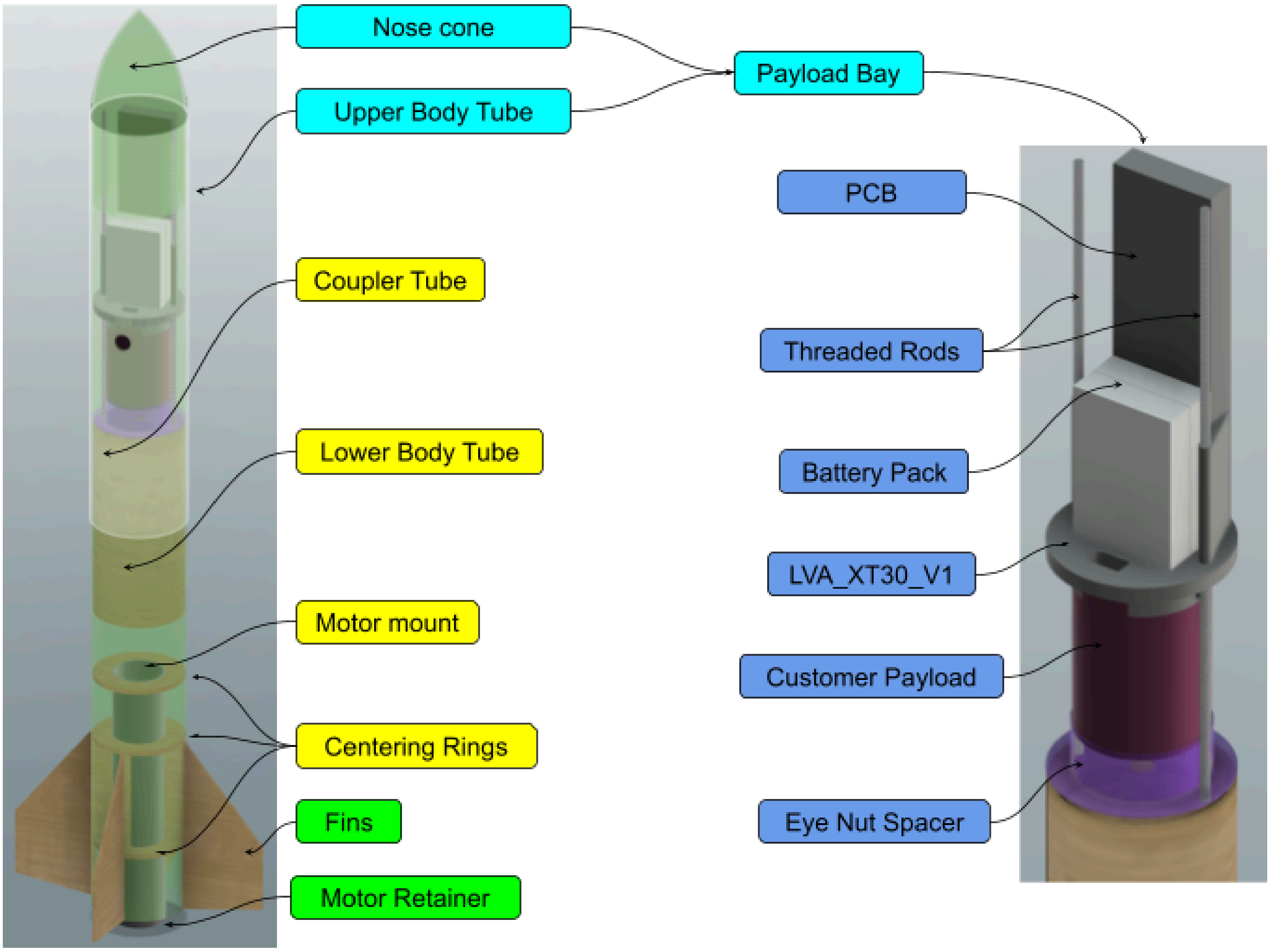
Phase	Task number	Task Description	Aero	Work load taken (%)	Structure	Work load taken (%)2	Recovery	Work load taken (%)3	Avionics	Work load taken (%)4
Critical Design Phase	1	Detailed RDP CAD & Mass estimation	Not Assigned	0	Not Assigned	0	Not Assigned	0	Assigned	100
	2	Detailed Body CAD & Mass estimation	Assigned	0	Not Assigned	0	Not Assigned	0	Not Assigned	100
	3	Sensor Calibration and Testing	Not Assigned	0	Not Assigned	0	Not Assigned	0	Assigned	100
	4	Detailed OR model	Assigned	0	Assigned	0	Assigned	0	Assigned	100
	5	Sensor testing and software development	Not Assigned	0	Not Assigned	0	Not Assigned	0	Assigned	100
	6	Structural strengthning	Not Assigned	0	Assigned	0	Not Assigned	0	Not Assigned	100
	7	Recovery system calculation	Not Assigned	0	Not Assigned	2	Assigned	0	Not Assigned	100
	8	Payload Integration	Assigned	0	Not Assigned	2	Assigned	0	Not Assigned	94
	9	CDR documentation	Assigned	0	Assigned	0	Assigned	0	Assigned	100
	10	Avionics and Software testing	Not Assigned	0	Not Assigned	2	Not Assigned	0	Assigned	100
		BOM list	Not Assigned	0	Not Assigned	2	Not Assigned	0	Assigned	100

Phase	Task number	Task Description	Aero	Work load taken (%)	Structure	Work load taken (%)2	Recovery	Work load taken (%)3	Avionics	Work load taken (%)4
Manufacturing and testing review	1	Detailed Manufacturing Process documenetation	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	2	Manufacturing of structure	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	2	PCB Order and Polulation	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	3	NRC structural requirement testing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	4	Hardware In Loop (HID) testing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	5	Telemetry testing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	6	Ground control station software GUI dev	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

3 Preliminary Concept

3.1 Launch Vehicle

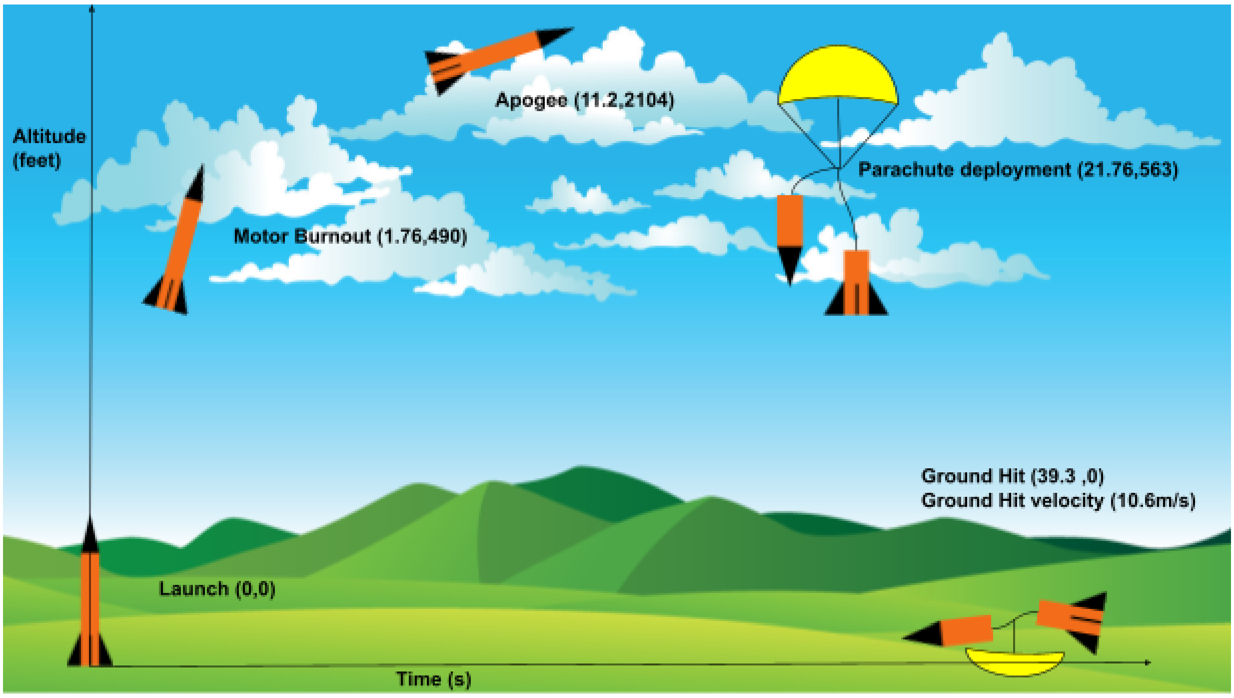
3.1.1 Launch Vehicle Overview



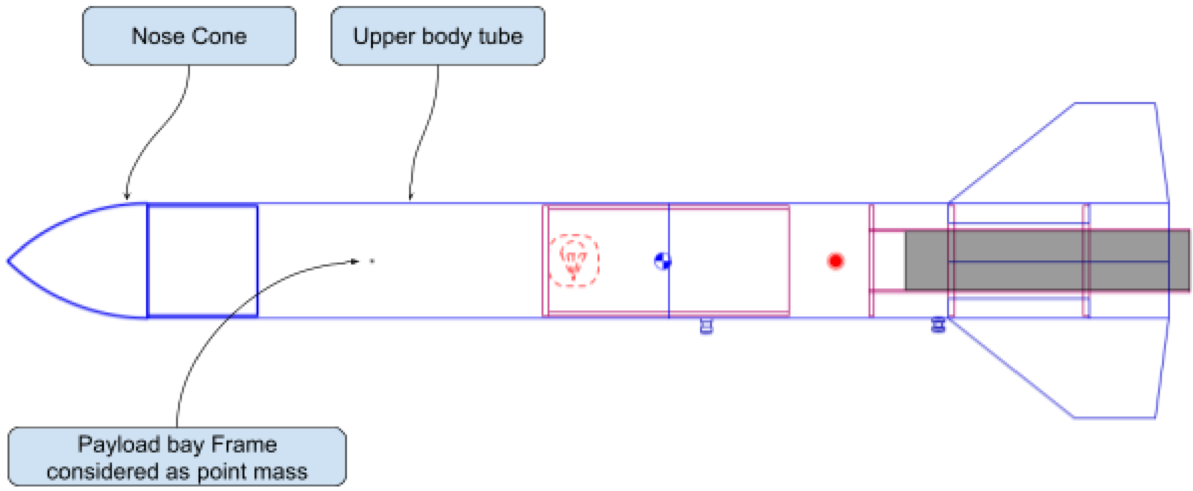
Tradeoffs

- Use of threaded rods provided structural integrity and ease of assembly however implementing this caused significant increase in structural mass budget.
- Use of a separate power system provides redundancy, less likely to lose power in both CPD & RPD when wire cuts off under g forces.
- Change from rover as RPD to a datalogger due to work delays, increasing complexity and lower structural rigidity which could lead to risk of termination because of lower safety standards.

3.1.2 Concept Of Operations (CONOPS)



3.1.3 OpenRocket Simulation

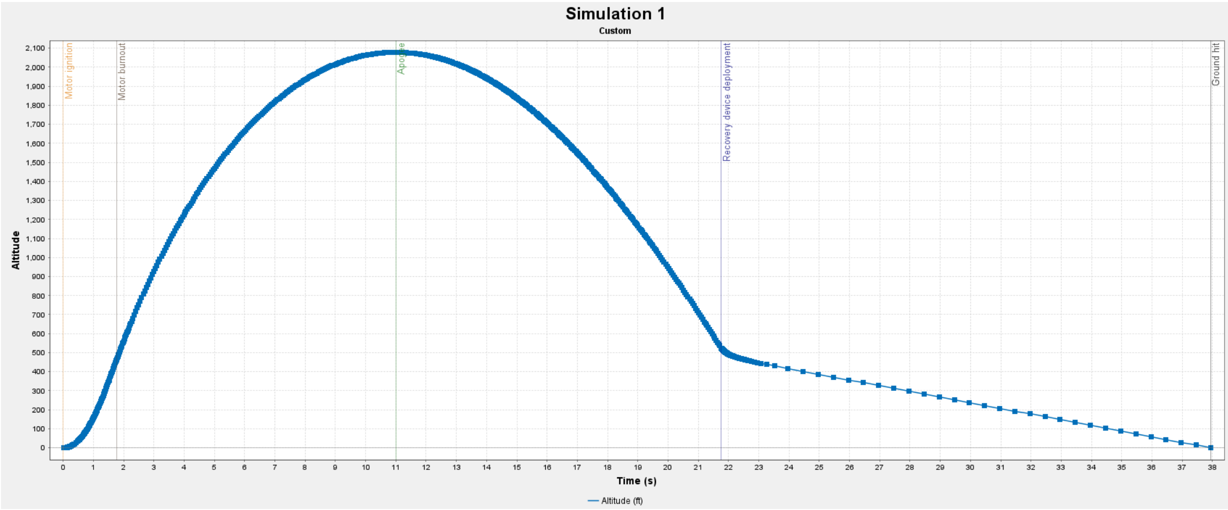


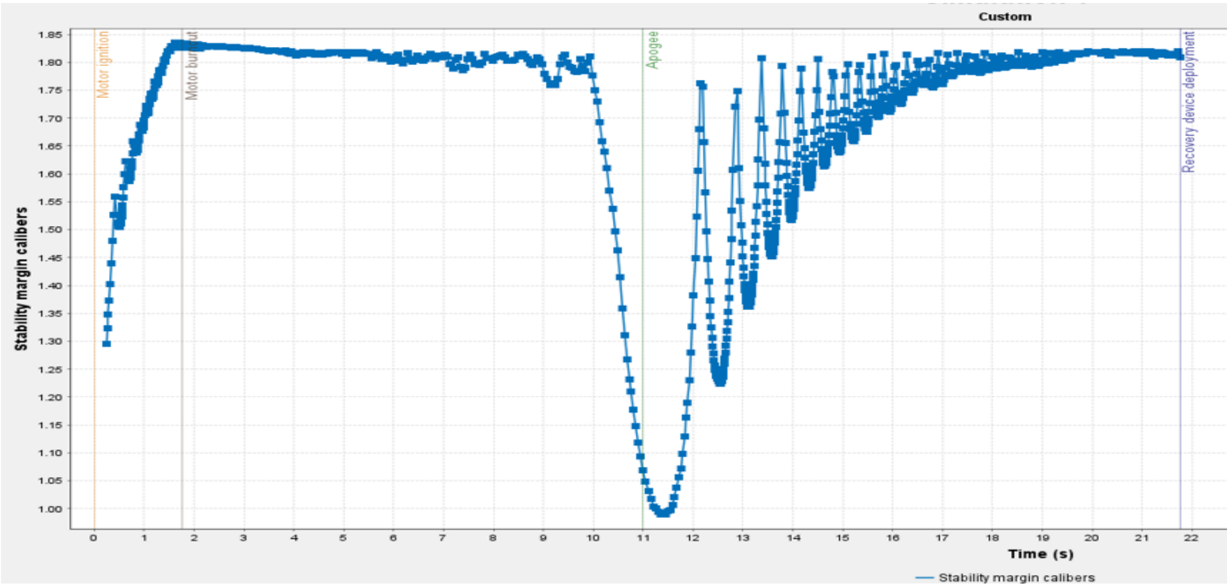
Point mass is not an assumption, it is calculated from CAD by associating each body with the right material property.

Assumption

- **Mass of epoxy = 0**
- **Mass of kevlar cord = 0.992**
- **Body tube to be perfectly symmetrical**
- **Flow is incompressible**

- **Smooth surface on 3D printed nosecone**
- **Fins will be strong enough for the requirement until load testing is complete.**
- **Negligible mass of M3 nut**





3.1.4 Recovery System Design

Parachute assisted recovery is used to achieve ground hit velocity of 10.6 m/s. The parachute deployment is triggered by gunpowder in the motor, charged to fire at 9s after burnout.

Rideshare payload determines landing using a combination of IMU and barometric data. Launch is detected by acceleration exceeding 2g and verifies an altitude surpassing 700 feet via the barometer. Post-landing, the system monitors acceleration, requiring it to remain near 0 for 30 seconds to confirm touchdown. A landing notification is transmitted via telemetry, though reception

may be unreliable due to the lack of line-of-sight. To ensure data integrity, the event is logged onboard an SD card for post-flight analysis. It can be externally turned on allowing rideshare payload to be turned on after it's on the launch rail. GPS data is transmitted over telemetry which allows locating rocket post landing

3.1.5 Launch Vehicle Components

Here is your opportunity to give a detailed description of your launch vehicle components. Examples could include: nose cone, airframe, payload bay, parachute and shock cords, fins, motor mount and retention and launch buttons.

Nose Cone

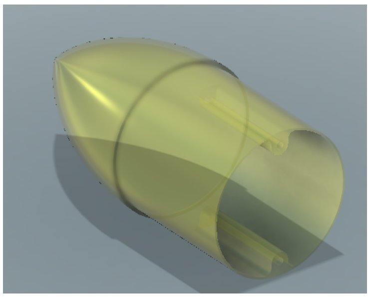
Material : PETG

Manufacturing : 3D printed

Shape : Ogive

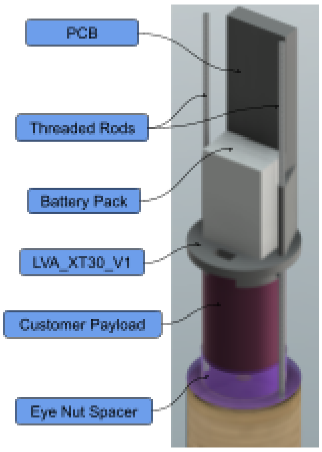
Length : 70 mm

Base Diameter : 57.2 mm



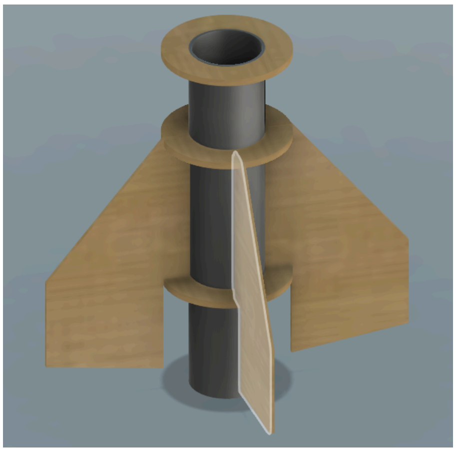
Payload Bay

It transmits load via threaded rods to the bottom bulkhead providing structural integrity and simpler assembly It also acts as a coupler with the nose cone. Both of which are joined together by a threaded rod.



Engine Block and fins

The engine block transmits load to the lower body tube via fins and centering ring. Third party motor retainer is used not allowing it to be modelled in CAD.



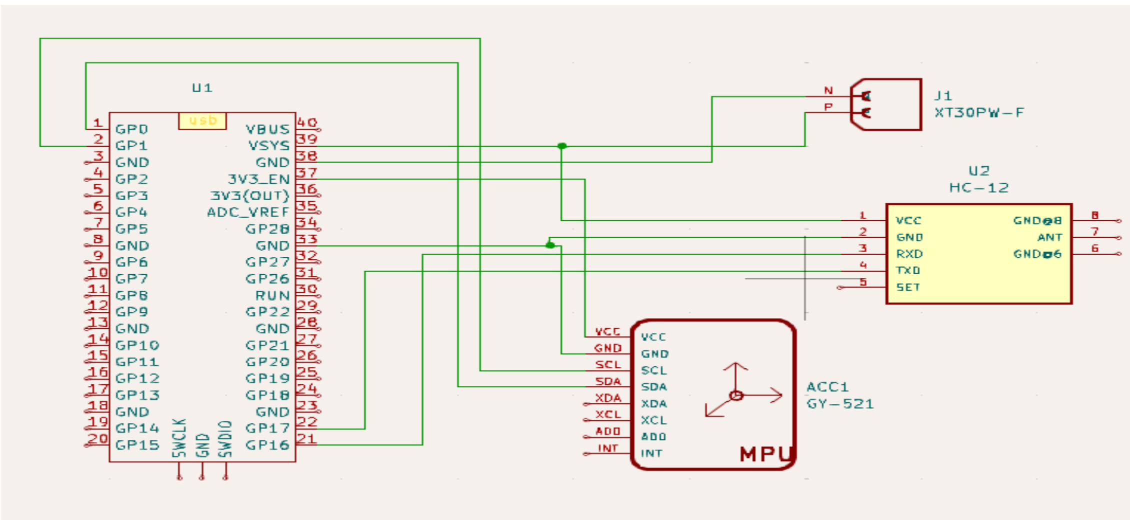
3.2 Rideshare Payload

3.2.1 General Overview

The rideshare payload consists of a power system, telemetry , microcontroller, IMU, Barometer, GNSS and RPD adapter. It shall log IMU and Altitude(Barometer) data onto an sd Card and transmit Location over HC-12. The microcontroller processes real time data to trigger launch and landing notification along with onboard conversion of pressure to altitude. The Schematic of PCB is not finalised so the volume occupied is estimated in the CAD.

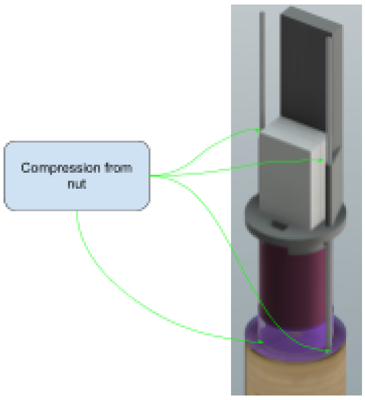
3.2.2 PCB Schematics

Partially complete schematic.



3.2.3 System Integration

CPD and RPD are inserted on threaded rods. Axially both are held in position by compression by nut applied from nosecone at top and from bulkhead at bottom



4 Systems Engineering

4.1 Requirement Compliance Analysis

At a minimum, this should cover all of UKSEDS' requirements. If you have derived your own requirements then you may also include these. This is likely to be quite a long table but it is included in the page limit.

Requirement ID	Met? [Yes, No, Partially]	Rational
MRD-MIS-001	Partially	Openrocket analysis shows the expected apogee to be 2104ft
MRD-MIS-002 MRD-MIS-003	Yes Yes	Openrocket analysis shows the expected apogee to be 2200ft with minimum mass estimation.
MRD-MIS-004 MRD-MIS-005 MRD-MIS-006	Yes Yes Yes	The order is placed for Ceseroni Technology Pro-29mm [108G68-13A-9] from UKSEDS' NRC organising team.
MRD-MIS-007	Yes	The rideshare payload weighs 150g including batteries and PCB to threaded rods adapter.
MRD-CPD-001	Yes	CPD is powered with 3.3-4.7V Li-ion battery
MRD-CPD-002	Yes	CPD's battery is powered by a 2000mAh battery which is higher than required capacity 1523mAh. (CPD battery not shared with RPD)

MRD-CPD-003	Yes	Battery has a discharge rate greater than 2.03C supplying 7.5w minimum for 45 min
MRD-CPD-004	Yes	XT30 Female connector will be provided by the team to power CPD
MRD-CPD-005	Yes	16GB micro sd card will be provided by us
MRD-CPD-007	Yes	Required space provided to place the CPD
MRD-CPD-008	Yes	Centre of CPD is placed directly above thrust vector of rocket motor
MRD-CPD-009	Yes	Holes in the body tube to provide access to the CPD.
MRD-CPD-010	Yes	Large holes in body tube keeps payload bay unpressurised
MRD-RPD-001	Partially	Premanufactured sensor modules and microcontroller is mounted on a PCB designed from scratch by us, for which schematic diagram is partially complete before CDR
MRD-RPD-002	Yes	Barometer is mounted on RPD that sits in unpressurised container
MRD-RPD-003 MRD-RPD-004	Yes Yes	Pressure to altitude processing occurs onboard the RPD. Live telemetry of altitude along with constant datalogging on sd card allows us to plot the graph rapidly
MRD-RPD-005	No	The Gerber file for PCB is not ready yet so this requirement is not fulfilled for now, however it will be included when the design is complete.
MRD-RPD-006	Yes	It collects -Location/time using (GNSS) -Vibration/time (IMU) -Landing recognition by processing live data

TSN-MOR-001	Yes	Motor is Clamped by aluminum retainer at bottom and 4mm plywood at front that has bore in the centre for gas to escape
TSN-MOR-002	Partially	The design is optimised to provide maximum support to the mount by securing the motor mount tube with 3 centering rings and connecting it to 4 fins. Load testing will be completed after manufacturing.
TSN-MOR-003	Partially	Mount is designed considering the requirement but validation requires testing which will take place after manufacturing
TSN-SMN-001	Yes	Open rocket shows velocity off rail = 20m/s
TSN-SMN-003	Partially	It takes 0.4 seconds to go from 1.31 to 1.5 and remains in the required range till apogee
TSN-SAR-001	Yes	It is designed to be 0° from longitudinal axis
TSN-SAR-002 TSN-SAR-003	Partially	Fins are supported internally and has 4mm thickness however load testing will be carried out after CDR
TSN-SAR-004	Partially	Upper and lower body tubes are supported with coupler tubes. However testing will completed after manufacturing
TSN-SAR-005	Yes	Body diameter is 57mm and the coupler tube is 120cm with 60cm shared with each direction.
TSN-SAR-006	Partially	Load testing required
TSN-SAR-007	Yes	Rocket equipped with 2 6mm rail buttons placed at position recommended.
TSN-SAR-008	Yes	No FEA is used to produce evidence
TSN-ESS-001	Yes	The PCB is planned to be turned on externally and is powered by 2000mAh battery
TSN-ESS-002	Yes	Arming is done without disassembly

TSN-ESS-003	Yes	Single core wires in the battery will be replaced with multicore ones.
TSN-ESS-004	Yes	Avionics rely on HC-12 433MHz for telemetry
TSN-RRS-001	Yes	Rocket uses 15" rocket for recovery
TSN-RRS-002	Yes	Open rocket shows decent velocity of 10.6m/s, Hand calculations supporting it.
TSN-RRS-003	Yes	Open rocket shows max lateral displacement of 400m
TSN-RRS-004 TSN-RRS-005 TSN-RRS-007	Yes	No Flight computer is used for recovery
TSN-RRS-006	Yes	No tilt switches are used
TSN-RRS-008	Yes	Recovery load is transmitted through an eye bolt with a nut on the other side.
TSN-RRS-007 TSN-RRS-008	Yes Yes	A kevlar cord with length of 2m is used
TSN-ARY-001 TSN-ARY-002 TSN-ARY-003	Not Relevant Not Relevant Not Relevant	

4.2 Budgets

Energy Budget

Component	Energy Budget
Customer Payload	2000mAh
Rideshare Payload	2000mAh
Total	**4000mAh**

Mass Budget estimated

Subsystem	**Mass estimation(g)**
Payload bay	250
Lower body + motor	350
Upper body and nosecone	100g
Total	**700**

Mass Budget estimated

Component/Subsystem	**Mass actual(g)**
Nose Cone	35
Upper Body Tube	71
Payload Bay (Power,RPD,CPD)	244
Lower Body + Motor	339
All subsystems	**689**

5 Manufacturing Processes

5.1 Launch Vehicle

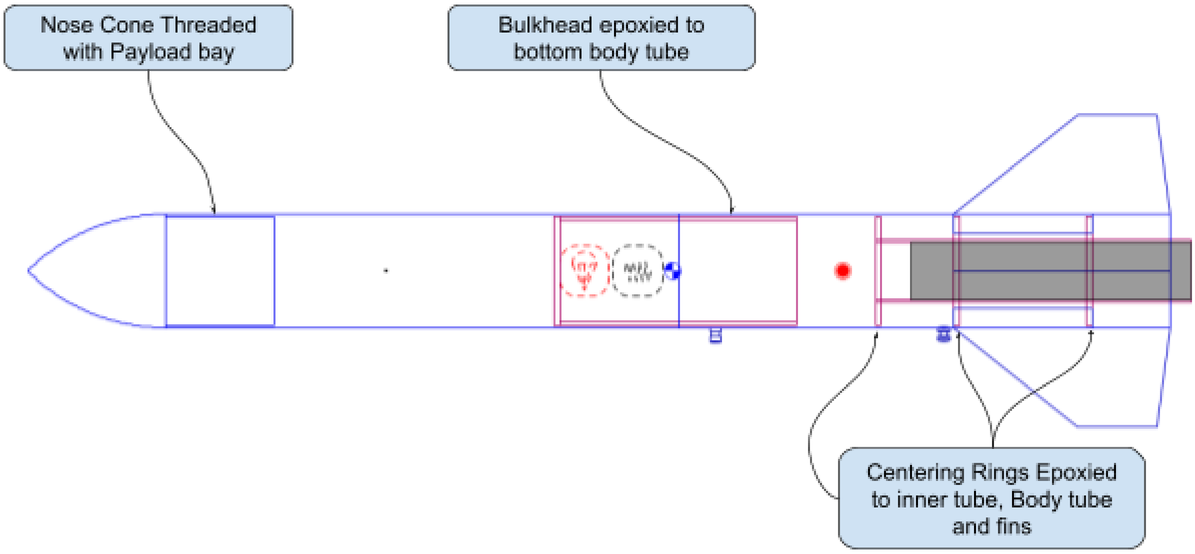
3D printing Components

- Nosecone
- Eye Nut Spacer
- RPD adapter
- Batterypack casing
- LVM_XT30

Laser Cut

- Centering Ring
- Bulkhead
- Fins

Joints



3D printed templates

- Ring shaped templates to cut tubes to correct length.
- Ring shaped cylinder with grooves to slice fin inserts on lower bodytube.

5.2 Rideshare Payload

- JLC PCB for PCB manufacturing

5.3 Issues and Solutions

Issue: - Square fins reduce apogee
Solution:- Rounded fins can improve altitude however there is a need to design a custom jig which can hold fins at an angle for sanding.

6 Testing

6.1 Test Matrix

Subsystem	Requirement ID	Description	Test Type	Status
Structure	TSN-MOR-002	The rocket motor mount shall be designed to withstand a lateral force in any direction equal to a thrust misalignment of 5° at the maximum motor thrust cantilevered about the vehicle's centre of gravity.	Physical experemntation	Pending
Structure	TSN-MOR-003	The rocket motor mount shall be designed to withstand a lateral force in any direction equal to a thrust misalignment of 5° at the maximum motor thrust cantilevered about the vehicle's centre of gravity.	Physical experemntation	Pending
Structure	TSN-SAR-002	Each fin must be able to support a suspended load from its tip equal to twice the fin mass times the rocket's maximum axial acceleration occurring during any flight phase.	Physical experemntation	Pending
Structure	TSN-SAR-003	Each fin shall withstand a transverse load equal to the rocket's launch mass when suspended from the fin tip with a maximum lateral deflection of less than 10° in either direction.	Physical experemntation	Pending
Structure	TSN-SAR-004	The launch-ready rocket shall deflect less than 10mm per metre length in any lateral direction when suspended from its centre of mass.	Physical experemntation	Pending
Structure	TSN-SAR-006	All structural parts shall withstand twice their expected maximum inertial and aerodynamic loads without failure.	Physical experemntation	Pending
Recovery	TSN-RRS-002	The recovery system shall reduce the rocket's vertical landing speed to less than 15 m/s.	Hand Calculation &Simulation	Complete
Avionics	SDR-001	Sensor Calibration and Compatability validation of IMU & Barometer	Physical experemntation	Complete
Avionics	SDR-002	Telemetery Range & Line of Sight Testing	Physical experemntation	Pending
Avionics	SDR-003	Hardware In Loop Testing for automated landing notification	Physical experemntation	Complete
Avionics	SDR-004	Real time data processing and datalogging	Digital observations	Complete
		SDR = Self Designed Requirements		

6.2 Test Results

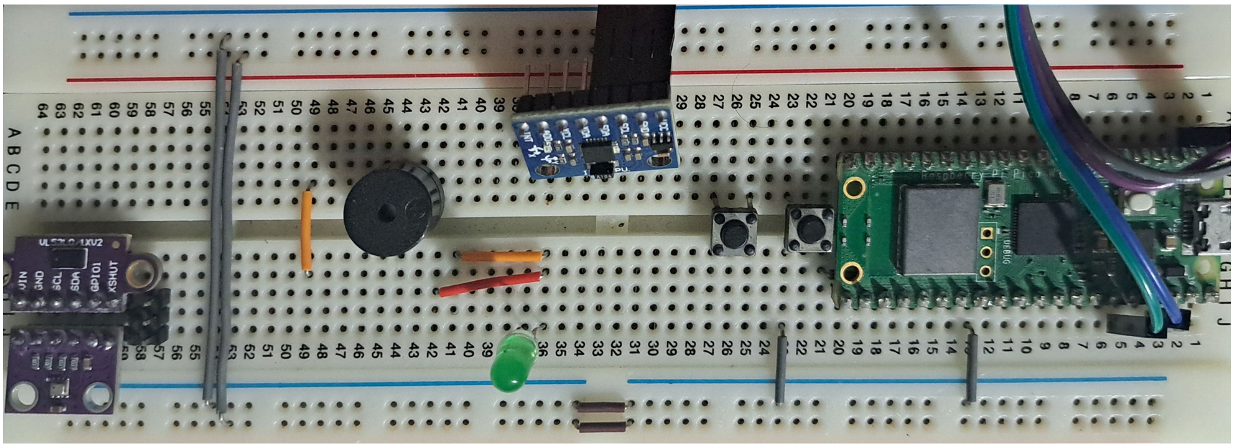
SDR-001 :- Aim of this test was to calibrate IMU which can have offset in axis from manufacturing. essentially zeroing the hardware, fortunately **IMU has negligible offset.** Additionally IMU always detects acceleration from gravity which is normally countered by normal forces which IMU is unable to detect. This reaction force is subtracted in real time to provide a = 0m/ss when it is stationary. This test also **tested the subtraction algorithm.**

The main logic is governed by the below python script

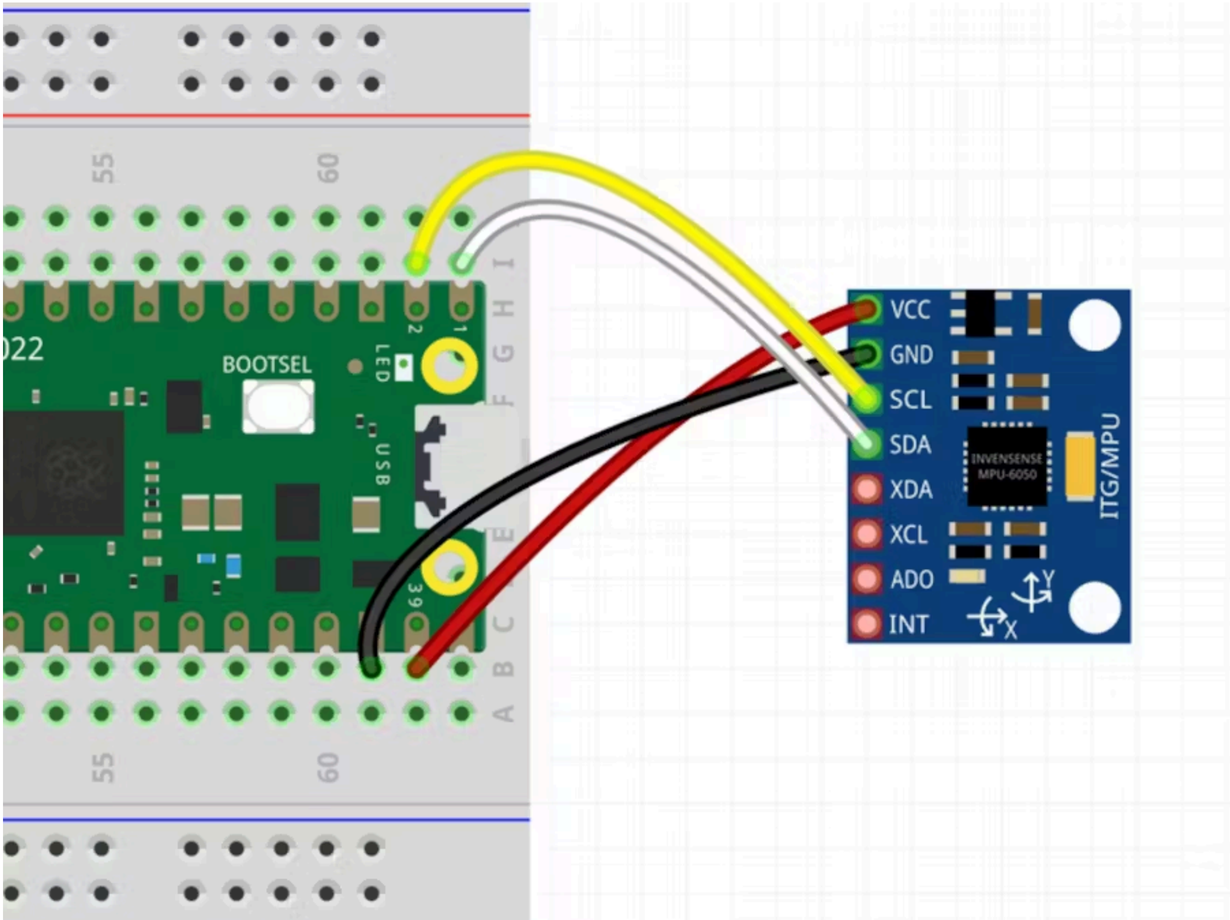
```
def estimate_gravity(roll, pitch):
        g_x = -math.sin(math.radians(pitch))
        g_y = math.sin(math.radians(roll)) * math.cos(math.radians(pitch))
        g_z = math.cos(math.radians(roll)) * math.cos(math.radians(pitch))
        return g_x, g_y, g_z
```

In short, the test was **successful** after 3 software patches.

Hardware Setup



Wiring



7 Final Design

7.1 Design Changes

Change in RPD from Rover to a datalogger

Due to the increasing complexity of the rover design and our inability to ensure sufficient structural rigidity within the given constraints, we decided to switch to a data logger with telemetry. This alternative allows us to gather real-time flight data while maintaining a more reliable and structurally sound payload, ensuring mission success. The new RPD design has launch and landing recognition software, making the rover concept viable for future competitions.

Change in Complete Design

As mentioned previously in 2.4, the body tube on which our design was based was no longer available. This required major redesign in every aspect of the project starting from integration to structural rigidity and component sizing. With reduced development time of just 10 days. Forcing us to brute force structural rigidity increasing the mass and lowering target apogee

7.2 Improvements and Future Work

The focus will be on better work distribution and increased team involvement. Emphasis will be placed on structural testing for safety, with improved manufacturing detail and concise drawings enhancing the process..

8 Acknowledgements

I would like to express my gratitude to Charles Deebank for providing us with valuable guidance on designing the motor mount and to NRC for their clear and helpful clarifications.

9 References

No particular reference style is preferred. Include citations in the text.

Appendices

Any supplementary material, which is not essential to the project, but will provide a more comprehensive overview of the project, can be included as appendices. **Anything in this section will not be directly marked.**

If you have carried out large numbers of trade-offs, you may place the tables here and refer to them in the main text.