USYD Rocketry Recruitment Tasks

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1 Coding Task

1.1 Introduction

The code for this task is available on the branch repository or in the provided ZIP folder. It determines the thrust force produced by the rocket engine during flight, based on data from the accelerometer, mass measurements, drag forces, and atmospheric conditions.

1.2 Methodology

The net force acting on the rocket is given by:

$$F_{\text{net}} = ma = F_{\text{thrust}} - F_{\text{gravity}} - F_{\text{drag}}$$

where:

- m is the rocket mass,
- a is the measured acceleration,
- $F_{\text{gravity}} = mg$ with $g = 9.8$ m/s^2,
- $F_{\text{drag}} = \frac{1}{2}\rho v^2 C_d A$.

Rearrange the equation to calculate the thrust force:

$$F_{\text{thrust}} = ma + F_{\text{gravity}} + F_{\text{drag}}$$

1.3 Interpolation Methods

Interpolation was used to estimate the drag coefficient C_d at each time step based on the rocket's Mach number. This coefficient is required to calculate the drag force.

I applied NumPy's built-in `interp` function, which performs linear interpolation. In general, linear interpolation assumes that between two known data points (x_0, y_0) and (x_1, y_1), the value at an intermediate point x can be approximated using:

$$y = y_0 + \frac{(x - x_0)}{(x_1 - x_0)} \times (y_1 - y_0)$$

[2]

In this case, the Mach number was calculated by dividing the velocity at each time step by the speed of sound. The corresponding C_d values were obtained from the dataset `mach_cd.csv`, which provides tabulated Mach numbers and their associated drag coefficients. The linear interpolation method then provided intermediate C_d values for Mach numbers not explicitly listed in the dataset.

1.4 Limitations and Assumptions

This analysis does not account for external environmental factors such as wind direction, wind speed, or weather conditions. For instance, strong crosswinds could alter the rocket's trajectory and may require additional thrust to maintain stability. Similarly, rainfall could increase surface drag, reducing the rocket's efficiency. These environmental variables introduce uncertainties that could act as limitations, since they depend on weather conditions that may be difficult to predict.

1.5 Improvements

A potential improvement would be to account for frictional forces if the rocket uses a launch rail or launch rod. During lift-off, the rocket may rub against the rail or rod, introducing additional resistance that slightly reduces the net thrust. Incorporating this factor into the calculations would provide a more accurate prediction of the rocket's performance.

2 Kicad Task

2.1 Component Selection

The main components used in this design are:

1. **Light-Emitting Diode (LED)**
2. **Button**
3. **PH Connector**
4. **Pin Header**
5. **Diode:** The circuit input is 4 V, which is the maximum voltage. The selected diode is the 1N5408, which has a maximum reverse voltage of 1000 V, providing protection against back voltage.
6. **Resistor:** The chosen resistor is CFM14JT130R. The battery supplies 4 V, and the voltage drop across the resistor is 2 V. The current through the red LED is 20 mA, so the power dissipation is $P = 2 \times 0.02 = 0.04$ W, which is safely below the 1/4 W resistor rating.

2.2 Circuit Diagram

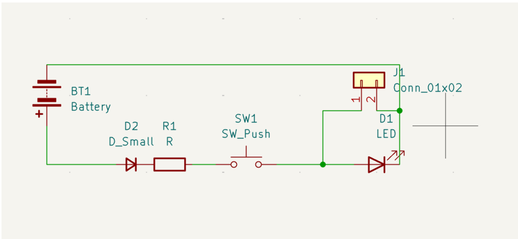

Figure 1: Schematic of the LED circuit.

The circuit schematic shows a series connection of the power supply, diode, resistor, and LED. To measure voltage, two pin headers were connected across the LED terminals. The diode provides protection against reverse polarity by blocking current from flowing from cathode to anode.

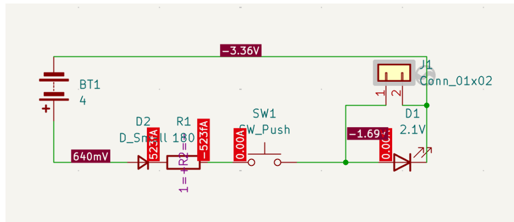

Figure 2: Simulation LED circuit

2.3 Circuit Simulation

Initially, there was confusion regarding the anode and cathode connections. After verifying the correct orientation of the LED in the simulation, a small current was still observed. A 180 ohm resistor was selected based on the LED datasheet and the 4 V battery voltage.

2.4 Trace Width Calculation

Using the DigiKey trace width calculator, for a maximum current of approximately 20 mA and 1 oz copper thickness, a minimum trace width of 0.25 mm was required. The recommended trace width for this design was set to 0.2 mm [6].

2.5 PCB Layout and 3D View

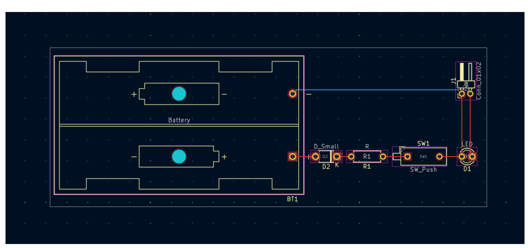

Figure 3: PCB layout of the LED circuit.

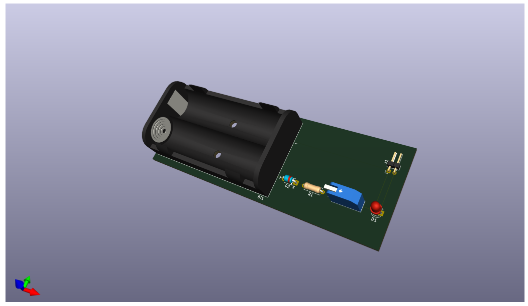

Figure 4: 3D view of the PCB.

3 Onshape Task

3.1 Components Designed in Onshape

I designed a rail button similar to the provided example, with an outer diameter of 1.6 cm and an inner diameter of 0.8 cm. The rail button head is designed to fit tightly inside the launch rail. Using two rail buttons, the rocket will be guided along the rail during take-off.

A 10-32 machine screw, approximately 0.483 cm in diameter, passes through the rail button [5]. I caved in the rail button by 0.03 cm to accommodate the screw head, ensuring the fit. To secure the rail button to the rocket, I designed a weld nut that tightens the machine screw. The calculated diameter for the weld nut is slightly off, which may require adjustment.

I also considered using a spring mechanism to retract the rail button into the rocket after launch. By cutting a small hole in the rocket body, the spring could compress as the rocket leaves the rail, retracting the rail button and reducing drag caused by the button protruding from the rocket. To accommodate this, I designed a spring seat to house the spring. However, the exact connection between the spring and the rail button is still to be determined.

For the components of the components oguide, guide, the rail button should bof a lightweightight low friction material such as Delrin plastic [4], wheasily slidesides inside the launch rail and resists wear. The weld nut requires high mechanical strength to handle the torque of the machine screw and is best made from zinc-plated steel[5], providing durability and resistance to stripping. The spring seat, which houses the spring and must resist deformation while remaining light, can be made from Delrin plastic if 3D printed or aluminum if machined or welded, offering sufficient stiffness and durability.

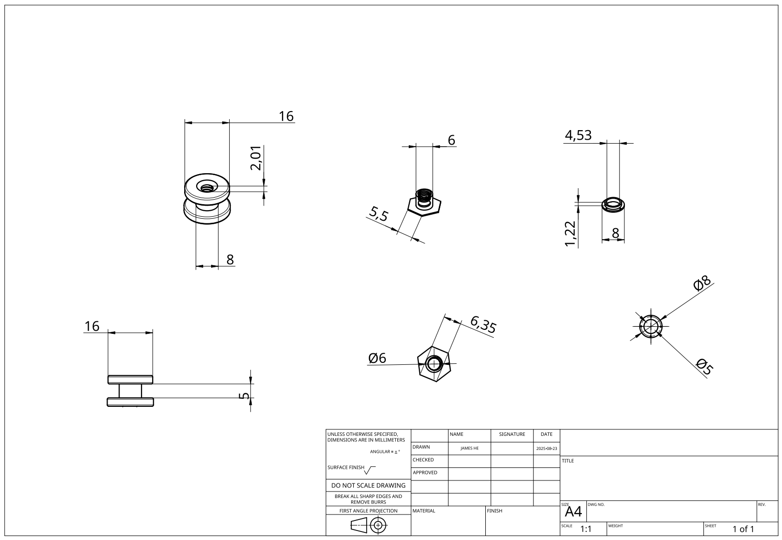

Figure 5: A4 engineering drawing of the rail guide assembly from Onshape.

4 OpenRocket Task

4.1 Engine Selection

The J435WS engine was selected because it provides the highest total impulse for a rocket with a diameter of 38 mm and a length of 40 cm. This engine uses a 14-second delay charge, which is suitable for optimizing altitude while allowing for safe deployment of recovery systems.

4.2 Nose Cone Design

The nose cone of the rocket was designed using the **Haack series**, specifically the Von Kármán profile, which minimizes drag at high speeds. This shape has one of the lowest drag coefficients at Mach 0.8–1.0 (see Figure 6). The nose cone length was set at approximately one third of the rocket body length to balance stability and performance.

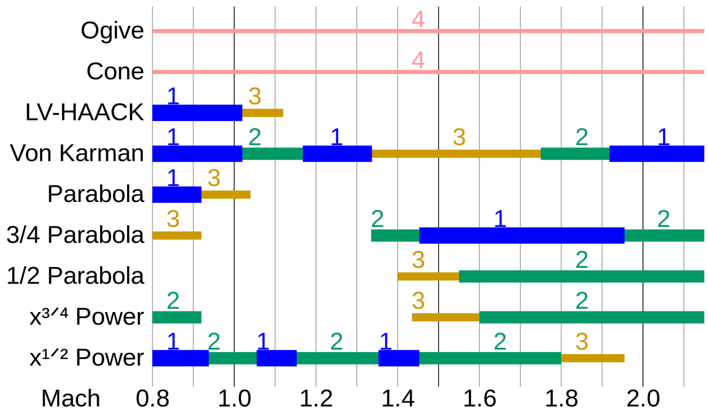

Figure 6: Drag comparison of various nose cone shapes (source: [1]).

4.3 Body Tubes

The rocket uses two body tubes: Body tube 1 with a length of 58.6 cm and Body Tube 2 with a length of 59.6 cm. This configuration supports internal components while maintaining structural integrity during launch.

4.4 Fins

The swept fins are designed to move the center of pressure (CP) rearward, inspired by commercial aircraft using swept-wing designs. The sweep angle contributes to an increase in the rocket's apogee [3]. Four swept fins were used to enhance stability while minimizing apogee loss due to drag. Plywood was chosen for the fin material because of its favorable strength-to-weight ratio, and the fins were finished with optimized paint to reduce surface roughness and aerodynamic drag. Additionally, aircraft sheet-metal components were used for critical surfaces where possible. While these improve aerodynamic performance and increase apogee, they are more challenging to manufacture.

4.5 Center of Gravity and Stability

The rocket was designed with the center of gravity (CG) located ahead of the center of pressure (CP), ensuring longitudinal stability during flight. Stability analysis confirmed that the static margin remained above 1.1, which is considered an optimal range for safe and stable flight.

4.6 Performance Results

With this configuration, the rocket achieved a calculated apogee of 1488 meters using the J435WS engine. This performance reflects the combined benefits of aerodynamic optimization, careful material selection, and the chosen engine.

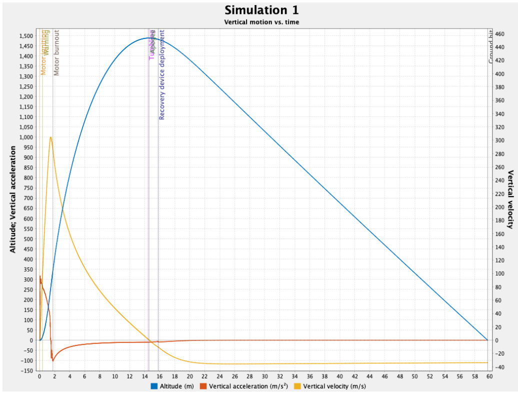

Figure 7: Flight profile: altitude, velocity, and acceleration vs time.

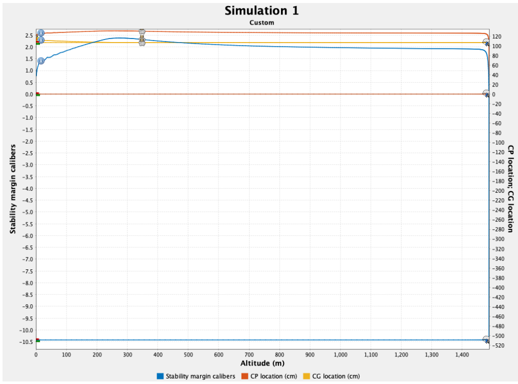

Figure 8: Stability margin vs altitude.

References

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[3] A. Pektas, Ü. Haciabdullahoğlu, N. Ejder, Z. Demircan, and C. Tola, ”Effects of different fin shapes on apogee and stability of model rockets,” *Proceedings of the 9th International Conference on Recent Advances in Space Technologies (RAST)*, 2019, pp. 193–199. Available: https://www.researchgate.net/publication/334631989_Effects_of_Different_Fin_Shapes_on_Apogee_and_Stability_of_Model_Rockets.

[4] MIT Rocket Team, ”MIT Rocket Team Home,” *MIT Wiki Service*, 2025. Available: https://wikis.mit.edu/confluence/display/RocketTeam/MIT+Rocket+Team+Home. Accessed: Aug. 23, 2025.

[5] Apogee Components, ”Standard Rail Button (fits 1 Rail - 1010),” *Apogee Rockets*, 2025. Available: https://www.apogeerockets.com/Building_Supplies/Rail_Buttons/1in_1010_Rail_Button_Standard. Accessed: Aug. 23, 2025.

[6] DigiKey Electronics, ”PCB Trace Width Conversion Calculator,” *DigiKey*, 2025. Available: https://www.digikey.com.au/en/resources/conversion-calculators/conversion-calculator-pcb-trace-width. Accessed: Aug. 23, 2025.