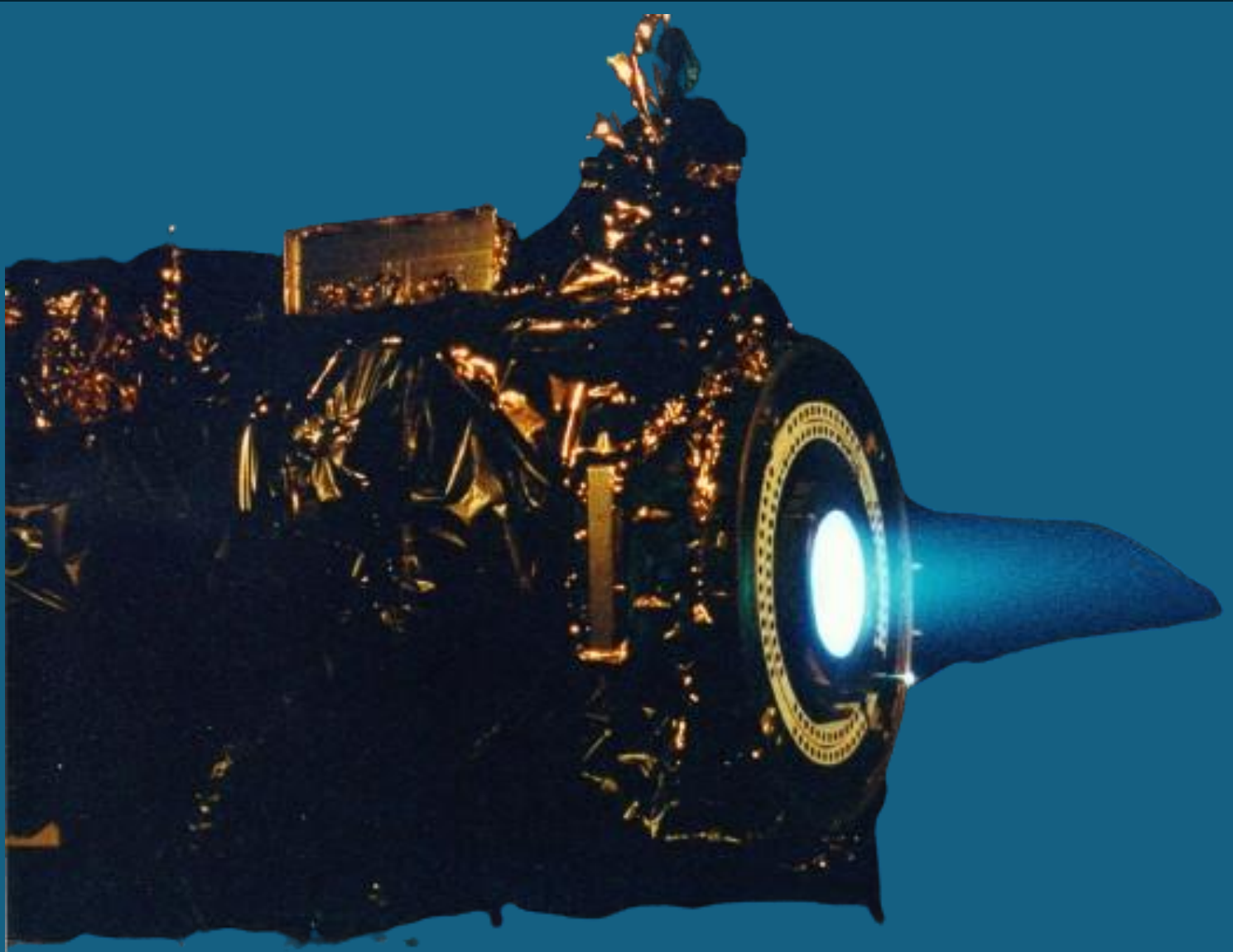




Power-to-Thrust Analysis

Investigating feasibility of Ionic Thruster

Performance for Space Launch

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Introduction

The discussion of space exploration methods in aeronautical engineering has been driven by the need for efficient and reliable propulsion systems.

Liquid rockets are observed to have high thrust but low propulsion efficiency (specific impulse of around 300s) (NASA, 2024).

The need for a more efficient propulsion system arises. Ionic propulsion, that

- *ionizes neutral atoms of propellant*
- *then accelerates the ions out of the thruster as an ion beam*

- *by an electric field created by the collector electrode,*

- *which all finally produces thrust,*

is a considerable and investigate-worthy alternative due to achieving high velocities and much higher specific impulse (ranging between 1500-10000 seconds) compared to the traditional methods (Patterson, 2015) (Wikipedia, 2025).

Research Objectives

“How does the power-to-thrust ratio of an ionic thruster scale, and what are the feasibility limits of its application for space launch propulsion?”

It is aimed to understand the potential and constraints of ionic thrusters in achieving necessary thrust for space launches by investigating the correlation between the power input and thrust output.

It is aimed to contribute to the broader understanding of propulsion technologies and their potential applications in space exploration, particularly in space-launch, and further point out the gaps in the research of efficient thrust.

Their potential application to space-launch missions would be beneficial in many ways, such as *increased payload capacity, increased efficiency, lowered fuel and launch cost, more precise and controlled thrust, and longer operational lifespan.*

Materials

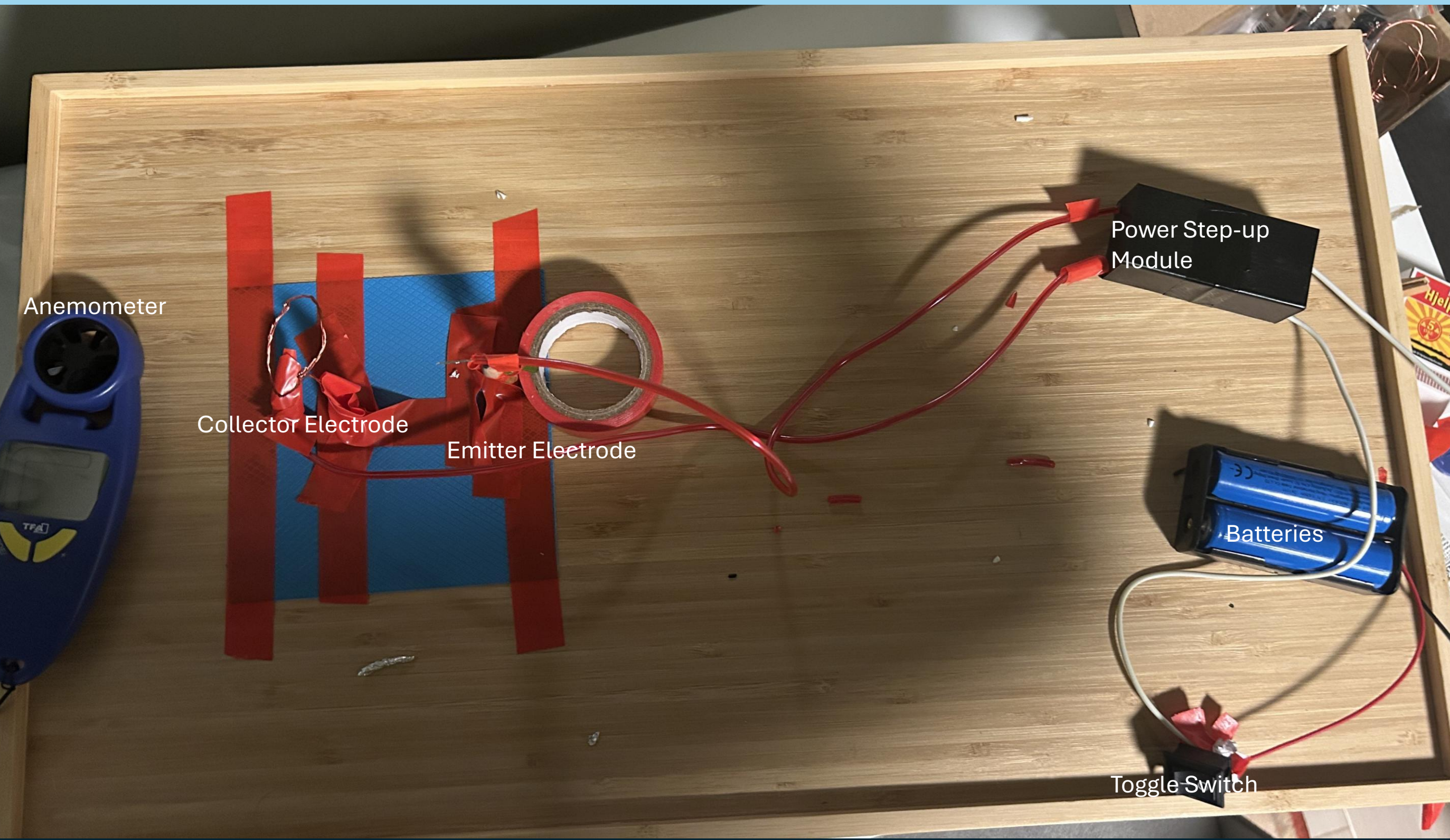
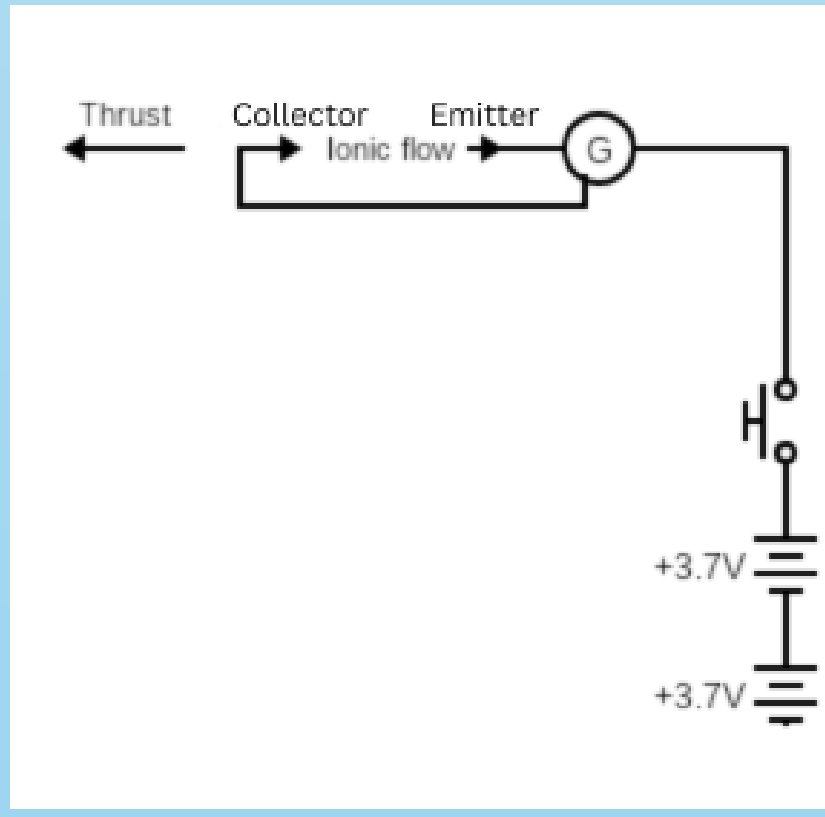
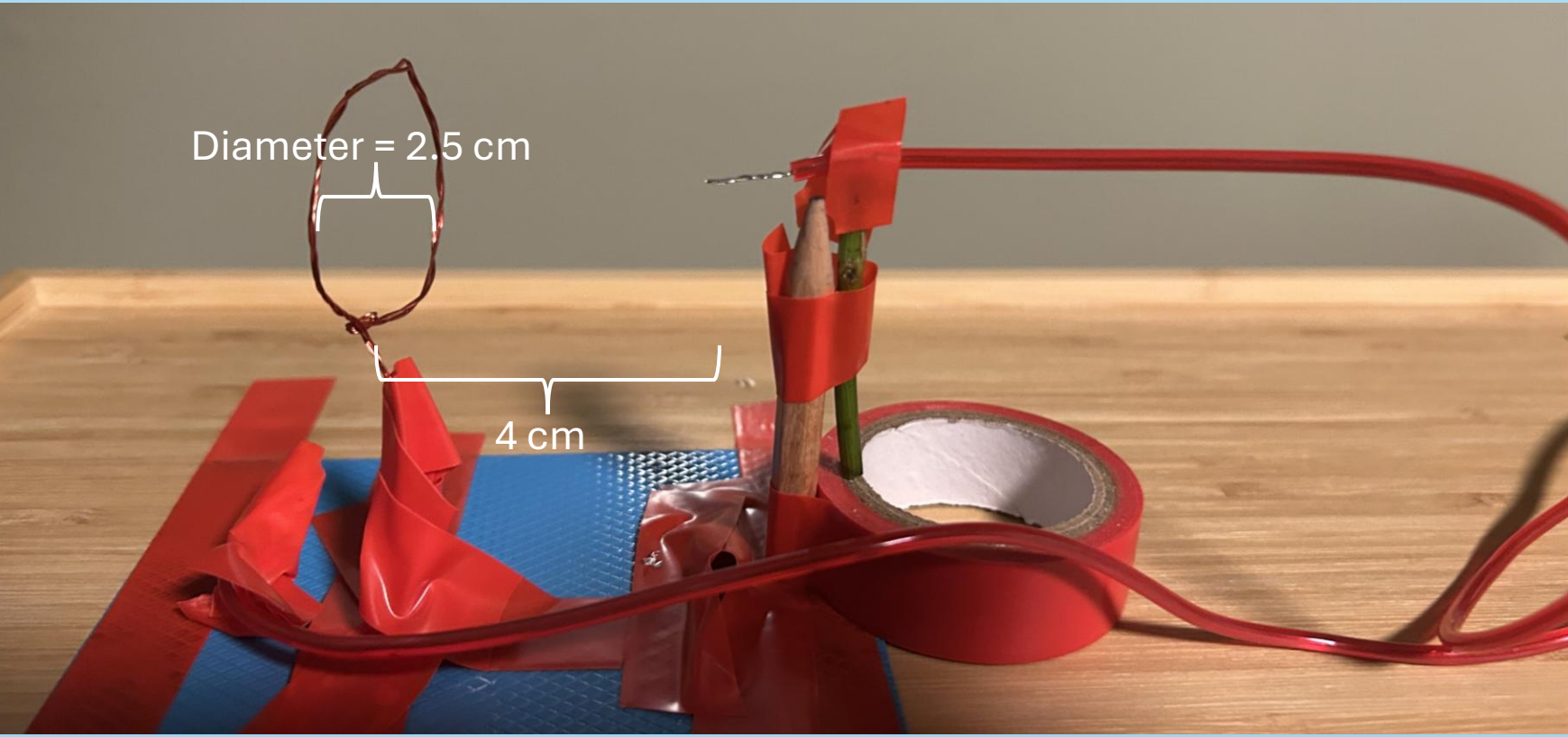
- One 800kv power step up module (a high voltage generator)
- Two batteries with 3.7 V and 2.6 amperes each
- One toggle switch
- The wire of the power module as an emitter electrode
- One ring formed copper wire (0.31 mm diameter) as a collector electrode.

Methodology

The voltage between the emitter and collector electrodes ionizes the air and accelerates the ions through the circularly sat copper collector electrode (single/quadruple strand varied).

Exhaust velocity measured by anemometer

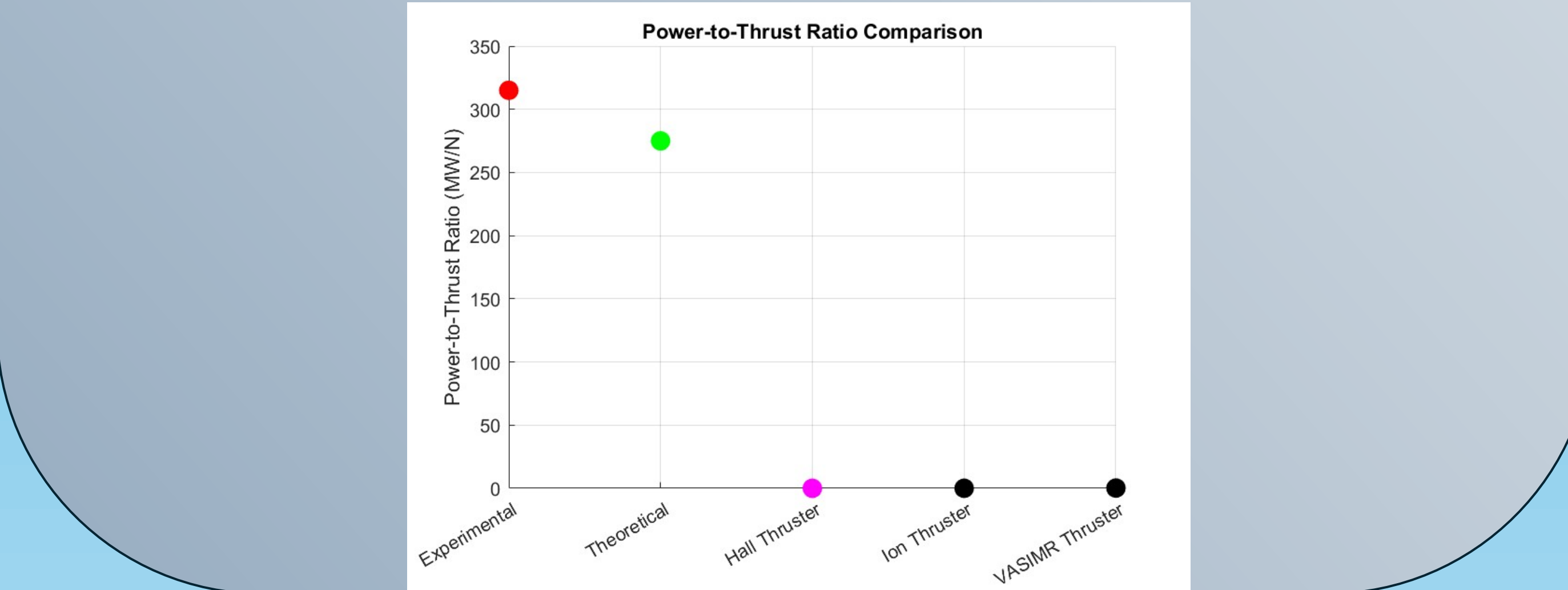
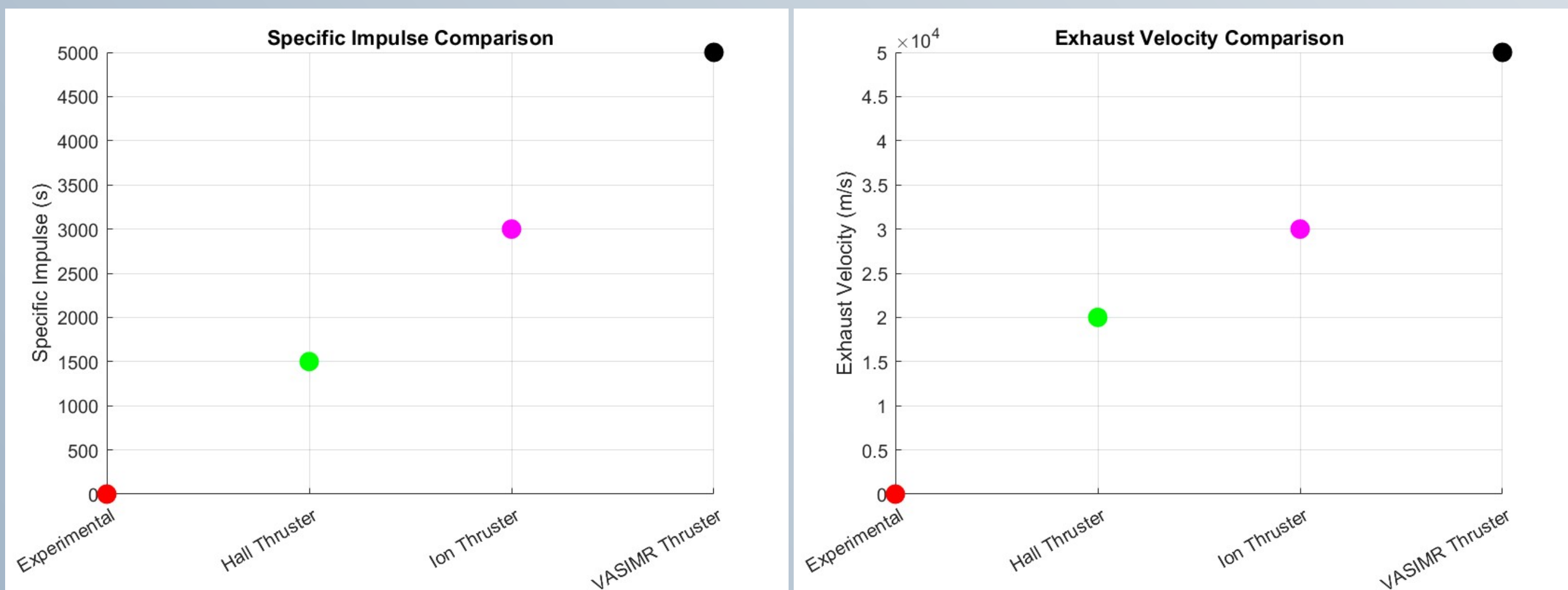
- $v_{ex} = \sqrt{\frac{2eV}{m}}$, hypothetical exhaust velocity with elementary charge ($e=1.602 \cdot 10^{-19}$ C), voltage (V) and mass of the air ions ($m=4.81 \cdot 10^{-26}$ kg)
- $\dot{m} = \rho \times A \times v_{ex}$, mass-flow rate derived from the cross-sectional area (A), air density ($\rho=1.293$ kg m⁻³ (NASA)) and exhaust velocity
- $F = \dot{m}v_{ex}$, Thrust from mass flow rate and exhaust velocity
- $P = V \cdot I$, Power from voltage and current (I)
- $\frac{P}{T} = \frac{V \cdot I}{\dot{m} \cdot v_{ex}}$, power-to-thrust ratio derived from everything above
- $I_{sp} = \frac{v_{ex}}{g_0}$, specific impulse is exhaust velocity over gravity (g)



Results

Wire type	Trial 1 (±0.05 km/h)	Trial 2 (±0.05 km/h)	Trial 3 (±0.05 km/h)	Average (±0.05 km/h)
Single-stranded	0.7	0.6	0.8	0.7
Quadruple-stranded	1.7	1.8	1.8	1.76±1.8

- $v_{ex} = 0.5$ m/s $\vee$ hypothetical $v_{ex} = 2.31 \cdot 10^6$ ms⁻¹
- $\frac{P}{T} = 315$ MW/N $\vee$ hypothetical $\frac{P}{T} = 275$ MW/N
- $I_{sp} = 0.051$ s



Data Analysis

The experiment demonstrated the feasibility of ionization to generate thrust. The collected data shows that an applied voltage of 800kV and a current of 0.5A could generate a record exhaust velocity of 1.8km/h, which is 0.5m/s, under atmospherically limited conditions. The anemometer introduced air resistance, underestimating actual exhaust velocity, which was very insignificant to begin with, which likely distorted the results on a bigger scale. Ion recombination, air drag, and electrical losses reduced the effective transfer of energy into thrust.

Discussion & Conclusion

The reached values of the home-made ionic thruster are significantly below the traditional ionic thrusters. This is both owing to simplicity of the circuit and some uncertainties about the actual measures (it wouldn't be wrong to suspect that the voltage and current values were lower inside the circuit). An ideal ionization efficiency was calculated, and through that, we've scaled our data to the theoretical exhaust velocity data, and seen both the limitations, but also the big potential to be further investigated. A more professionally designed model with well-insulated wires and known measures would be a better representation of potential of EPs.

Future Work

Ionization Efficiency: There is a lack of efficiency when ionizing air and accelerating ions, decreasing thrust. Energy losses can occur during ionization, and to-heat-conversion is present.

Thruster Design: The efficiency of the thruster design itself may be a limiting factor. The design of the electrodes and the wires do lack insulation and efficiency.

Unprecise equipment: These results arise a considerable uncertainty about the actual voltage and current in the system, a voltmeter and ammeter would be beneficial to determine arcing and leakages. However, ionic thrust particularly remain as a viable promise for space-launch propulsion. By efficiency, it seems promising, while it needs significant material improvement.

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