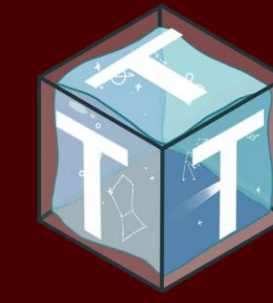




# Icarus I: Triboelectric Lunar Drone

## Team Daedalus

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### Background

This project addresses the need for technologies to maintain lunar infrastructure for long duration missions, as identified in the NASA Civil Space Shortfalls list. Future missions will rely on structures up to 15 meters tall, where inspection and repair pose safety risks and demand significant astronaut labor. While drones are effective for structure maintenance on Earth, they cannot operate on the Moon due to the lack of an atmosphere for aerodynamic lift. There is currently no technology that provides controlled aerial mobility on the moon. Developing this technology would also expand capabilities for resource collection, transport, and surface surveying.

### Objective

The long-term objective of this project is to create a feasible, fully functional lunar drone capable of controlled vertical and lateral movement on the lunar surface. The drone must be capable of reaching structures up to 15 meters tall and should use a propellant source locally available on the moon. This semester, the objective was to quantify the feasibility of a novel type of propulsion that uses triboelectric charging to accelerate lunar regolith. The goal was to design the electrical, propulsion, and chassis systems of the drone, and build a prototype of the propulsion system for testing and validation.

### Design Decisions

Design requirements for the drone included:

- Reach at least 15 meters
- Lateral control in all four planar directions
- Weigh less than 10 kilograms
- Use a locally available propellant source
- Consume less than 200 W energy
- Be independent of astronaut involvement

Propulsion System Decision Matrix

Criteria	Weight	Cold Gas	Triboelectric	Hydrogen Peroxide
Weight	40%	3	5	5
Control	20%	4	5	5
Simplicity	10%	4	5	4
Renewability	15%	6	9	3
Efficiency	15%	4	8	8
<b>Totals</b>	<b>100%</b>	<b>3.90</b>	<b>6.05</b>	<b>5.05</b>

The above trade study was conducted to select between types of propulsion derived from different lunar resources. Triboelectric propulsion is a novel method that the team designed where lunar regolith is charged and accelerated through an electrode system to produce thrust. The regolith is charged via the triboelectric effect, a material contact charging method that doesn't require a power supply.

### Prototype and Analysis



Figure 1: Side View of Surveying Drone Design

- Drone Specifications:
- 6061-T6 Aluminum Outer Body
  - Cr3C2-NiCr Coatings for Abrasion Resistance
  - Steel "shoes" at Landing Points
  - Carbon-Fiber Reinforced Polymer Boom Frame
  - Gimbal Thrusters
  - Cameras for Visual Data Collection
  - Robotic Arm for Sample Collection

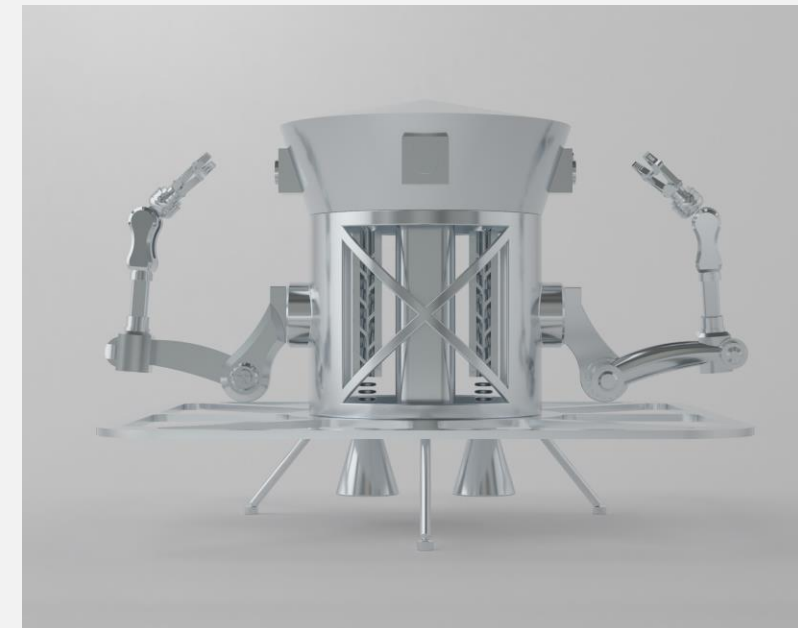


Figure 2: Side View of Collection Drone Design

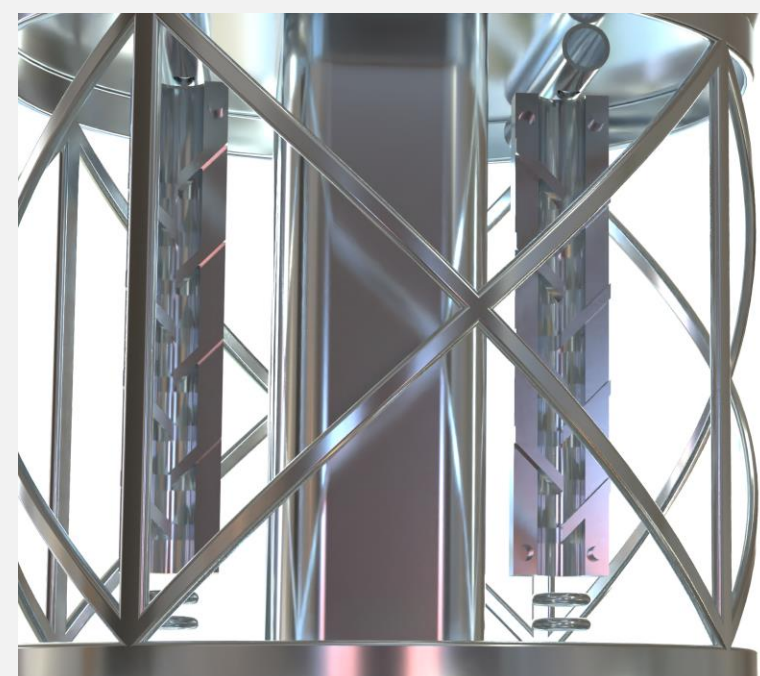


Figure 3: Hopper to Triboelectric Tube to Electrode Transition



Figure 4: Triboelectric Tube Prototype

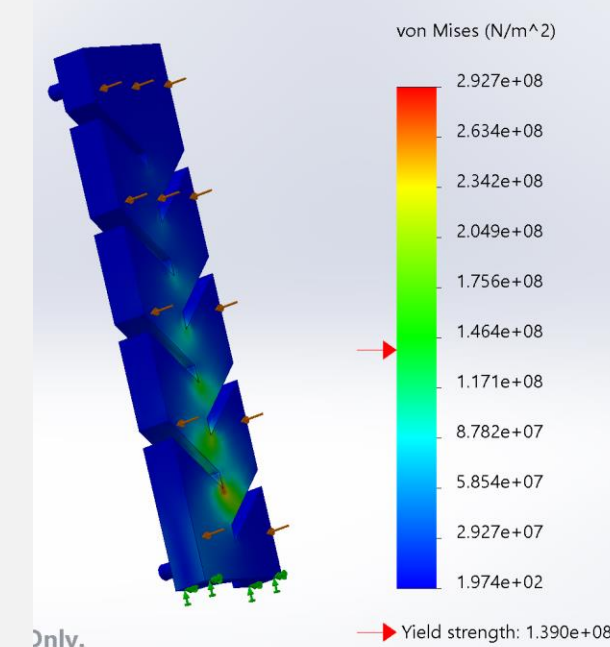


Figure 5: FEA Analysis of Triboelectric Tube

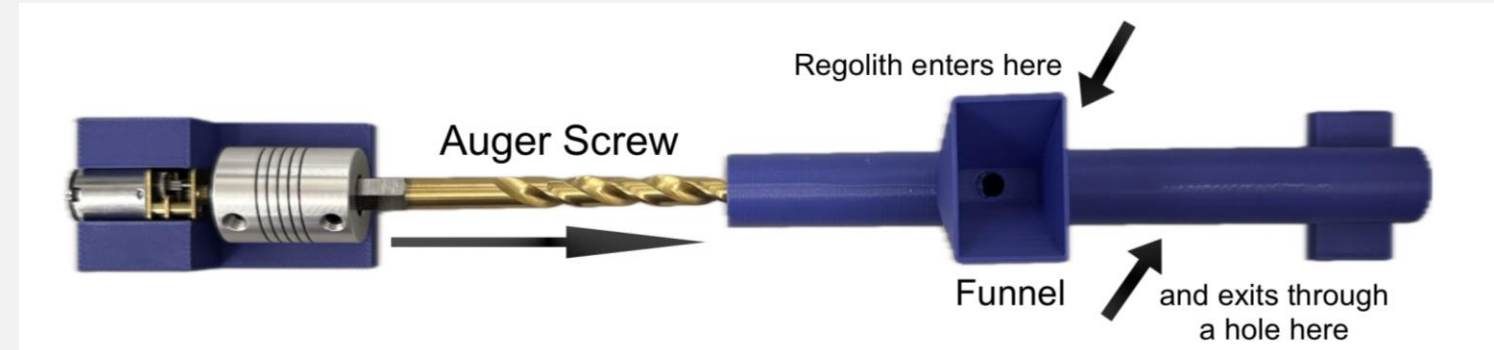


Figure 6: Auger Screw Feeder Prototype



Figure 7: South Pole Lunar Regolith Simulant Size Groups

Testing was done using commercial lunar regolith simulant to determine the charge imparted on different sizes of regolith particles by the triboelectric tube. A multimeter was connected to the first aluminum step and used to measure the voltage difference after one gram of regolith moved through the system. The calculated capacitance of the aluminum step was used to determine the amount of charge imparted onto the regolith by the triboelectric effect.



Figure 8: Regolith Accelerator Prototype

### Results

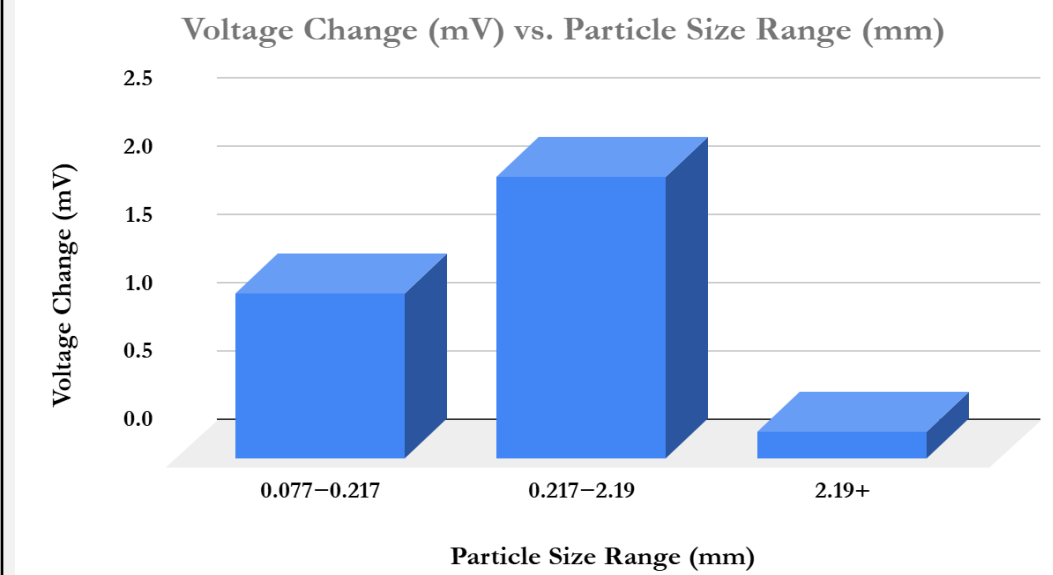


Figure 9: Voltage Change Per Gram of Regolith

Empirical data identifies the 0.217mm - 2.19mm size fraction as the optimal propellant regime, yielding a peak potential shift of ~2 mV. This range provides the most effective electrostatic coupling, ensuring maximum kinetic energy and exit velocity during the acceleration phase, as higher charged regolith accelerates quicker through the electric field created by the electrodes.

### Conclusion

The measured charge that each aluminum step induces on the regolith matches the expected charge necessary for thrust of a 10 kilogram load up to 15 meters. Further validation testing is necessary to confirm these results on a larger scale. This design greatly expands lunar mission capabilities by providing a form of aerial mobility that parallels terrestrial drones. The use of triboelectric charging for propulsion is a novel concept that allows for the use of lunar regolith as propellant, maximizing in-situ resource utilization and minimizing the need for complex resource collection and processing on the moon.

### Future Work

Future testing of the regolith charging design should be conducted using a Faraday Cup, which is capable of directly measuring charge for a greater mass of regolith. Further development of the drone would include development of thermal and thruster systems and a full prototype.

### Acknowledgements

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References:

