CRIMSON: Dust Mitigation in Lunar Habitats

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WERC 35th Environmental Contest

NM STATE — BE BOLD. Shape the Future. College of Engineering

35th WERC ENVIRONMENTAL DESIGN CONTEST

Design Challenge Mission

- Let's keep our astronauts and their mission's dust free and ready for the future.
- Removal of Lunar Dust from cargo and airlock.
- Keep our astronauts safe.
- Save millions of dollars in equipment.

Research

Lunar exploration presents numerous technical challenges, of the most significant, the pervasive presence of lunar dust, otherwise known as regolith, serves as an example of the harsh environment's humans may contend with in the future of space exploration. Unlike terrestrial dust, regolith is highly abrasive in conjunction with its toxicity and electrostatic properties, pose a significant threat to the functionality of habitats, equipment, and more than anything else, human health.

Past solutions included mechanical brushing and vacuuming, but these were ineffective for finer dust. More advanced methods, like electrodynamic dust shields (TRL 8), electrostatic collectors (TRL 4), electron guns (TRL 4), and protective coatings, have shown promise but require further optimization. Passive methods, such as surface coatings and texture modifications, offer energy-efficient alternatives but may degrade over time. A mitigation strategy integrating multiple approaches is necessary for long-term lunar exploration.

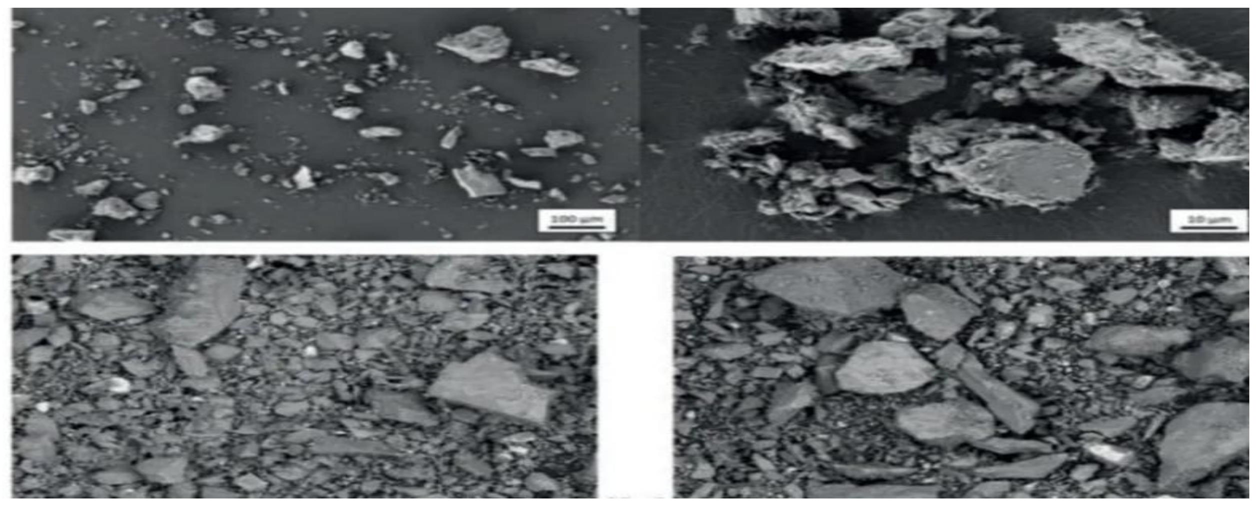

Figure 1. Abrasive Lunar Dust

Figure 2. Spacesuit contaminated by Lunar Dust during Apollo Missions

Final Design

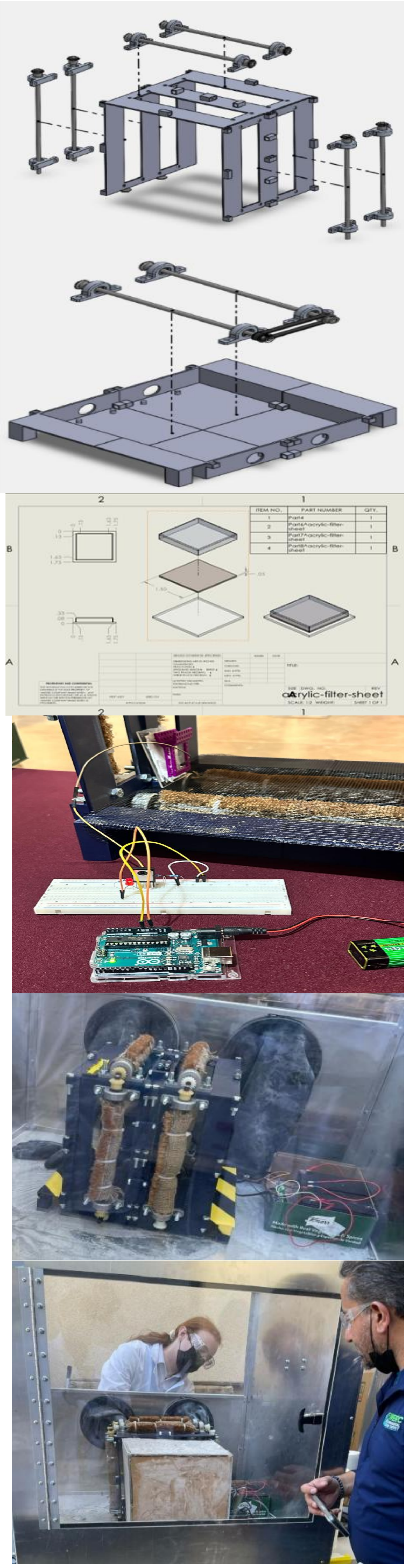

Figure 5. Final Design Components.

THUNDER revolves around combating the abrasive and electrostatically charged lunar regolith using a mix of mechanical (rotatory brushes), electrostatic (magnetic filter), and filtration (dust collector).

- ***Mechanical:*** Inspired by shiners car wash systems, Thunderstruck mechanical system consists of a rotative design that uses a DC brushless motor, shafts, gears, and bearings to clean the large size particles of dust simulant from the cargo container.
- ***Electrical:*** Originally it was thought to be a system with electrostatic plates, however this was discarded as she showed the potential risk of discharge and the weight of the plates. Instead, electrostatic system with a filter was proposed, the concept includes creating an electrostatic field that would be used to attract and collect the negatively charged particles.
- ***Enclosure:*** It was printed in Bambu Lab X1C using 1.1 kg of Dark Blue ABS filament. The reason for using this material was the good thermal and mechanical properties it has against PLA and PLA+, which are the most common filaments for 3D printing. The entire enclosure was divided into 16 sections: 4 in the lower chassis, 4 on the left side, 4 on the right side, and 4 in the top side. It was designed incorporating bolt holes to join the parts.

Results

Validation tests confirmed that the THUNDER can effectively mitigate fine particulate and filtrate it for safe and later disposal. The motor's speed can go up to 3000 rpm, but operational considerations keep it approximately at 200 rpm. Weighting 13.58 kg.

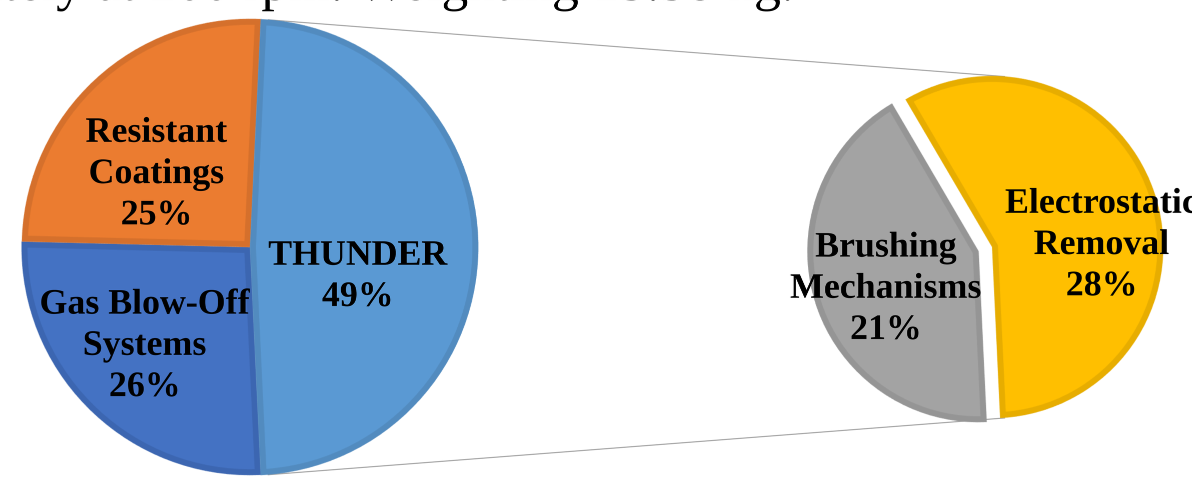

Figure 6. THUNDER vs Market Alternatives Effectiveness

THUNDER demonstrated durability, ease of operation, and compatibility with existing habitat interfaces, making it viable and usable both on Earth and the Moon. Using the top side of the mechanical system we test the efficiency of the brushes in one acrylic sheet. The results are shown below.

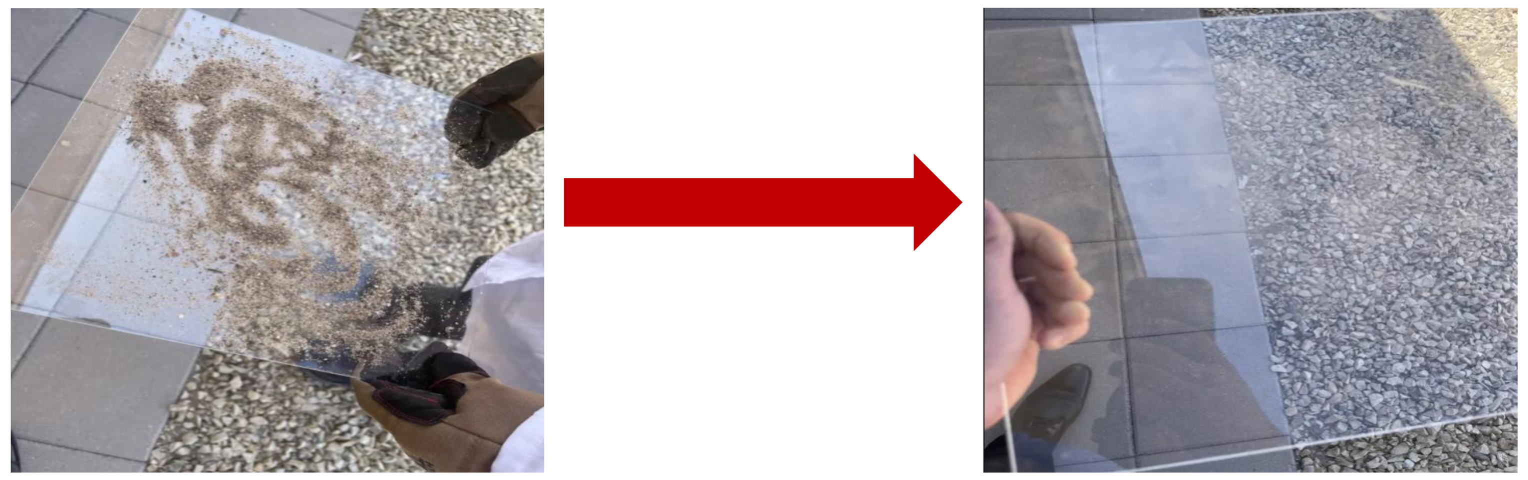

Figure 7. Before and After Testing

Concept Development

We were tasked to design a mechanism that could either clean an astronaut's suit or cargo transfer bag (CTB) used in Lunar Missions. Team Thunderstruck opted for the second proposal. Before coming up for this idea, several concepts were considered, among these we can find: Rotary Airlock and with a Dust Removal System. Carwash Concept and Blower/Vacuum, Electrodynamic Dust Shield integrated into Surface of CTB, Surface, Shape of CTB and Adhesive Roller for Collecting Dust, and Cyclone Dust Collectors.

After testing several combinations for better performance, we decided on THUNDER, Technology for Hazardous Ultrafine Nanoparticle Dust Elimination and Retention, which was later modified for the final prototype.

Needs (Higher better)	Rotating Airlock+ EDS + Vaccum	Electrostatic Plates + Brushes	Rotating Airlock+ Electrostatic Plates + Brushes	Centrifugal + Electrostatic Plates + Vacuum + Brushes	Electrostatic plates + Roller + Brushes
Efficiency	4	3	4	5	3
Durability	2	3	3	1	3
TOTAL	6	6	7	6	6

Table 1. Unweighted combinations for Efficiency (50%) and Durability (50%).

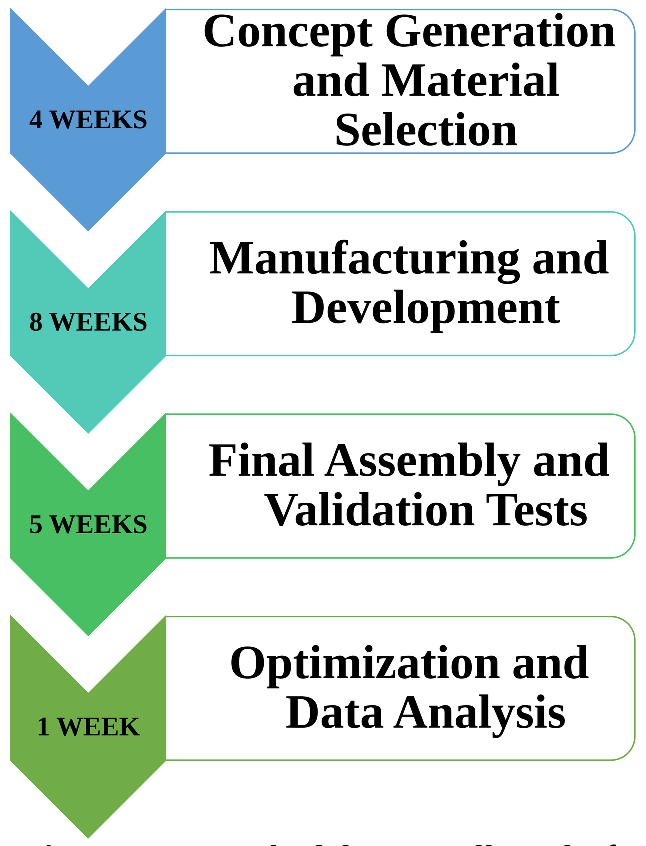

Figure 3. Methodology Followed for THUNDER.

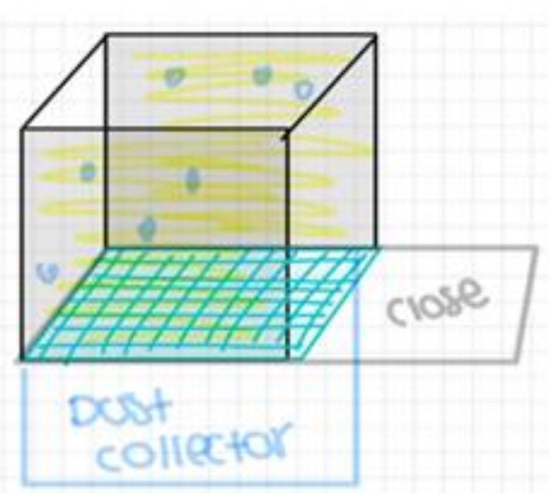

Figure 4. First Concept Prototype.

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