TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

TOPIC # - TDC - 112

Lunar Dust (Regolith) Mitigation for Habitat Entry Systems

BACKGROUND

Develop an innovative and manufacturable lunar dust (regolith) mitigation system specifically for astronaut entry into lunar habitats. The system shall minimize lunar dust intrusion into pressurized habitat environments to protect crew health, preserve life support and mechanical systems, reduce contamination, and extend habitat operational life. Solutions must be manufacturable and qualification-tested on Earth prior to lunar deployment.

The design challenge may include habitat airlocks, suitports, vestibules, electrostatic dust removal systems, brushes, vacuum systems, adhesive surfaces, dust-tolerant flooring, cleaning chambers, robotic systems, or integrated habitat entry systems. Designs should focus on preventing lunar regolith from entering the habitat interior while maintaining efficient crew operations and safety.

PROBLEM/DESCRIPTION

Lunar Habitat Dust Mitigation Design: Develop a robust dust mitigation architecture specifically for lunar habitats. Systems may include suitports, segmented airlocks, decontamination chambers, electrostatic or magnetic cleaning systems, brushes, blow-off systems, adhesive mats, or robotic dust removal tools integrated directly into the habitat entry sequence.

Crew Safety & Health Protection: Reduce astronaut exposure to abrasive lunar dust that can affect lungs, eyes, skin, and overall crew health. Minimize dust transfer into crew quarters, life support systems, avionics, sleeping areas, food preparation zones, and scientific equipment inside the habitat.

Manufacturability & Qualification: Design with manufacturability in mind, emphasizing full Earth-based fabrication, integration, and qualification testing prior to launch. Participants shall demonstrate how their system can be produced using terrestrial manufacturing methods and verified through dust chamber testing, vacuum testing, thermal cycling, abrasion testing, and habitat operations simulations.

Reliability & Durability: Lunar dust is highly abrasive, electrostatically adhesive, and difficult to remove. Designs must demonstrate long-term survivability against repeated habitat ingress/egress cycles and remain functional after thousands of crew operations.

Mass & Packaging Efficiency: Optimize system mass, volume, and power requirements to remain compatible with lunar habitat launch and deployment constraints. Systems should be compact, modular, and scalable for different habitat sizes.

Habitat Integration: Enable integration with lunar habitat structures, suitports, airlocks, life support systems, habitat power systems, crew workflows, and EVA operations. Designs should allow standard interfaces with habitat power, controls, and pressurized systems.

Automation & Robotics (Optional): Incorporate robotics, automated cleaning cycles, smart sensors, or AI-based monitoring to reduce crew workload and improve contamination control during habitat entry.

DELIVERABLES

Phase 1: Concept Design
Define the dust mitigation system purpose, operational flow, and lunar habitat integration approach. Submit schematics, system architecture, and design philosophy.

Phase 2: Engineering Analysis & Validation
Conduct analyses for dust removal efficiency, abrasion resistance, thermal survivability, structural integrity, power consumption, and operational reliability. Include Earth-based test plans such as vacuum chamber testing, simulated lunar dust exposure, thermal cycling, and crew operations testing.

Phase 3: Habitat Operations Plan
Define how the system will be deployed, maintained, and used during lunar habitat operations. Include EVA timelines, cleaning procedures, astronaut workflow, and maintenance requirements.

Phase 4: Prototype & Qualification Testing (Required for Advanced Track)
Develop prototype hardware and conduct qualification-level testing under simulated lunar conditions. Testing should include dust intrusion measurements, repeated ingress/egress cycles, vacuum operation, abrasion resistance, thermal performance, and long-term reliability.

Key Constraints & Considerations:

- Mass Limit: ≤ 2 metric tons for the complete habitat dust mitigation system
- Volume Limit: Compatible with lunar habitat airlock or vestibule dimensions
- Lunar Environment: Must operate in vacuum, reduced gravity, extreme temperatures, and abrasive dust conditions
- Thermal Range: Survive -130°C to +120°C lunar conditions
- Dust Removal Efficiency: Demonstrate at least 90% reduction in regolith transfer into the habitat

- Crew Throughput: Support rapid ingress/egress of at least 4 astronauts within 30 minutes
- Power Usage: Minimize power consumption and enable compatibility with habitat power systems
- Reliability: Demonstrate capability for at least 1,000 operational cycles without major maintenance
- Safety: Prevent crew injury, suit damage, contamination of life support systems, and accidental depressurization

Evaluation Criteria

Category	Criteria
Innovation & Technical Merit	Novelty, creativity, and effectiveness of the dust mitigation concept
Dust Removal Performance	Ability to reduce regolith contamination entering the habitat
Crew Safety & Health	Reduction of crew exposure to hazardous lunar dust
Manufacturability	Compatibility with current or near-future manufacturing techniques
Structural & Environmental Performance	Ability to survive lunar temperature extremes, vacuum, and repeated operations
Mass & Power Efficiency	Optimization of system size, weight, and power usage
Reliability & Maintainability	Durability, maintenance simplicity, and operational lifetime
Habitat Integration	Compatibility with lunar habitat structures, airlocks, suitports, and EVA operations
Automation Potential	Use of robotics, sensors, or autonomous cleaning functions
Scalability	Ease of adapting the system for different lunar habitat sizes and crew numbers

DESIGN TEAM PROFILE

NASA MENTOR:	Robert Nuckols (robert.s.nuckols@nasa.gov)
LEVEL:	Undergraduate students of any level
MAJOR/DISCIPLINE:	Open to all majors
TEAMS:	All teams eligible
DURATION:	One Semester (Second semester optional)