NASA's Integrated Dust Strategy

Adhesion Society
Keynote Address

February 24, 2021

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Technical Integration Manager

Gene Cernan, Apollo 17 Commander

Probably the most difficult job of all the closeouts was trying to dust the suits…..The real-time transcripts will show just how much time and effort was spent in dusting." – Gene Cernan, Apollo 17 Commander

EVA 3 Closeout Audio Transcript

Cernan: "…Boy, I tell you, I ain't going to do much more dusting after I leave here. Ever."

........3 minutes later………

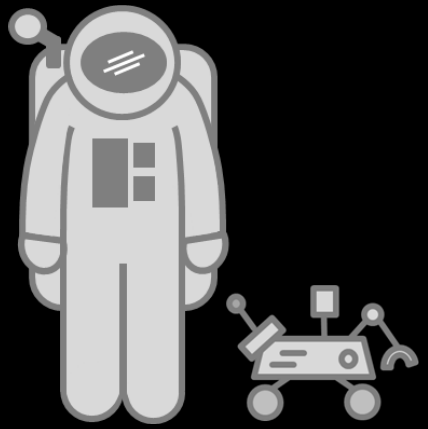
"Boy, you got dirty today. I think we're just going to have to live with it."

Capability Needs

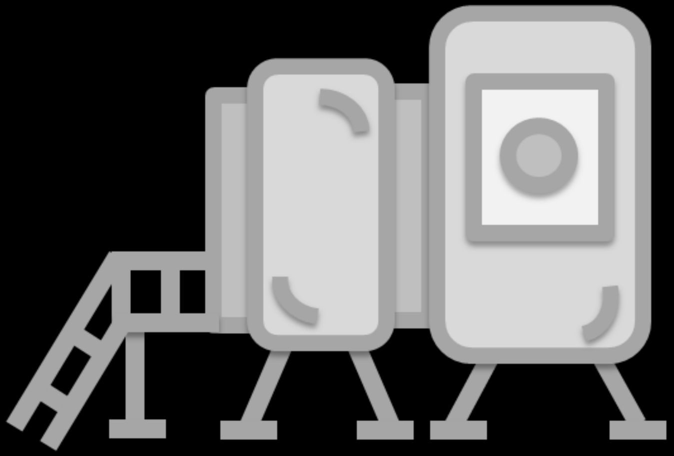
- *Optical Systems* – Viewports, camera lenses, solar panels, space suit visors, mass spectrometers, other sensitive optical instruments
- *Thermal Surfaces* – Thermal radiators, thermal painted surfaces, thermal connections
- *Fabrics* – Space suit fabrics, soft wall habitats, mechanism covers
- *Mechanisms* – Linear actuators, bearings, rotary joints, hinges, quick disconnects, valves, linkages
- *Seals and Soft Goods* – Space suit interfaces, hatches, connectors, hoses
- *Gaseous Filtration* – Atmosphere revitalization, ISRU processes
- *Lunar Surface Modification* – Lunar landing pads, dust free zones and workspaces

Integrated Dust Mitigation Strategy

SURFACE OPERATIONS

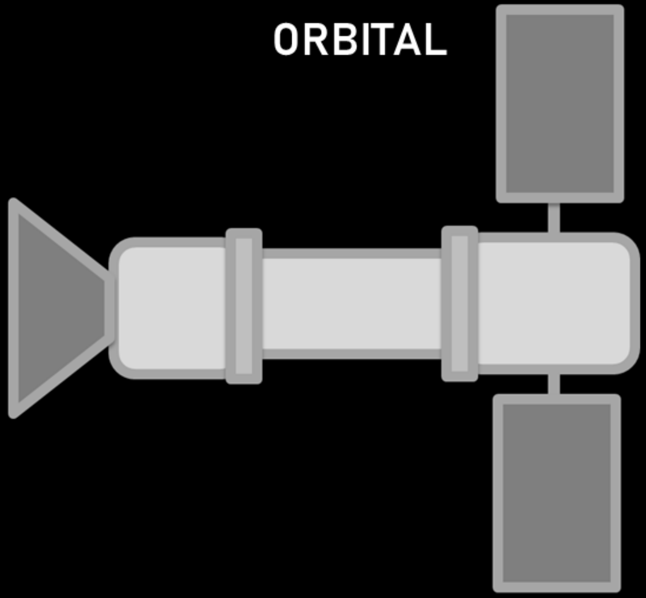


HABITATS



DESCENT/ASCENT

ORBITAL



Lunar Surface Innovation Initiative (LSII)

STMD develops and performs demonstrations that allow the primary technology hurdles to be retired for a given capability at a relevant scale. While there may be additional engineering development required for scale-up, there should be none required for the foundational technologies.

In Situ Resource Utilization

Collection, processing, storing and use of material found or manufactured on other astronomical objects

Surface Power

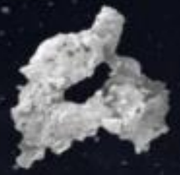
Enable continuous power throughout lunar day and night

Extreme Access

Access, navigate, and explore surface/subsurface areas

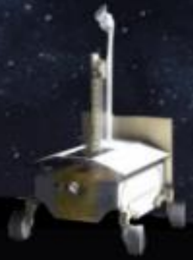
Surface Excavation & Construction

Enable affordable, autonomous manufacturing or construction



Lunar Dust Mitigation

Mitigate lunar dust hazards



Extreme Environments

Enable systems to operate through out the full range of lunar surface conditions

- **Accelerate technology readiness for key lunar infrastructure capabilities enabling technology demonstrations for early un-crewed commercial missions, as well as informing development of crewed flight systems.**
- **Implement through a combination of in-house activities, competitive programs, and public-private partnerships.**
- **Coordinate with NASA's Science Mission Directorate and Human Exploration and Operations Mission Directorate to identify priorities.**

LSII System Integrator - APL

A key tenet of LSII is to implement a multitude of novel collaborations across industry, academia, and government in order to successfully develop the transformative capabilities for lunar surface exploration.

Origin of the APL Task

- NASA was investigating using a University Affiliated Research Center (UARC) to bring efficiencies to development
- LSII initiated a tasked APL, to assess system integration role for the Lunar Surface Innovation Initiative
- APL established a Lunar Surface Consortium with academia and industry representatives, as well as NASA experts, that span a broad range of capabilities to execute timely studies, tasks, and/or acquisitions

The Consortium will assist NASA in

- Identifying lunar surface technology needs and assessing the readiness of relative systems and components
- Making recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration
- Providing a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results

LSIC Dust Mitigation Workshop

Dust Mitigation Workshop

Thursday, February 4, 2021

Venue: *Virtual*

EVENT DETAILS

Date: Thursday, February 4, 2021
Time: 11:00AM - 5:00PM EDT
Location: Virtual

Registration is closed.

Abstracts are not being accepted at this time.

Meeting Link

Click here to join the webinar.

Links for the afternoon breakout sessions were emailed to registered attendees.

If at any point during the event you need assistance, please click here to visit our **HelpDesk**.

You can also contact Andrea Harman for support at ams573@alumni.psu.edu.

Sign up for the LSIC

Dust Mitigation Investments

STMD Game Changing Development Program Investments

- **Dust Mitigation Development**
  - Dust Tolerant Mechanisms
    - Elevate TRL for dust tolerant mechanisms and joints, using existing high TRL mechanisms
  - Lo-DuSST
    - Materials and Active mitigation investigations
- **Dust Mitigation Demonstration**
  - Electrodynamic Dust Shield for CLPS
    - Active dust mitigation technology demonstration on CLPS payload
  - CLPS Payload for Plume Surface Interactions Measurements
    - Trade study on PSI measurement tools
  - Patch Plate Materials Compatibility Assessment
    - Dust adherence on notional materials and passive technologies and dust imaging and characterizing capabilities
- **Dust Mitigation Standards**
  - Dusty Environments Classifications
    - Addresses requirements, integration, architecture, and technology developer needs.
  - Dust Mitigation Best Practices Guide
    - A “How To” Guide for dust mitigation to be used by stakeholders

SBIR Dust Mitigation Investments

- Active and Passive Surfaces (Z13.01)
  - Hedgefog Research, Inc. – Bendable Electrodynamic dust Shields
  - PolyK Technologies, Inc. – Integrated Approach for Space Active and Passive Dust Mitigation Enabled by Electroactive Polymer Technology
  - WattGlass – Solar Array Coatings for Mitigating Lunar and Martian Dust
- Dust Tolerant Mechanisms (Z13.02)
  - Triton Systems, Inc. – Dust Tolerant Joints
  - Off Planet Research, LLC – Self Cleaning Dust Proof Fluid and Gas Connector
  - Astrobotic Technology, Inc. – High Power Near-Field Wireless Transfer for Dust Intensive Applications
- Lunar Dust Management Technology for Spacecraft Atmospheres and Spacesuits (H3.03)
  - BlazeTech Corporation - Lunar Dust Filter for Spacecraft Atmospheres
  - Applied Particle Technology, Inc. - In-situ optical speciation and size distribution monitoring instrument for lunar dust management
  - Mainstream Engineering Corporation - Cyclone Precipitator Sub-Micron Particulate Separator

SBIR FY21 Dust Mitigation Solicitation

- Z13.01 - Active and Passive Dust Mitigation Surfaces
  - Active Surfaces
  - Materials
- Z13.02 – Dust Tolerant Mechanisms
  - Rotary joints (steering, suspension, hinges, bearings, etc.).
  - Linear joints (latches, shafts, restraint systems, landing gear, etc.).
  - Static joints (quick disconnects, covers, airlocks, sample tools, etc.)
- Z13.03 – Lunar Dust Mitigation Technology for Spacesuits
  - Garment Protection
  - Venting Portable Life Support System (PLSS) Covers
  - Non-venting Portable Life Support System (PLSS) Covers
- Key Dates
  - Proposals due January 8, 2021
  - Selections announced March 18, 2021

[FY21 SBIR Focus Areas]

NASA BIG Idea Challenge 2021

- **B**reakthrough, **I**nnovative, **G**ame-changing Idea Challenge
- Active and passive technologies in one or more of the following areas
  - Landing dust mitigation
  - Spacesuit dust tolerance
  - Exterior dust clean up
  - Cabin clean up
- Design, build, and test novel dust mitigation (or dust tolerant) technologies that could be used for lunar applications.

BIG IDEA CHALLENGE

National Aeronautics and Space Administration (NASA) and the National Institute of Aerospace (NIA)

The 2021 BIG Idea Challenge seeks novel and robust concepts for near-term dust mitigation solutions in the lunar South Pole.

2021

Theme Preview

Full competition details will be available on the BIG Idea Challenge website by August 3, 2020.

Some details may be subject to change.

Breakthrough, Innovative & Game-changing (BIG) Idea Challenge

The BIG Idea Challenge is a university-level design competition sponsored by NASA and managed by the NIA. To participate, **university teams of 5-25 students will submit proposals on concepts for a wide range of solutions for issues including reducing dust clouds upon landing, difficult dust removal from spacesuits and other surfaces, dust obstruction of optical systems, and in-cabin particulate levels, among others.** Selected teams will receive up to $180,000 to build and test their proposed dust mitigation solutions, then will present their test results to a panel of NASA and industry subject matter experts (SMEs) at the BIG Idea Forum in November 2021.

Background

Through the agency's Artemis lunar exploration program, NASA has its sights set on a place no humans have ever gone before: the lunar South Pole. The Moon's environment presents unique challenges, and lunar dust is one of the principal limiting factors in returning to the lunar surface for extended duration missions. Lunar dust is difficult to remove or mitigate as it is extremely abrasive, highly cohesive, electrically charged, and small in size.

For future lunar exploration missions, dust will inevitably be introduced into habitable spaces, where, under lunar gravity, fine lunar dust particles will be a health hazard to humans. In addition to threatening astronaut health, lunar dust issues have also resulted in incorrect instrument readings, vision/optical system obscuration, performance reduction, altered thermal properties, and equipment failure. High-velocity dust ejected by descent engine exhaust can cause damage to the lander, as well as nearby surface assets.

To enable sustainable human operation of the Moon in the coming decade, NASA is looking for near-term, innovative and viable solutions for dealing with the Moon's abrasive dust. Dust mitigation technologies can be categorized into active and passive technologies. Active technologies are those that are used to clean or protect a surface from dust deposition through external forces. Passive technologies do not require activation, such as chemically pretreated surfaces and dust tolerant coverings.

Basic Challenge

Develop active and passive dust mitigation (or dust tolerant) capabilities and technologies to be used in components of future lunar missions, in one or more of the following categories:

- Landing dust mitigation
- Spacesuit dust tolerance
- Exterior dust clean up
- Cabin clean up

Design Constraints

- Able to manage and mitigate abrasive dust
- Able to mitigate small particles (1-50 μm)
- Minimal barriers to NASA adoption (e.g. low mass, small size, low power, etc.)
- Cost-effective solution
- Non-flammable
- Able to work in harsh environments
- Tech should reach a minimum technology readiness level (TRL) of 4

http://bigidea.nianet.org

Important Dates

Notice of Intent Deadline – September 25, 2020
Proposal Deadline – December 13, 2020
Selection Notifications – January 29, 2021
Mid-Point Report Deadline – May 20, 2021
Technical Paper Deadline – October 27, 2021
2021 BIG Idea Forum – November 17–19, 2021

Eligibility

Participation is limited to teams of undergraduate and graduate students at accredited U.S.-based colleges and universities officially affiliated with their state's Space Grant Consortium. However, non-Space Grant affiliated colleges/universities may partner with a Space Grant-affiliated institution. (5-25 people/team)

Awards

A wide range of award sizes is expected (in the range of $50,000 - $180,000 per team). Proposers are encouraged to request what is actually needed to conduct the proposed work.

Dust Mitigation Technologies

Teams submit proposals for novel active and passive dust mitigation technologies that could be used for lunar applications, including but not limited to:

- Dust-free zones (i.e., landing pads, lunar surface modification, dust-free workspaces)
- Optical systems (i.e., viewports, camera lenses, solar panels, space suite visors, mass spectrometers, other sensitive optical instruments)
- Thermal systems (i.e., thermal radiators, painted surfaces, or connections)
- Dust-tolerant textiles and fabrics (i.e., space suit fabrics, soft wall habitats, mechanism covers)
- Dust-tolerant mechanisms (i.e., linear actuators, bearings, rotary joints, hinges, quick disconnects, valves, linkages)
- Seals and soft goods (i.e., space suit interfaces, hatches, connectors, hoses)
- Gaseous filtration (i.e., atmosphere revitalization, In-Space Resource Utilization [ISRU] processes)

NASA BIG Idea Challenge 2021 Finalists

Brown University with Rhode Island School of Design

"TEST-RAD: Tufted Electrostatic Solution To Regolith Adhesion Dilemma"

California Institute of Technology

"Habitat Orientable and Modular Electrodynamic Shield"

Colorado School of Mines with ICON, Masten Space Systems and Adherent Technologies Inc.

"Lunar In-Situ Landing/Launch Environment (LILL-E) Pad"

Georgia Institute of Technology

"Hybrid Dust Mitigation Brush Utilizing EDS and UV Technologies"

Missouri University of Science & Technology

"Contaminant Ultrasonic Removal via Vibration Ejection from Solar Cells"

University of Central Florida with Morphotonics

"LETO - Lunar Dust Mitigating Electrostatic micro-Textured Overlay"

Washington State University

"Leidenfrost Dusting as a Novel Tool for Lunar Dust Mitigation"

BIG Idea Selection Announcement

Early Stage Innovations 2020

- Topic 2 - Modeling of Lunar Dust Behavior and Mitigation Techniques
    - Particle adhesion/cohesion
    - Particle transport
    - Lunar dust particle characteristics
    - Evaluation of mitigation techniques
- Two proposals selected
    - University of Colorado Boulder (Horanyi)
        - *Investigate lunar dust structure, charging, and mobilization by developing numerical models that couple the microphysics of grain-scaled processes with the near-surface plasma environment*
    - Johns Hopkins University in Baltimore (Ni)
        - *Develops a multi-scale, multi-physics framework to model lunar dust characteristics ranging from microscale physics to macroscale transport in a vacuum environment and conditions inside spacecraft. The model will help evaluate lunar dust transport mechanisms and mitigation strategies for lunar missions*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
HEADQUARTERS
SPACE TECHNOLOGY MISSION DIRECTORATE
300 E Street SW
Washington, DC 20546-0001

SPACE TECHNOLOGY RESEARCH GRANTS PROGRAM,

EARLY STAGE INNOVATIONS APPENDIX

to

NASA Research Announcement (NRA): Space Technology – Research, Development, Demonstration, and Infusion 2020 (SpaceTech–REDDI–2020), 80HQTR20NOA01

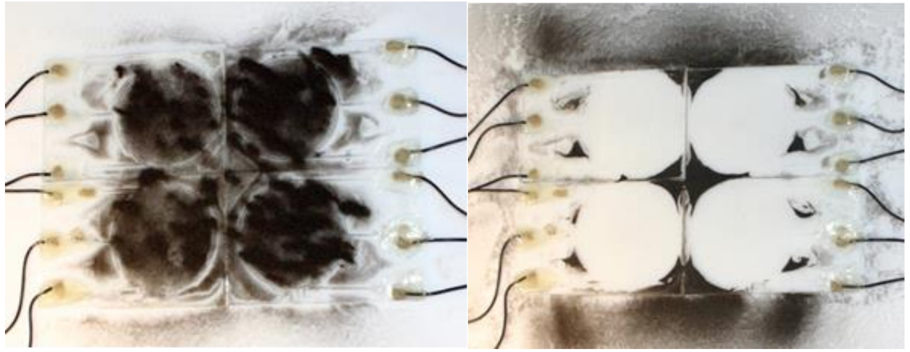
APPENDIX NUMBER: 80HQTR20NOA01-20ESI-B2

Appendix Issued: April 29, *2020*
Notices of Intent Due: *May 20, 2020* (5 PM Eastern)
Proposals Due: *June 17, 2020* (5 PM Eastern, 2 PM Pacific)

Early Stage Innovation Selection Announcement

Commercial Lunar Payload Services

- **Regolith Adherence Characterization (RAC):** will determine how lunar regolith sticks to a range of materials exposed to the Moon's environment at different phases of flight. Components will be derived from the Materials International Space Station Experiment (MISSE) facility currently on the International Space Station.
- **Electrodynamic Dust Shield (EDS):** a technology that generates a non-uniform electric field using varying high voltage on multiple electrodes. The non-uniform field generates a dielectrophoretic (DEP) force which, in turn, moves the particles, and has potential implications for thermal radiators, spacesuit fabrics, visors, camera lenses, solar panels, and many other technologies.



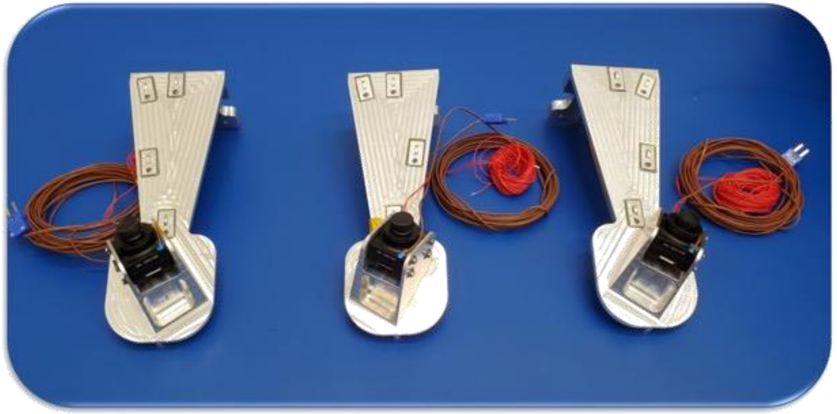
Electrodynamic Dust Shield

Stereo Cameras for Lunar Plume Surface Studies (SCALPSS 1.1): will capture video and still-image data of the area under the lander from just before the point the engine plume first disturbs the lunar surface through engine shutdown. Long-focal-length cameras will determine the pre-landing surface topography.

Lunar PlanetVac (LPV): a technology for acquiring and transferring lunar regolith from the surface to other instruments that would analyze the material, or put it in a container that another spacecraft could return to Earth.

CLPS Press Release

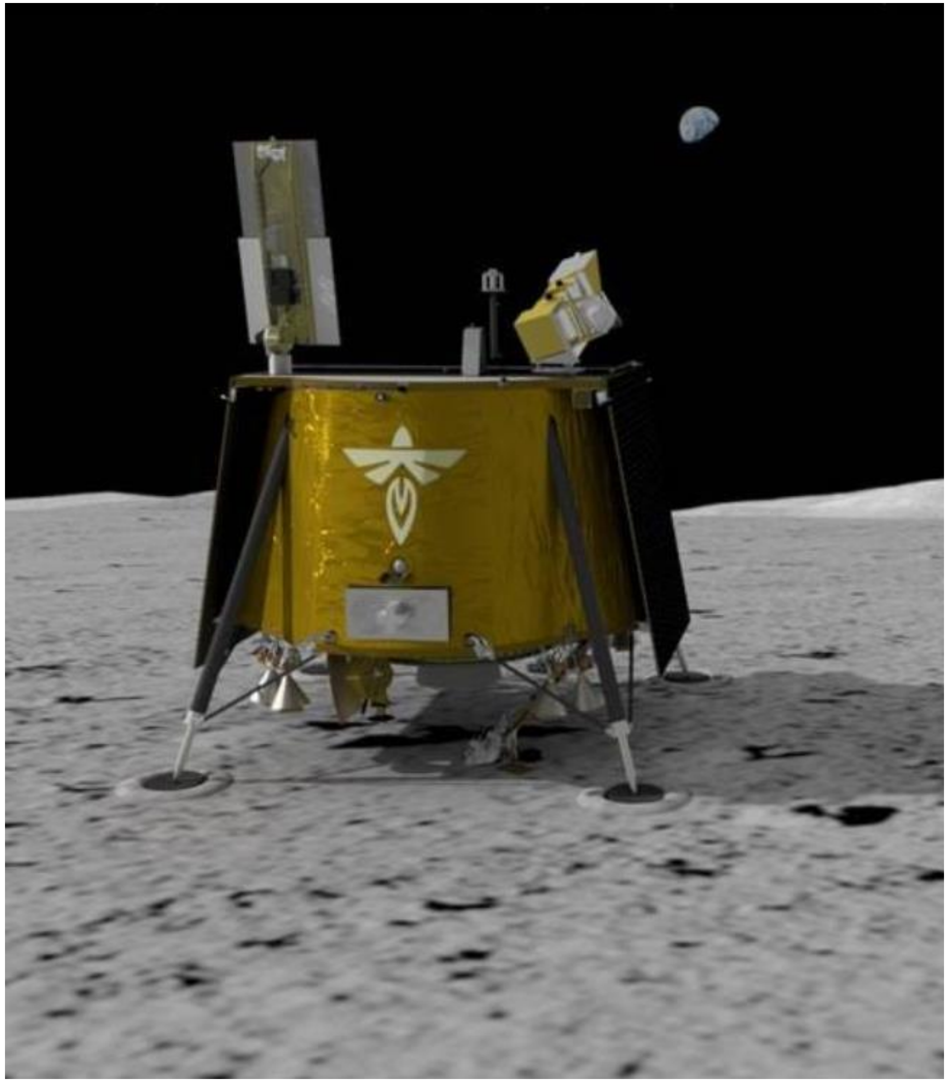
SCALPSS Press Release



SCALPSS Cameras

CLPS 19D Lander Selection

- Firefly Aerospace - Blue Ghost Lander
- Awarded $93.3M
- Landing site – Mare Crisium (17.0° N, 59.1 E)
- Deliver 10 payloads to the lunar surface in 2023 totaling 207 pounds
- Payloads related to dust mitigation include
  - Electrodynamic Dust Shield
  - SCALPSS 1.1
  - Lunar PlanetVac
  - Regolith Adherence Characterization



CLPS 19D Lander Selection Announcement