NASA Dust Mitigation Strategy

Plenary Address

The Impacts of Lunar Dust on Human Exploration

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The “Dust Problem”

"The dust went as far as I could see in any direction and completely obliterated craters and anything else... I couldn't tell what was underneath me. I knew I was in a generally good area and I was just going to have to bite the bullet and land, because I couldn't tell whether there was a crater down there or not." - Pete Conrad, Apollo 12 Commander

“At about 50 to 60 feet, the total view outside was obscured by dust. It was completely IFR (Instrument Flight Rules). I came into the cockpit (that is, switched his attention from the view out the window to the instrument readings that Jim was giving him) and flew with the instruments from there on down” – David Scott, Apollo 15 Commander

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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."

Dust Definition for Dust Mitigation

Disclaimer: Dust has a specific definition from geologic and other scientific and technical areas. Dust, soil, and other terms used to define the particulate on the lunar surface can have different meanings to different scientific groups. Furthermore, the word "dust" has been used loosely to mean anything from a very specific particle size distribution to nearly all of the particulate. This loose definition of dust has been used in NASA official documents, including past and future solicitations. Even furthermore, when developing technologies and strategies for dealing with the lunar particulate, it may not (and likely is not) necessary to have two classes of technologies: one for dust and one for larger or smaller sized particles. Even *more* furthermore, the "finest fraction" of lunar material will be the most troublesome for most systems. However, particle sizes outside of the finest fraction will likely still pose a threat to systems. Excluding all but the finest fraction of particulate from the definition of dust (based on NASA's history of using the word) may mislead commercial entities and technology developers that any particle outside of the geologic definition will not present a problem to NASA architecture.

Proposed definition: The term "dust mitigation" will include all lunar particulate that will need to be mitigated.
The term "finest fraction" of lunar regolith should be used to define the fine particulate that will likely cause the most concern – potentially aligning with the geologic definition of dust.

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

Market Analysis

Dust is realized to be one of the principal issues in returning to the lunar surface. It has been shown that lunar dust is very abrasive and highly cohesive, impairing optical instrumentation, altering thermal properties, and fouling mechanical systems. A number of NASA technologies have been developed to mitigate the effects of lunar dust for future exploration missions. However, it is possible that dust mitigation solutions exist outside of the solution space that is currently known by the agency. A number of terrestrial industries must also manage fine particulates – such as industrial plants processing cosmetics, powdered sugar, and pharmaceuticals. The focus of this broad search should find novel dust mitigation solutions within government, industry, and academia.

Market Analysis Results

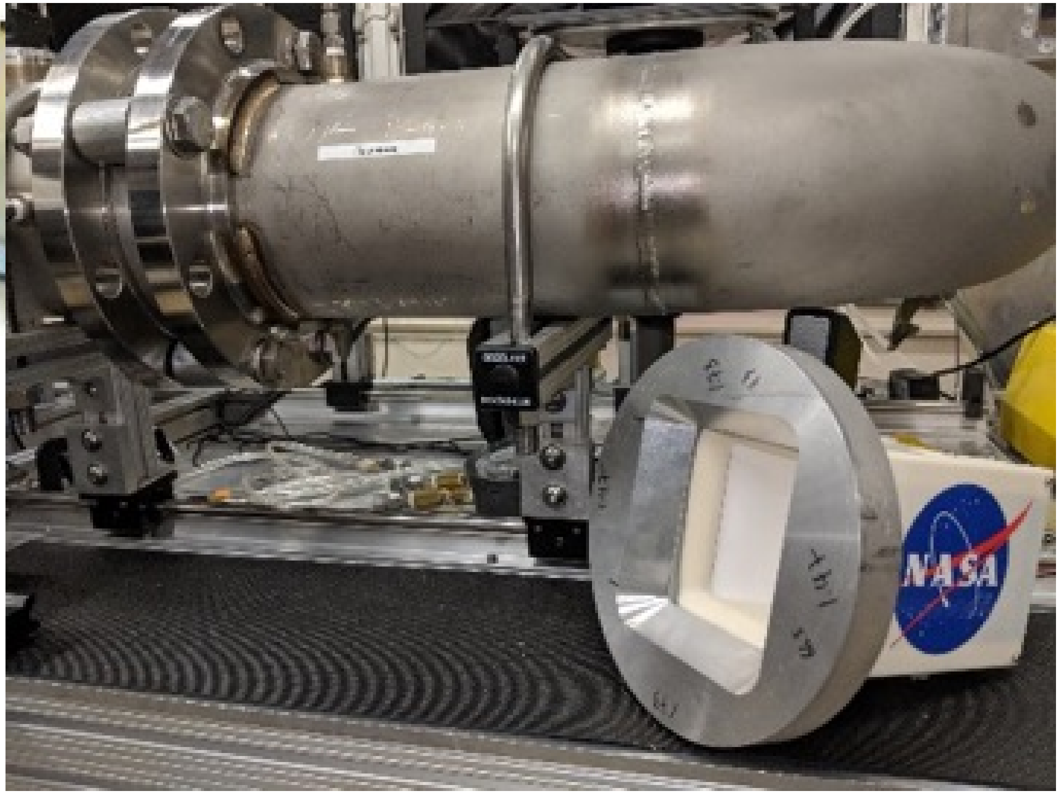
- The firm was given a large quantity of documents as a starting point
- 82 new leads in dust mitigation technologies
  - 12 Considered *Highly Interesting*
- Insights
  - Soil stabilization/binders
  - Filters
  - Surface Coatings
  - Electromechanical
  - Textiles
  - Monitoring
  - Testing/Standards

Agency Facilities and Capabilities

Photo Credit:Phil Toledano/National Geographic

Dirty Vacuum Chambers

Lunar Dust Adhesion Bell Jar



Mars Flow Loop

Technology Strategy

STMD FY20 Dust Mitigation Strategy

- Project Kickoff – January 22, 2020
- One project with four tasks
  - CLPS Payload Development
    - Electrodynamic Dust Shield
      - Active dust mitigation technology demonstration on CLPS payload
    - Patch Plate Materials Compatibility Assessment
      - Dust adherence on notional materials and passive technologies and dust imaging and characterizing capabilities
  - Technology Development
    - Dust Tolerant Mechanisms
      - Elevate TRL for dust tolerant mechanisms and joints, using UPR as the subject
    - Dust Mitigation Best Practices Guide
      - A "How To" Guide for dust mitigation to be used by stakeholders
  - Out year planning in work

SBIR Dust Mitigation Topic

- "…. This fine dust can foul mechanisms, alter thermal properties, and obscure optical systems. It can abrade textiles and scratch surfaces. With near term goals to return to the Moon, lunar dust is of particular concern. It has the potential to negatively affect every lunar architecture system. The goal of this topic is to develop dust mitigation technologies that can be incorporated into space exploration systems."
- Three subtopics in the FY20 SBIR solicitation
  - Active and passive surfaces
  - Dust Tolerant Mechanisms
  - Spacecraft and Spacesuit Atmospheres
- SBIR solicitation released in January 2020

Integrated Strategy

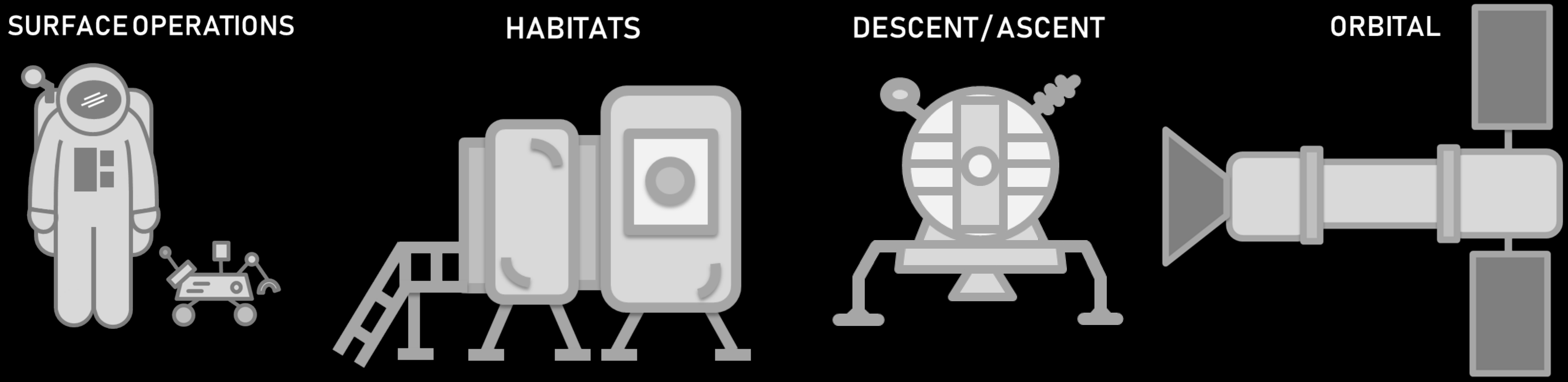
Working Groups

- Dust Mitigation Stakeholders Working Group
  - Meets weekly
  - Stakeholders include – EVA, HLS, Gateway, and other key players
  - NASA internal due to the nature of discussions
  - External communications typically come in the form of RFI, RFP, other official communications
  - Topics include – Requirements, test plans, technology SOA
- Technology Developers Working Group
  - Meets monthly
  - Ensures NASA tech developers have the most up to date information on architecture, etc.
  - Forum to form new collaborations and share ideas
  - External communications for NASA needs come in the form of official communications

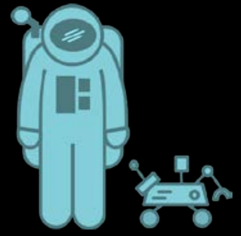
Dusty Environments Classifications

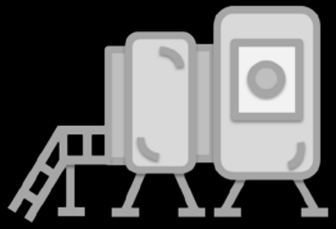
- Interest in formulating an environments ‘classification’ for lunar dusty environments
- Standardization across the Agency for how we handle the dust problem
- The classes would be defined by surface and volumetric concentrations of lunar dust (and other parameters) that would have associated testing protocols and design considerations for each class
- A first draft of these classifications are currently in work.

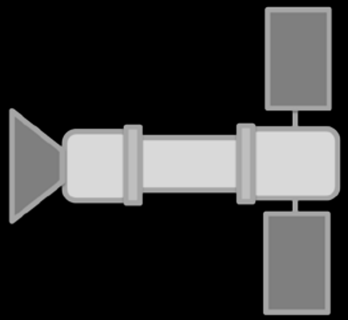
Integrated Dust Mitigation Strategy

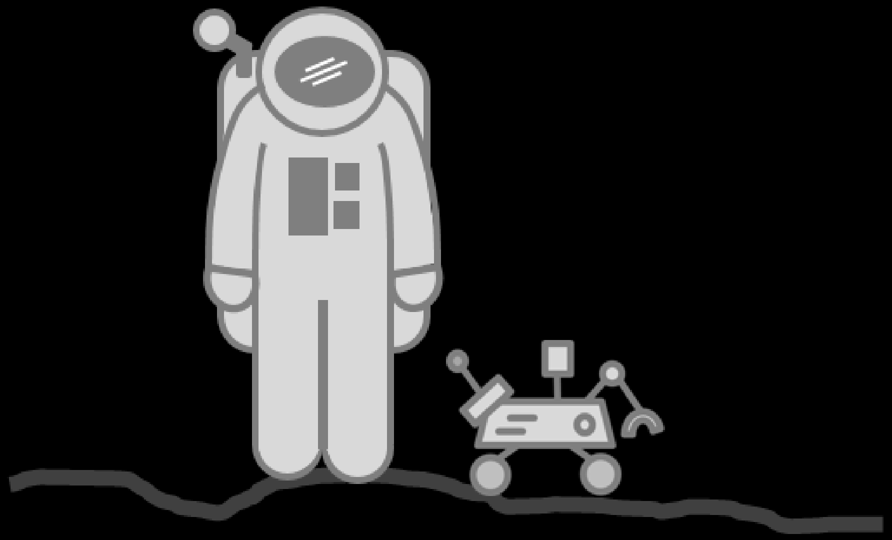


Surface Operations









Notional Dust Architecture/Operations Considerations

- Slow, methodical movements
- Kickoff boots and lower extremities/removable dust covers
- Adequate time for dust cleaning protocols
- Ground Preparation/Dust Tarp near Lander/Habitats/Other elements
- Quick Disconnects
- Dust Tolerant Mechanisms
- Brushes
- Other passive means and materials
- Active technologies