
DUST
MITIGATION

Advancements in Lunar Dust Mitigation and Leveraging the Contamination Control Community

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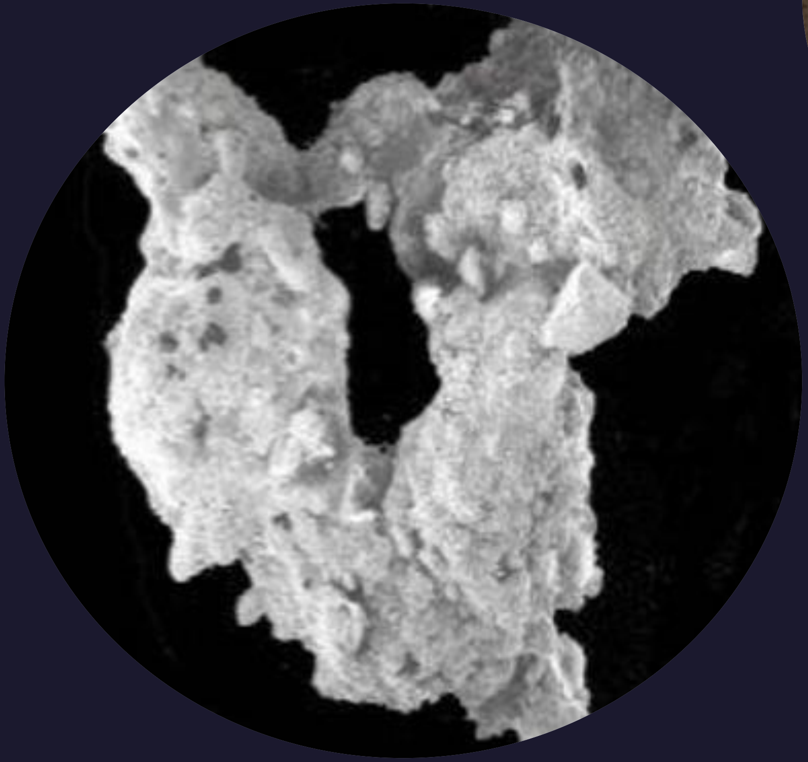
Agenda

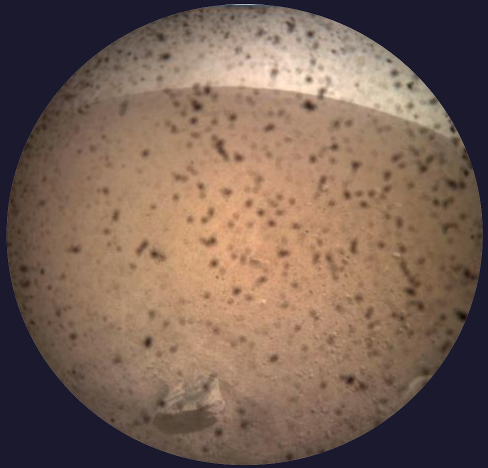
Dust, the dust problem, and dust mitigation

Defining "dust"

Adhesion experiment

Dust accumulation sensor





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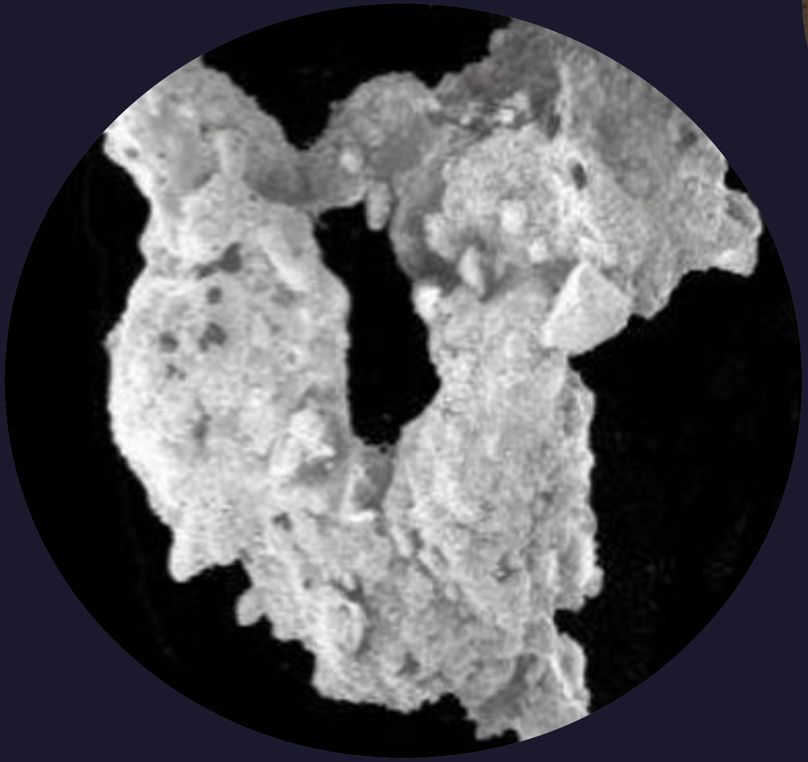
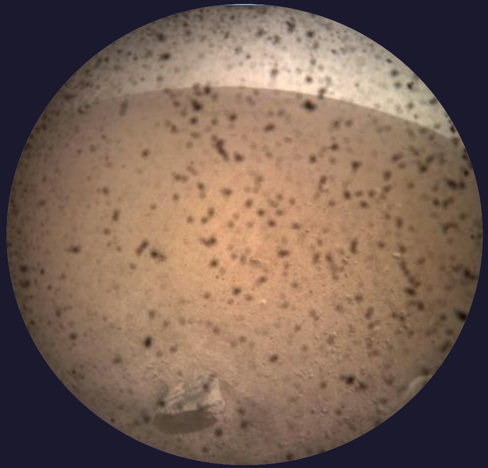
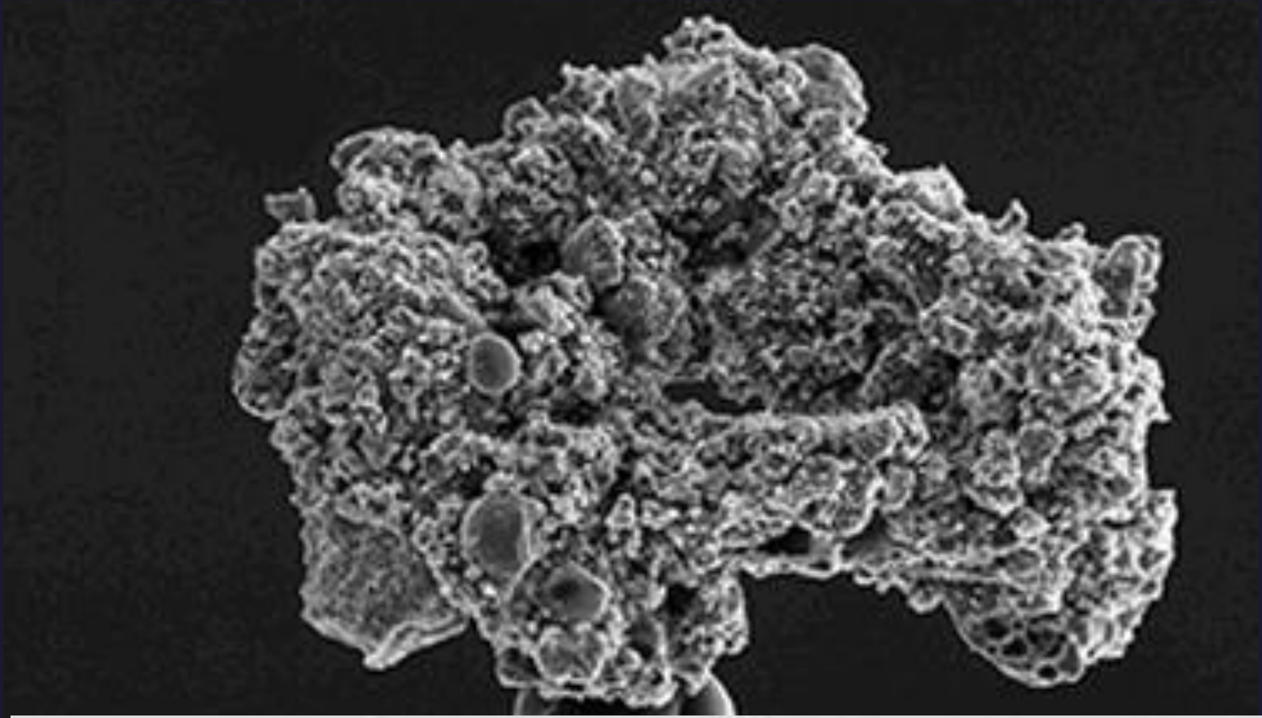
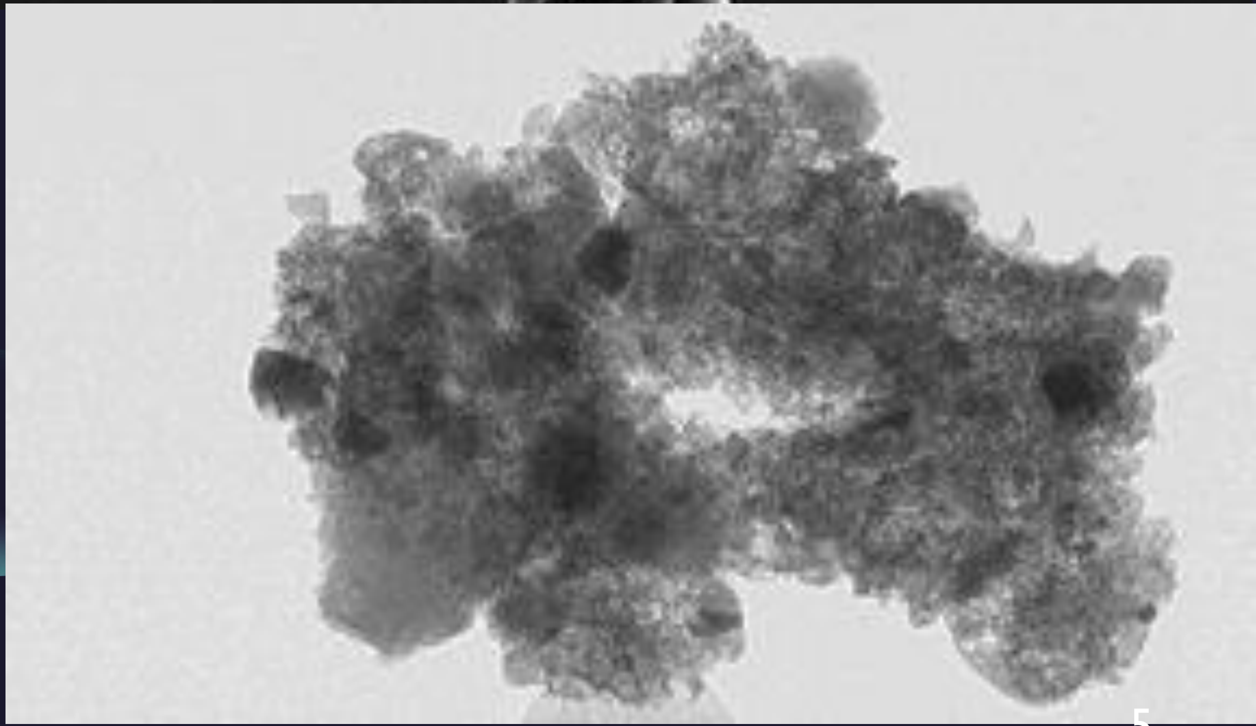




Assumption

- You are already aware of the dust and that dust will be a problem…
- But in case you're not…





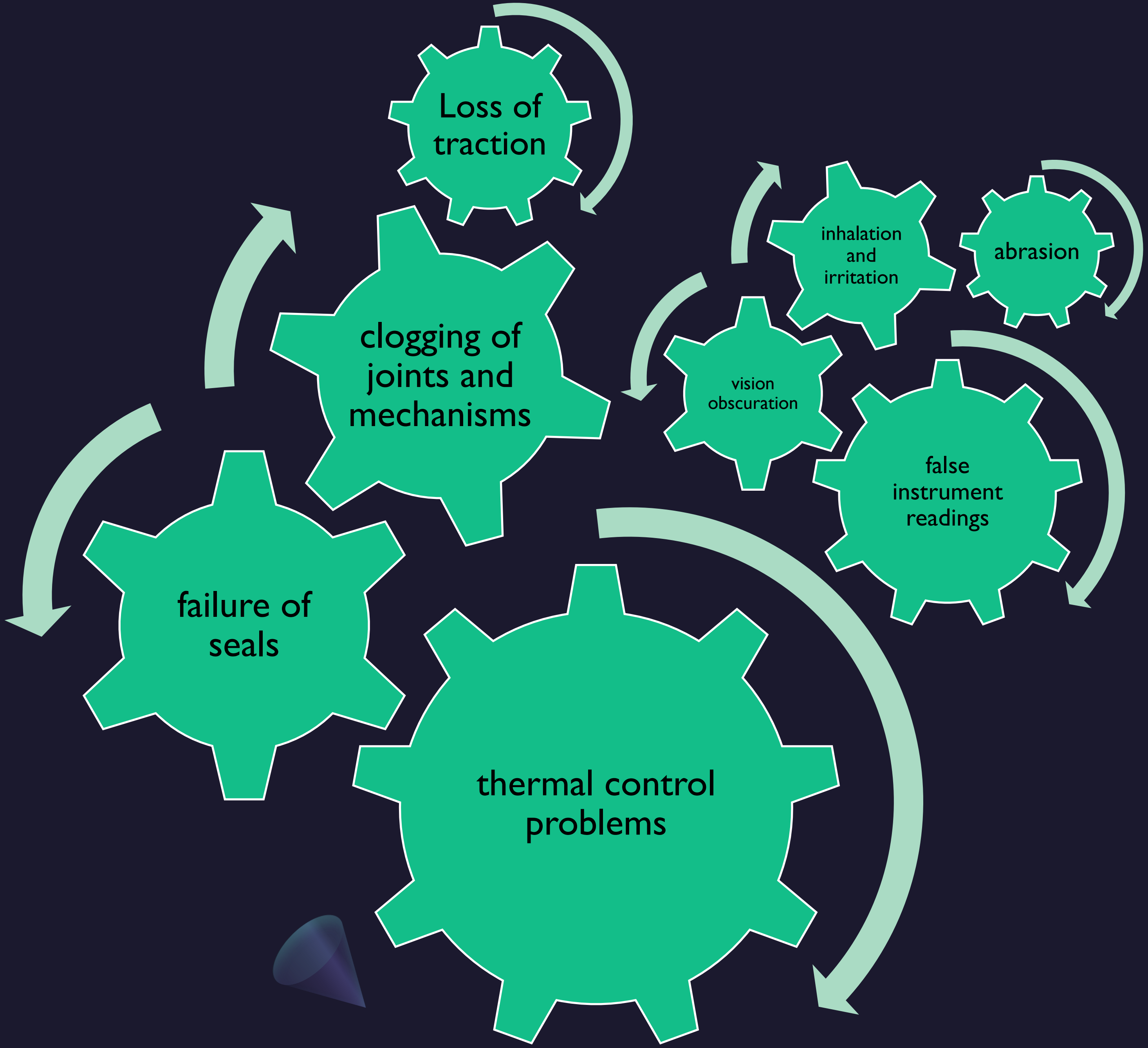
Courtesy of LeHigh University, Department of Materials Science and Engineering

Why is dust such a problem?

- **Electrostatic** and ferromagnetic in an environment with no natural grounding… so it sticks to anything carrying a charge.
- **Fine-grained**, with a significant fraction that is smaller than the human eye can resolve... so visibly clean isn't clean.
- **Jagged**, so it scratches and abrades everything from suit fabrics to human lungs.
- **Widely varied -** we only really know about the composition of dust in the places we've been.
- **Unpredictable -** behavior of lunar dust in space is governed by different forces than on earth.
- **Difficult to analyze** because the behavior can't be replicated without low gravity and zero atmosphere, making model validation difficult.

Assumption

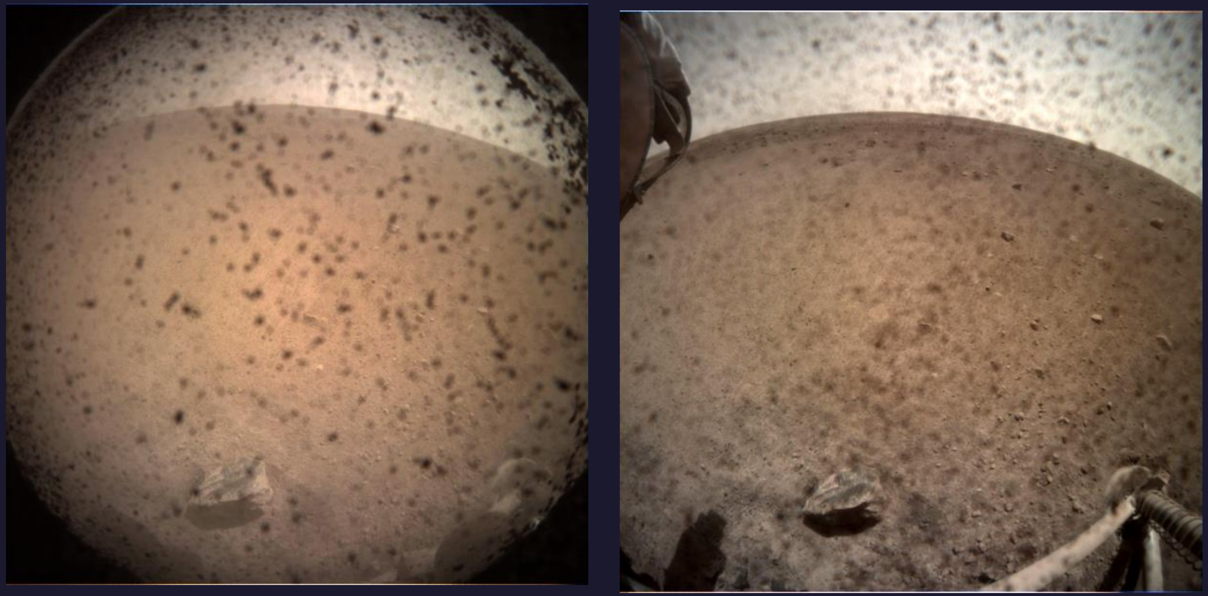
- You know that Apollo alerted us to some of the challenges from the dust
- But in case you're not…



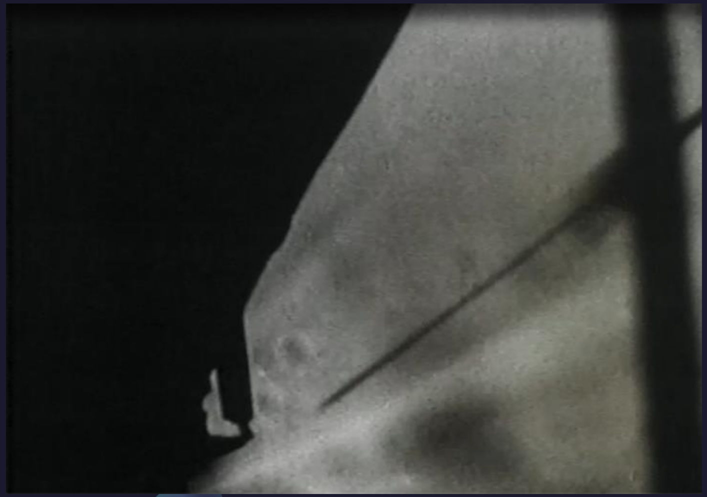
Reference: NASA/TM—2005-213610
The Effects of Lunar Dust on EVA Systems During the Apollo Missions by James R. Gaier

Assumption

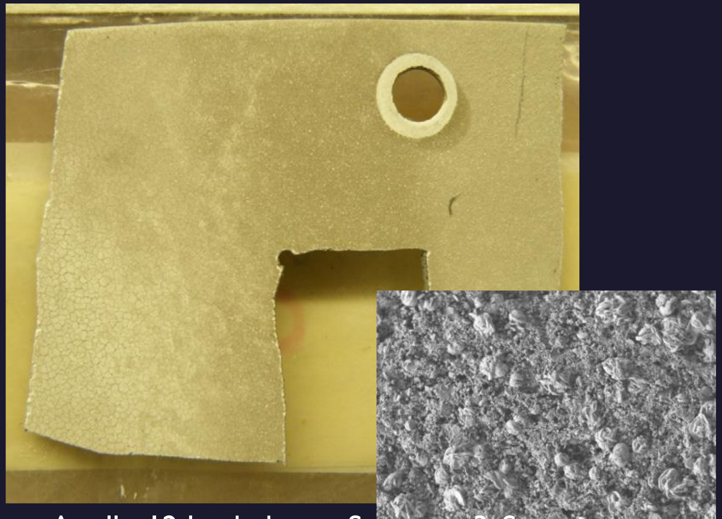
- You are already aware of the potential impacts from plume surface interactions (PSI)
- But in case you're not…
  - Plume-surface interactions (PSI) occur when a rocket engine exhaust (or other gas jet) interacts with a planetary surface
  - PSI effects will be a **large** contributor for lunar dust accumulation on any descending vehicle
  - Regolith ejecta poses a hazard to spacecraft and to surrounding assets



Mars Insight - Material breached lens cover



Ejecta streams visible during Apollo 11 landing



Apollo 12 landed near Surveyor 3; Scouring, pitting and cracking on Surveyor material coupon & SEM image (See Immer et al. 2010)

Good resource: Mehta et al. 2011, Rocket Plume Interactions for NASA Landing Systems

"When large systems fail, it is due to multiple faults that occur together in an unanticipated interaction, creating a chain of events in which the faults grow and evolve."

Source: National Academy of Sciences,
Why do errors happen?
ncbi.nlm.nih.gov

Examples in history:

Columbia, Challenger, Three Mile Island

Interesting reads: Henry Petroski – To Engineer is Human & Design Paradigms

A confluence of environmental factors

How does dust impact hardware?

Power

Dust accumulation on solar panels leads to reduction in available power.

Communications

Communication equipment can be covered in dust.

Thermal

Dust coats thermal radiators and equipment increases in temperature.

Optics

Optics concerns include accumulation on cameras/optics as well as concerns for thermal optical properties (transmittance, reflectance, and absorptance).

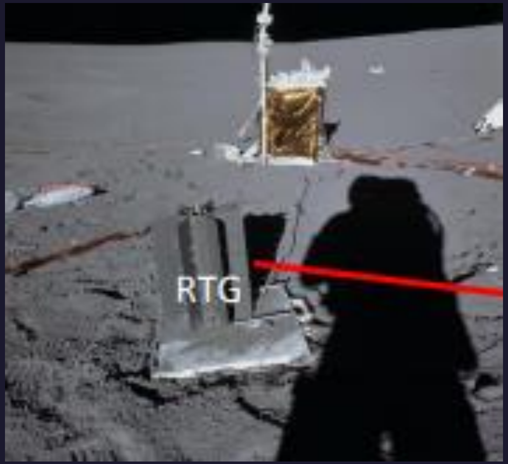
What to do about it?

NASA-STD-1008 provides guidance on how to test for this. (Sections on dust testing for thermal & optical testing.)

The Best Practices "Guidebook" discusses potential solutions to mitigate these challenges.

Another one bites the dust

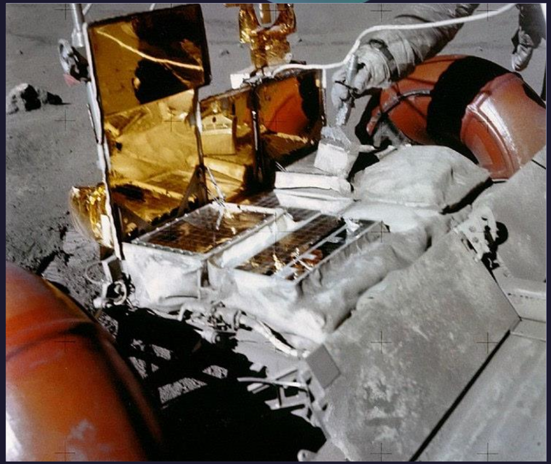
Lessons learned from the surface…



Apollo astronauts could not avoid getting dust on deployed ALSEP Experiments

Lunokhod 2 robotic rover only lasted through 4 lunar temperature cycles

Dust was a problem on the space suits, communications, TV cameras, and other equipment



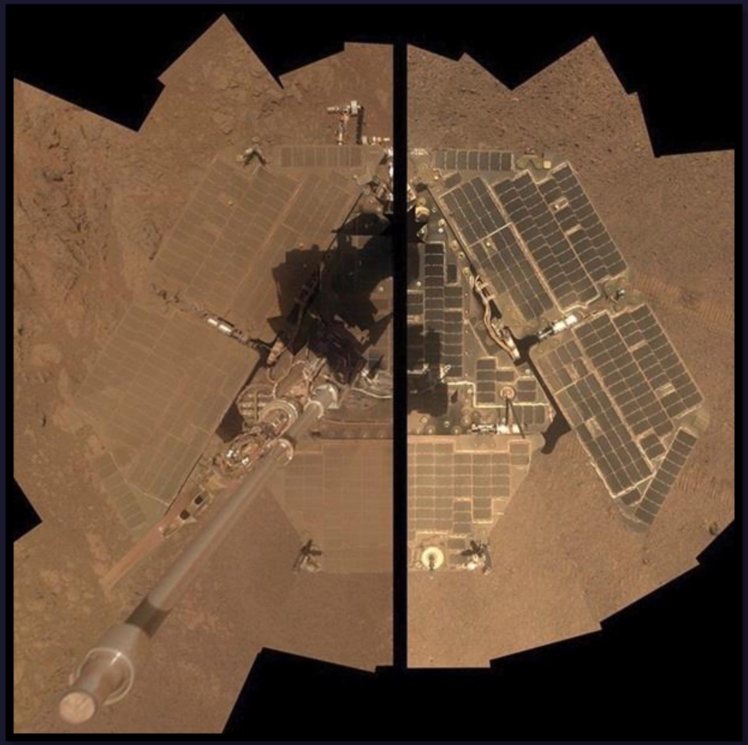
Dust accumulated on the radiators of the battery for the LRV of Apollo 16

The Apollo astronauts encountered marked degradation of performance in heat rejection systems for the lunar roving vehicle, science packages, and other components. – Jim Gaier

An insulating layer of dust on radiator surfaces could not be removed and caused serious thermal control problems. NASA/TM—2005-213610

Lunar Dust on Power & Thermal Systems

- Power connectors & heat exchangers → internal clogging, scratching
- Heat rejection/radiators → performance degradation, lower efficiency, system overheat
- Reflective and other surfaces → compromised by excessive dust, mirrors obscured
- Power generation/solar arrays → solar thermal conversion effects such as heat absorption, reduced power output
- PV arrays, cells, sensors → reduced power output, lower efficiency
  - Modeling and ground-based analysis shows power output from PV cells is cut in half by a covering of less than **3 mg/cm^2**; measurements from the Sojourner rover on Mars found that PV cells lost efficiency of **0.28%/day** owing to dust deposition.



Mars Opportunity Rover

Did radiators degrade during Apollo?

Yes!

Apollo 12 Temperatures measured were approximately 68 °F higher than expected (3-16)

Apollo 15 LRV batteries ran 68 to 78°F high because dust accumulation on radiators (94)

Apollo 16 Instrument performance degraded by overheating due to dust on radiators (4-10, 4-19)

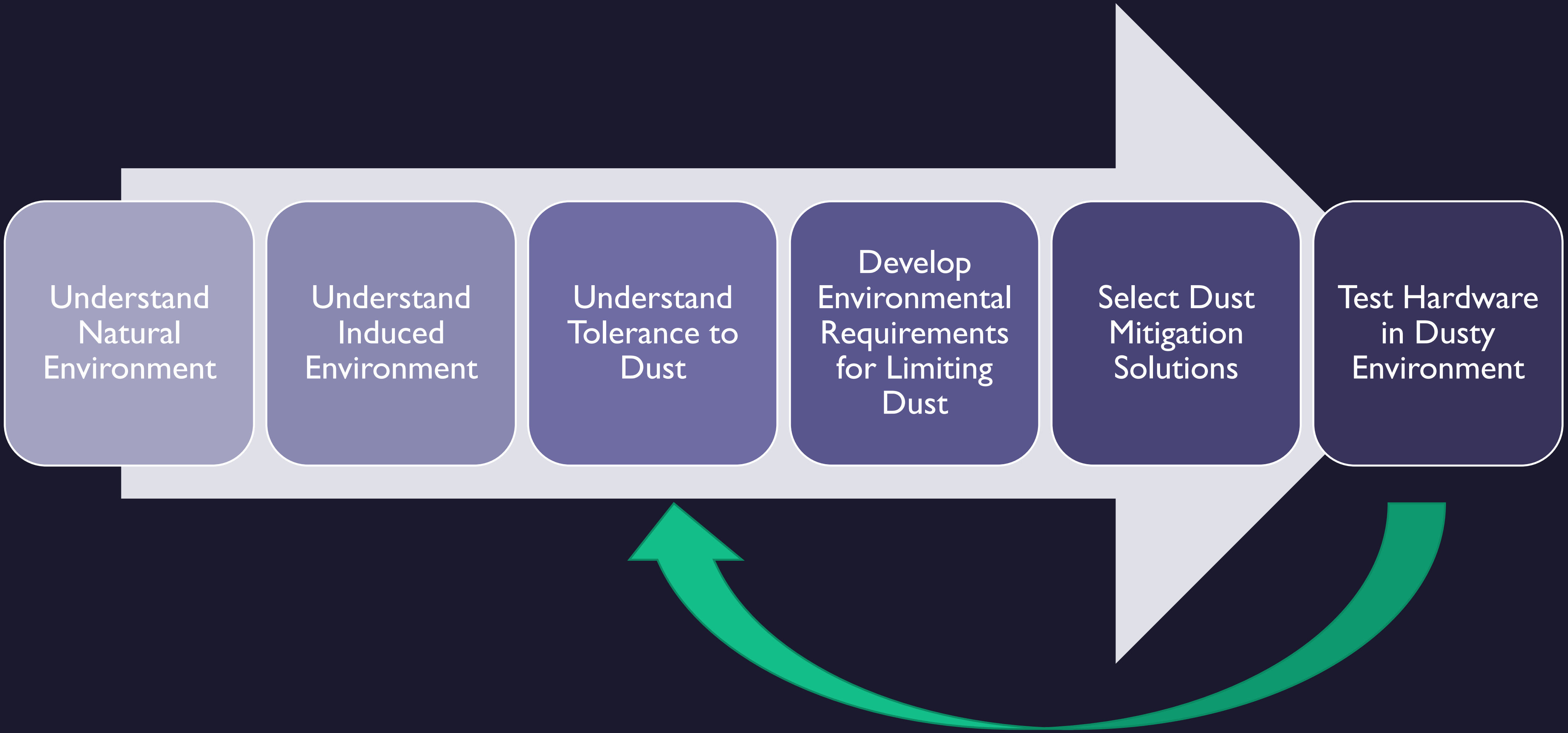
Apollo 16 Dust on Lunar Rover battery mirrors caused overheating (9-42)

Apollo 17 Instrument shut down when terminator passing to mitigate dust collection (15-29)

So you're going to the surface?

It sure would be nice if you had a…

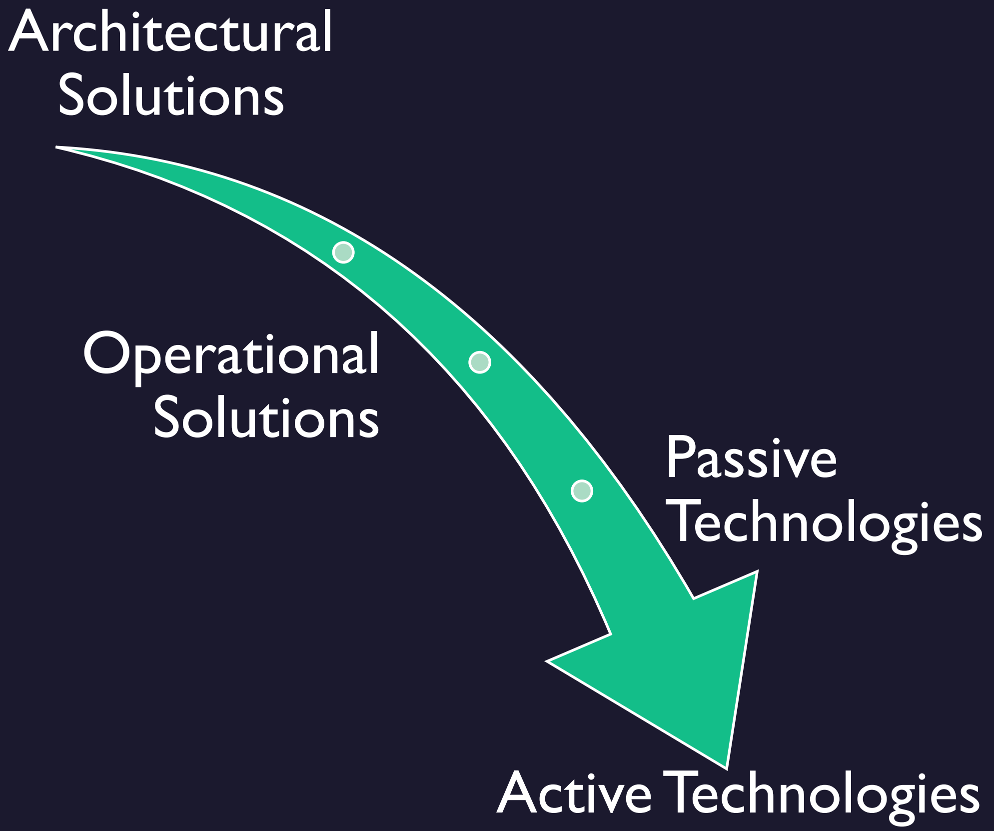
Dust Mitigation Strategy



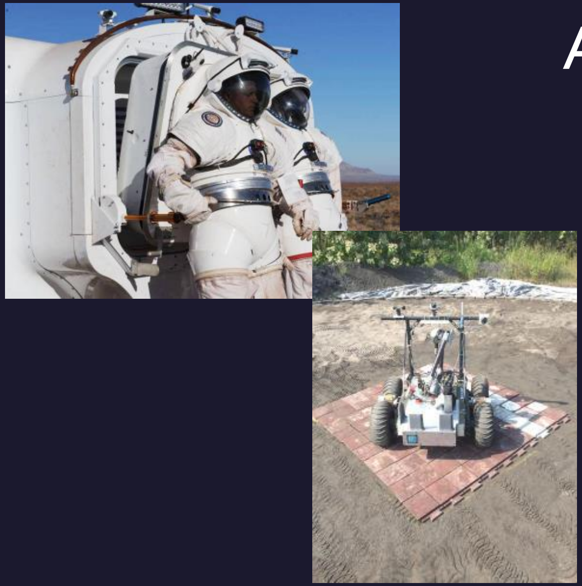
Dust Mitigation Strategy

Dust management

1. Tolerating dust exposure
2. Detecting/monitoring dust
3. Controlling entry of dust into vehicles/systems
4. Removal of dust



Dust Mitigation Solutions



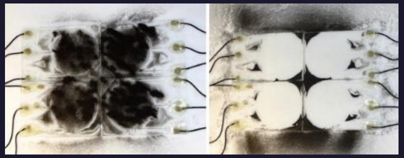
Architectural Solutions

Operational Solutions

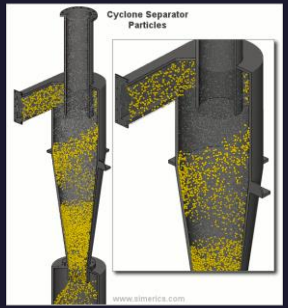
Passive Technologies

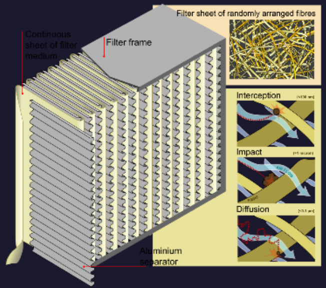
Active Technologies

- <u>Active technology solutions:</u>
- **Electrostatics**
- **Compressed air**
- Vacuums
- **Electrodynamic dust shield**



- <u>Passive technology solutions:</u>
- HEPA filters
- Cyclone separators
- Softwalls
- **Low-energy surface coatings**
- Coveralls/aprons/**covers**
- Dust tarps
- Brushes
- Tape
- Wipes





<u>Architectural & Operational solutions:</u>
- Suitports
- Severable airlocks
- Mud-rooms
- Porches
- Landing Site Selection
- **Prepared Landing Pad**
- Optimized EVA and **traverse planning**

Dust Mitigation Technology "Swimlanes"

Dust Tolerant Components

- Dust Tolerant Mechanisms, Seals, Bearings, Joints
- Covers
- etc

Passive Solutions

- Coatings
- Materials
- Filtration
- etc

Active Solutions

- Electrostatics
- Compressed air
- Vacuums
- etc

Dust Measurements

- Models
- Sensors
- Experiments
- Characterization
- etc

Active mitigation: Mitigation measure that require human intervention (or power) to operate properly (FEMA)
Passive mitigation: Mitigation measures that require no human intervention (or power) to operate properly (FEMA)

Dust Mitigation Efforts at NASA

Several dust mitigation solutions exist or are in work via partnerships

In-house STMD DM Portfolio

- GCD DM Projects (includes tech dev, characterization, guidance, and testing standards)
- ECIs
- CIF IRADs
- Flight Ops

STMD DM Partnerships

- LSIC
- SBIRs
- ESIs
- STRGs
- ACOs/TPs
- Challenges & Crowdsourcing

STMD DM Collaborations

- ESD
- SMD
- NESC
- Industry
- Academia

→ "The Big Ole List of Dust Projects"

Testing with Dust?

1. Look at Available Dust Testing Papers & Publications
2. Review Current Dust Testing Efforts
3. Read the Dust Mitigation Best Practices Guide
4. Understand the NASA Standard for Dust Testing

   https://standards.nasa.gov/standard/NASA/NASA-STD-1008
5. Select your Simulants (Simulant Advisory Committee)

   https://ares.jsc.nasa.gov/projects/simulants/
   https://lsic.jhuapl.edu/Resources/Lunar-Simulants.php
6. Identify your Facilities (LSIC Facilities Directory)
   https://lsic-wiki.jhuapl.edu/display/CD

Simulants

"What simulant should I use for testing?"

One of the most common questions we get

Simulant selection is critical to performing relevant tests

Simulant Characteristics to Consider

Aerosol Ingestion Testing: *PSD, Hardness, Morphology*
Abrasion Testing: *Hardness, Morphology, PSD*
Optical Testing: *Opacity, PSD, Albedo*
Thermal Testing: *Thermal Conductivity, Emissivity*
Mechanisms Testing: *Hardness, Morphology, Electrostatic Charging, PSD*
Seals and Mating Surfaces Testing: *Hardness, Morphology, PSD*
Reactivity Testing: *Chemical Composition, Morphology, PSD*
Electrostatic Properties: *Electrical Conductivity, Tribocharging, Permittivity*
PSI Testing: *Geotechnical, Electrostatics, Chemical Composition*

Per Lunar Dust Testing Standards, vetted with NASA Simulant Advisory Committee

Solution: Talk to the NASA Simulant Advisory Committee

https://ares.jsc.nasa.gov/projects/simulants/

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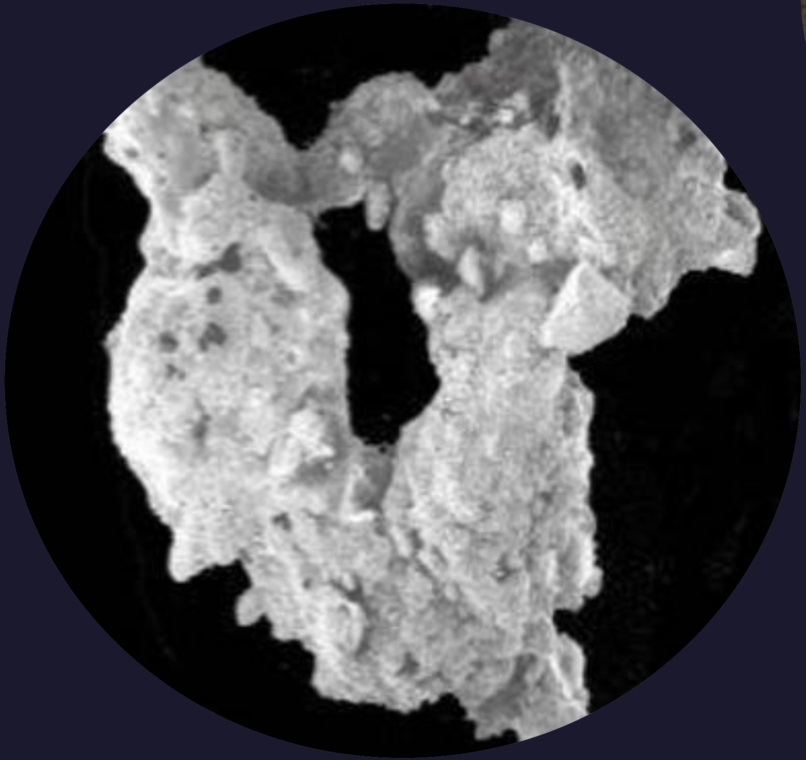
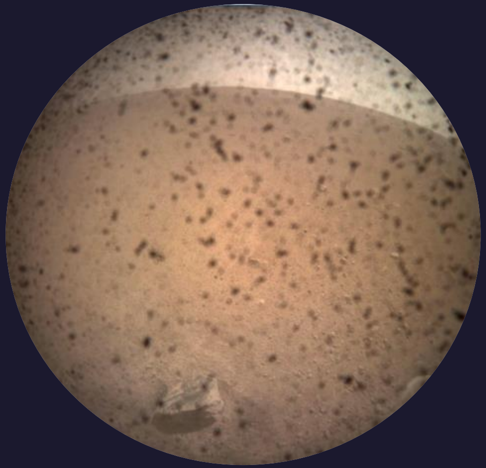




Defining "Dust"

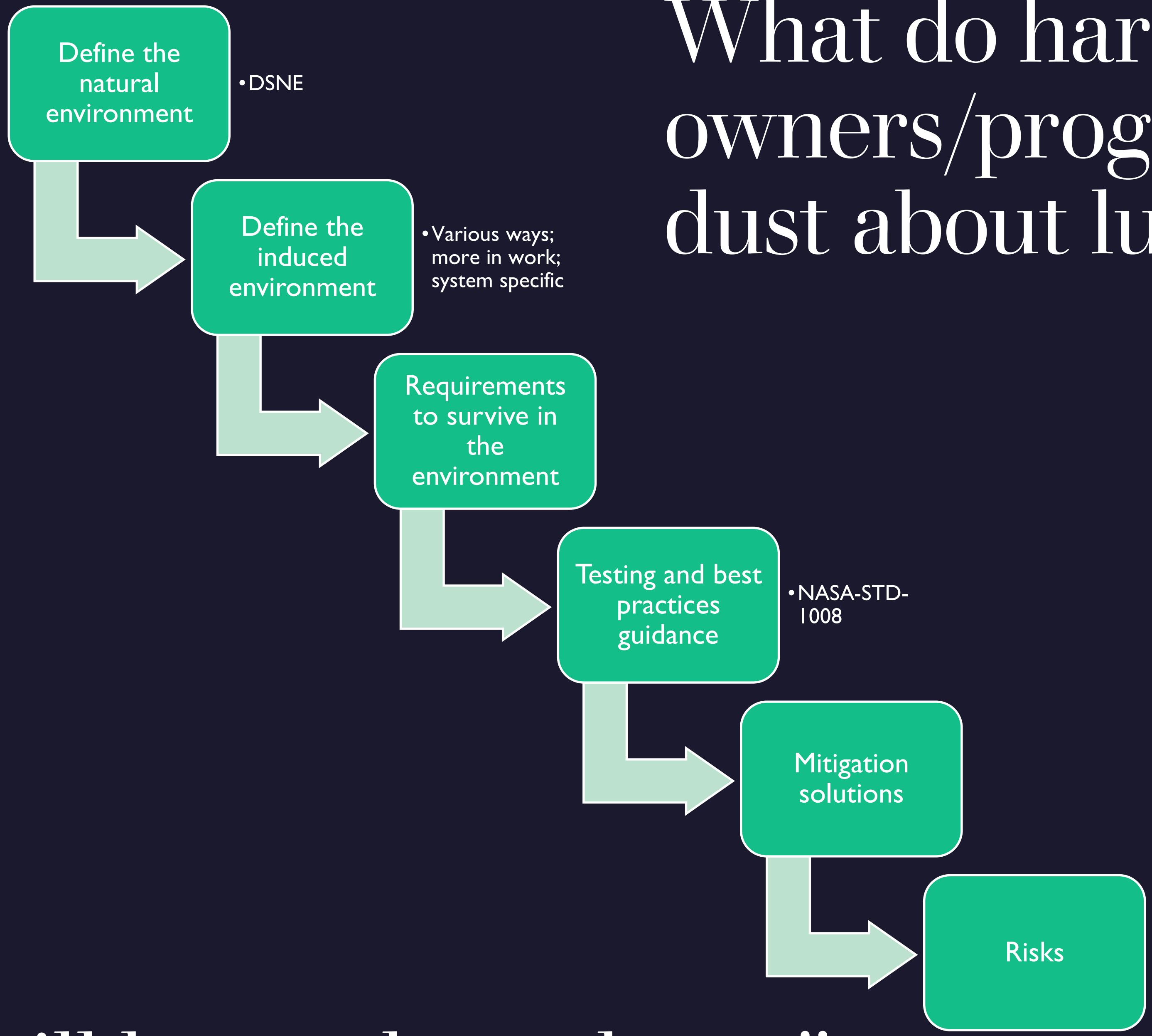
From NASA-STD-1008

Dust: For the purpose of this NASA Technical Standard, we define "dust" pragmatically as the regolith size fraction that poses any functional or longevity concerns or risks to hardware, components, or systems. This is defined by an upper particle size bound and includes smaller particles. Estimates of source size fractions are given in this NASA Technical Standard for various dust transport mechanisms. The unit micrometer (µm) is used to define dust sizes in this NASA Technical Standard.

Note: The definition of "dust" can have different meanings to different scientific groups, and the word "dust" has been used to characterize anything from a very specific size particle distribution to nearly all of the particulate matter in a given sample/volume. Various definitions of dust have been used widely in NASA official documents and in other scientific documents. However, when designing, developing, and testing technologies and systems for dealing with the particulate matter, it is not ideal to have two classes: one for dust and one for larger- or smaller-sized particles.

Or simply put: All lunar particulate that will need to be mitigated.

What do hardware owners/program/projects dust about lunar dust?



But we still have a lot to learn!!

Going Forward

- The dust mitigation community is advocating for information on dust characterization needs based on scientific and engineering knowledge gaps that will aid in the design and survival of designed and future systems, and address the challenges related to defining the lunar environment and mitigating lunar dust effects on systems and operations.

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requirements, risks, hazard controls, mission success

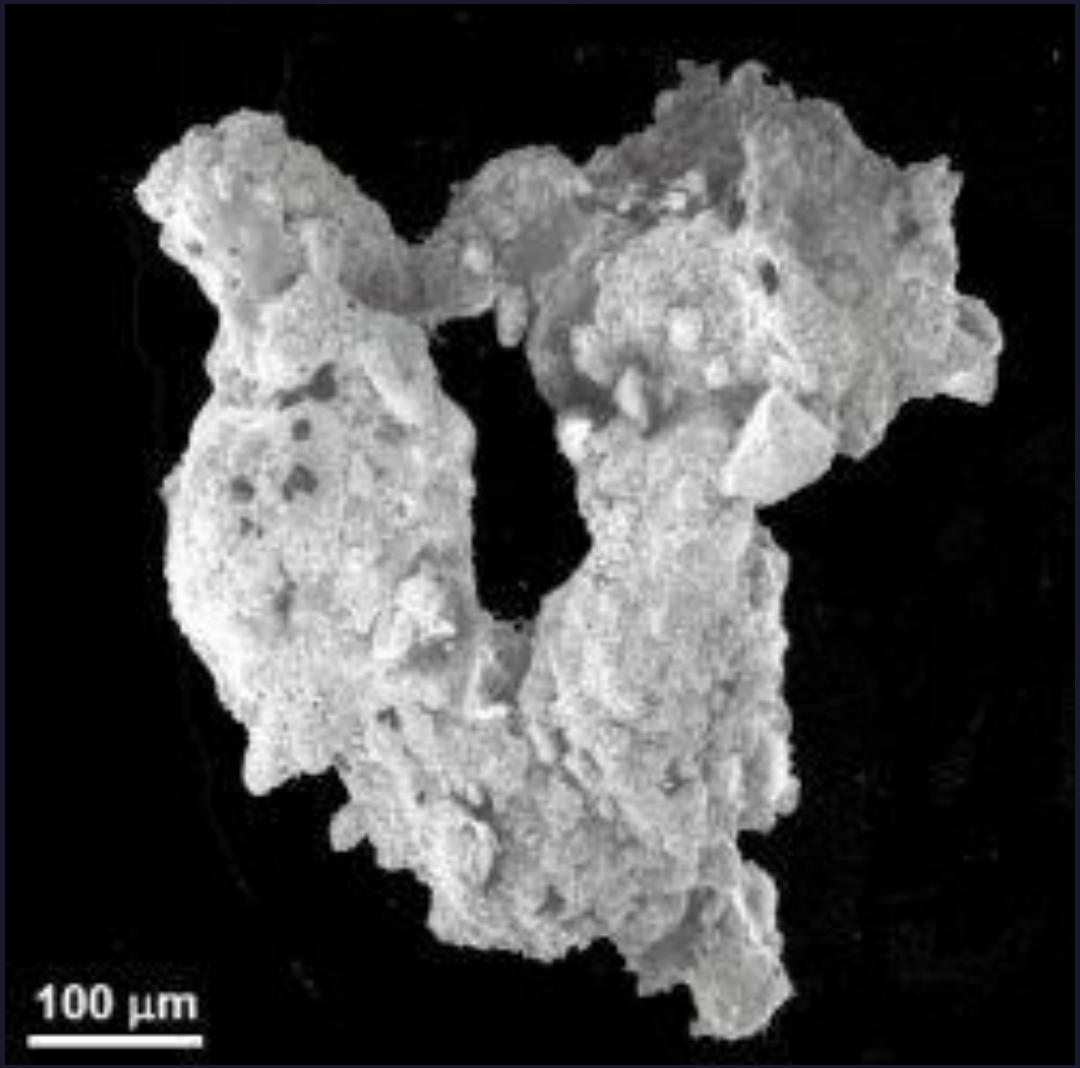
capability gaps, technology gaps, program and project needs, etc

SLS-SPEC-159 DSNE

dust mitigation technologies or strategies

NASA-STD-1008 (i.e. testing)

+use the data to inform models



Sources of our list

- Guidance and Standards
  - SLS-SPEC-159 DSNE
  - **NASA-STD-1008**
  - Induced Environments documents in work
- Gaps/Areas we need more information on
  - 2020 publication "The Impact of Lunar Dust on Human Exploration"
  - PSI white paper
  - Gaps identified within NASA programs and projects
  - Lunar simulant limitations
  - Dust parameters needed to improve modeling efforts
  - What are we missing? Please reach out to me!

What is NASA-STD-1008?

- "Classifications and Requirements for Testing Systems and Hardware to be Exposed to Dust in Planetary Environments" approved by the Office of the NASA Chief Engineer on 2021-09-21 through an Agency-wide review and is publicly available at https://standards.nasa.gov/standard/nasa/nasa-std-1008
- "The purpose of this NASA Technical Standard is to establish **minimum** requirements and provide effective guidance regarding methodologies and best practices for testing systems and hardware to be exposed to dust in dust laden and generating environments. The intent is **to facilitate consistency and efficiency** in testing space systems, subsystems, or components with operations and missions in dusty environments."

METRIC/SI (ENGLISH)

NASA TECHNICAL STANDARD

Office of the NASA Chief Engineer

NASA-STD-1008

Approved: 2021-09-21

CLASSIFICATIONS AND REQUIREMENTS FOR TESTING SYSTEMS AND HARDWARE TO BE EXPOSED TO DUST IN PLANETARY ENVIRONMENTS

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Table 3—Planetary Pressurized Lunar Sources of Dust and Associated Dust Parameters

PP Lunar Sources of Dust	Particle Size (µm)	Surface Accumulated Loading (g/m^2)	Volumetric Loading (g/m^3)	Dust Velocity (m/s)	Charge to Mass Ratio (nC/g)
Extravehicular Activity (EVA) Suit Cross-Hatch Transported Dust	<500 µm [TBR] [1]	50 g per suit per EVA [2][3][5]	10 g/m^3 per suit per EVA [2][3][4]	Variable [6]	N/A
Hardware Cross-Hatch Transported Dust	<500 µm [TBR] [1]	Variable g/m^2 [2]	Variable g/m^3 [2]	Variable [6]	N/A

Section 4 provides estimated dust parameters and references for each estimate.

Section 5 describes testing methods and facility needs.

What is NASA-STD-1008?

- “Classifications ar… be Exposed to D… of the NASA Chi… review and is pub… https://standards.…
- “The purpose of … requirements and … and best practices … dust in dust laden … **facilitate consis…** subsystems, or co… environments.”

1.2 Applicability

This NASA Technical Standard is applicable to any system, subsystem, or component that will be exposed to planetary dust (refer to definition in section 3.2 in this NASA Technical Standard). There are four different environments in which hardware may be exposed to dust: planetary external (PE), planetary pressurized (PP) volumes, in-space pressurized (SP) volumes, and in-space external (SE). In this NASA Technical Standard, the environments are referred to as working dust environments. The word “pressurized” does not necessarily imply habitable. Where applicable, habitable volumes are identified in the text of this NASA Technical Standard.

This NASA Technical Standard allows for broad usage for missions to the Moon, Mars, and small bodies (e.g., asteroids) when working with dust or regolith. However, section 4.2 (Sources of Dust) and section 5.4 (Simulants) have been broken into Lunar, Martian, and Small Bodies sections, with the Martian and Small Bodies sections currently marked as reserved.

The environmental conditions defined in this NASA Technical Standard (sources of dust, particle sizes, system surface, and/or volumetric loading) are based on estimates from current data sets or studies. Future insight into these environments through missions, technology demonstrations, laboratory studies, modeling, or analyses may unveil new definitions, at which time this NASA Technical Standard will be revised. Appendix A provides context for why it is necessary to test and examine the effects of dust on hardware and systems as it relates to the operational environment.

…vides estimated …s and references …te.

Section 5 describes testing methods and facility needs.

NASA-STD-1008 Section 4

SECTION 4. Dust Requirements & Standards

4.1 Dust Impact Assessment Process

4.2 Sources of Dust

a. Planetary External (PE)

b. Planetary Pressurized (PP)

c. In-Space Pressurized (SP)

d. In-Space External (SE)

Table provided for each section that contains guidance on particle size, surface accumulated loading, volumetric loading, dust velocity, and charge to mass ratio. It provides this information for various sources of dust depending on the environment.

a. PE – Human generated surface transported dust, rocket plume dust, natural charged dust transport, natural impact ejecta
b. PP – EVA suit cross-hatch transported dust, hardware cross-hatch transported dust
c. SP – micro-G free floating dust, micro-G surface adhering dust
d. SE – rocket plume dust, natural charged dust transport, natural impact ejecta

NASA-STD-1008 Section 5

SECTION 5.

Testing Methodologies & Best Practices

5.1 Simulant Prep & Storage

5.2 Simulant Loading Definitions

5.3 Testing Practices & Categories

- 5.3.1 Aerosol Ingestion
  - 5.3.1 Simulant Characteristics
  - 5.3.2 Facility Capability
  - 5.3.3 Methodology
  - 5.3.4 Best Practices
- 5.3.2 Abrasion
- 5.3.3 Optical
- 5.3.4 Thermal

5.3 Testing Practices & Categories (cont.)

- 5.3.5 Mechanisms
- 5.3.6 Seals & Mating Surfaces
- 5.3.7 Reactivity
- 5.3.8 Electrostatic
- 5.3.9 Plume Surface Interaction

5.4 Simulants

5.5 Facilities

NASA-STD-1008 Testing Categories

5.3.1 Aerosol Ingestion
Aerosol ingestion testing supports the development and use of hardware/system(s) that have the potential to ingest dust. This section is applicable to hardware/systems(s) exposed to dust within any pressurized habitable volumes/compartments and surface atmospheric environments.

5.3.2 Abrasion
Abrasion testing supports the development and use of materials used in hardware/system(s) that frequently interact and wear over time. This section is applicable to soft goods, which are flexible materials (e.g., textiles or thin films of synthetic or natural materials and hard goods, which are inflexible materials (e.g., rigid metals or ceramics).

5.3.3 Optical
Optical testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by dust. This section is applicable to optical equipment (e.g., solar panels, viewports, camera lenses, laser-based optical systems, all mirrors, wavelength filter lenses, and radiative measurement sensors) and relative navigation equipment (e.g., docking targets, reflectors.)

5.3.4 Thermal
Thermal testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by dust. This section is applicable to active thermal management components/systems, dust loading, and associated thermal impacts on hardware/systems. The primary focus is on radiators, as this is expected to be a key component directly impacted by dust buildup/coverage. However, consideration of other hardware/system(s) that generate heat (e.g., motors, power supplies) must be considered to determine potential impact to operational conditions.

5.3.5 Mechanisms
Mechanisms testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by dust. This section is applicable to hardware with interacting surfaces in relative motion (e.g., bearings, gears, screws, and slip rings), mechanism casings and soft goods (i.e., lubricants and grease), and their seals at the system level. Other applicable mechanisms can include, but are not limited to: deployable appendages including solar arrays, retention and release mechanisms, antennas and masts, actuators, transport mechanisms, switches, rotating systems including momentum wheels, reaction wheels, control moment gyroscopes, motors, and roll rings.

5.3.6 Seals & Mating Surfaces
Seals and mating surfaces testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by dust contamination. This section is applicable to static seals for hatches, docking systems, space suits, habitation modules, and sample containers.

5.3.7 Reactivity
Reactivity testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by dust contamination or chemical reactivity. This section is applicable to surfaces and organic and inorganic materials that have the potential to react with activated dust surfaces. This section is different than previous sections in that it serves to show how simulants may be altered to recreate the natural reactivity of lunar surface environment dust particle reactivity.

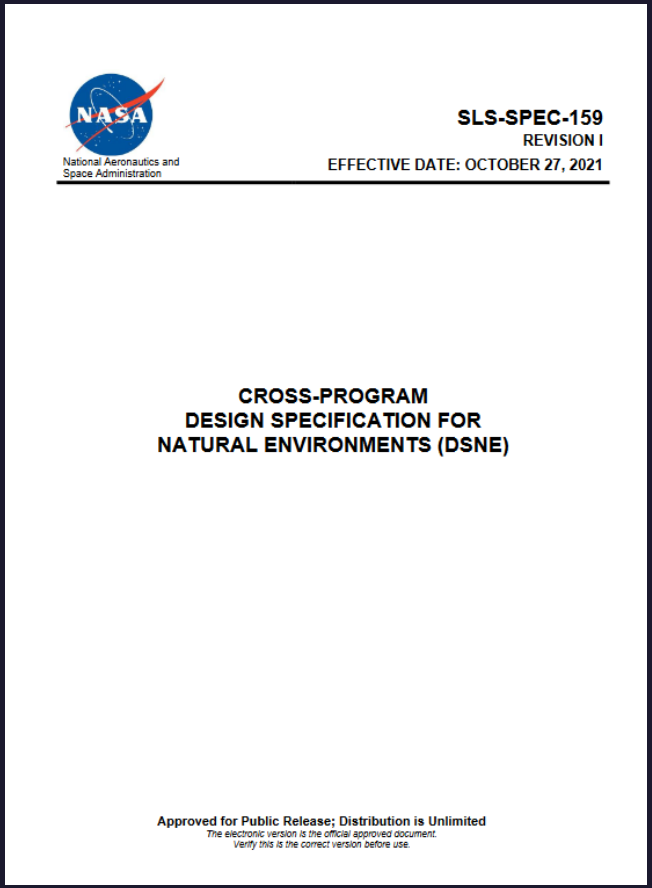
5.3.8 Electrostatic Properties
Electrostatics testing supports the development and use of hardware/system(s) that have the potential to have their properties and operation altered by the electrical properties of dust. This section encompasses electrostatic properties of granular materials, electrostatic discharge (ESD) circuit shorts from accumulated dust, and electrical arcing.

5.3.9 Plume Surface Interaction
Rocket engines produce gas plumes that interact with the planetary surface environment. When vehicles conduct near-surface operations (e.g., landing or take-off), gas plumes interact with planetary surfaces and may cause erosion, lofting, and/or heating of surface materials. Ejected dust may strike the vehicle producing the plume, hardware/system(s) in the vehicle's immediate vicinity or objects on orbit. PSI may cause dust loading or impact damage (e.g., media blasting). The nature of PSI effects depends on the target body's regolith, atmospheric, topographic, and gravitational properties; the vehicle's architecture, engine configuration and duty cycle, and the flight path of the landing vehicle; and the proximity of nearby hardware/system(s).

What is the DSNE?

SLS-SPEC-159: Cross-Program Design Specification for Natural Environments (DSNE)

Latest revision available on NTRS


National Aeronautics and Space Administration

SLS-SPEC-159
REVISION I
EFFECTIVE DATE: OCTOBER 27, 2021

CROSS-PROGRAM
DESIGN SPECIFICATION FOR
NATURAL ENVIRONMENTS (DSNE)

Approved for Public Release; Distribution is Unlimited
The electronic version is the official approved document.
Verify this is the correct version before use.

1.2 Purpose

The DSNE completes environment-related specifications for architecture, system-level, and lower-tier documents by specifying the ranges of environmental conditions that must be accounted for by NASA ESD Programs. To assure clarity and consistency, and to prevent requirements documents from becoming cluttered with extensive amounts of technical material, natural environment specifications have been compiled into this document. The intent is to keep a unified specification for natural environments that each Program calls out for appropriate application.

Example programmatic requirement:
The “system” shall meet all safety, functional, performance, utilization, and mission objectives during and after exposure to natural environments as defined in SLS-SPEC-159 Cross-Program DSNE.

3.0 Natural Environment Specification
- 3.1 Prelaunch - Ground Processing Phases
- 3.2 Launch Countdown and Earth Ascent Phases
- 3.3 In-Space Phases
- **3.4 Lunar Surface Operational Phases**
- 3.5 Entry an
- 3.6 Conting
- 3.7 Recover
- 3.8 Interplar
- 3.9 Mars Or
- 3.10 Mars A
- 3.11 Mars M
- 3.12 Near E

3.4 Lunar Surface Operational Phases

- 3.4.1 Lunar Surface Geological and Geomorphological Environment
- **3.4.2 Lunar Regolith Properties**
- 3.4.3 Luna
- 3.4.4 Luna
- 3.4.5 Opt
- 3.4.6 Luna
- 3.4.7 Luna
- 3.4.8 Luna
- 3.4.9 Lunar Illumination
- 3.4.10 Lunar Neutral Atmosphere

3.4.2 Lunar Regolith Properties

- 3.4.2.1 General Description of the Lunar Reg
- 3.4.2.2 Particle Size and Shape
- 3.4.2.3 Mechanical Properties of Lunar Regol
- 3.4.2.4 Derived Physical Properties

For section 3.4, numerous published data sets from orbiting spacecraft and analysis of Apollo and other sample return missions were used. References are cited for all design environment data.

Chapter 9 of Lunar Sourcebook

Table 3.4.2.3-1 Summary of bulk regolith properties taken as representative of typical lunar characteristics based on prior landed missions and sample properties.

Property	Value	Units	Notes	DSNE Section	Sources
Bulk Density (ρ)	1.58 ± 0.05: 0-30 cm 1.74 ± 0.05: 30-60 cm	g cm^{-3}	Intercrater areas	3.4.2.3.1	Carrier et al. 1991
Relative Density (D_R)	74 ± 3: 0-30 cm 92 ± 3: 30-60 cm	%	Intercrater areas	3.4.2.3.2	Carrier et al. 1991
Specific Gravity (G) [equivalent to particle density (ρ_P; g/cm^3)]	3.1	Dimensionless or g/cm^3	Based on limited number of bulk samples. This is the recommended value.	3.4.2.3.3	Carrier et al. 1991
Typical highlands particle density ($\rho_{P\_highlands}$)	2.75 ± 0.1	g/cm^3	Highlands or polar regions. Based on limited number of bulk samples.	3.4.2.3.3	Kiefer et al., 2012
Typical mare particle density (ρ_{P_mare})	3.35 ± 0.1	g/cm^3	Mare regions. Based on limited number of bulk samples.	3.4.2.3.3	Kiefer et al., 2012
Porosity (n)	49 ± 2: 0-30 cm 44 ± 2: 30-60 cm	%	Calculated	3.4.2.3.4	Carrier et al. 1991
Void Ratio (e)	0.96 ± 0.07: 0-30 cm 0.78 ± 0.07: 30-60 cm	-	-	3.4.2.3.4	Carrier et al. 1991
Permeability			Firing of Surveyor vernier		Choate

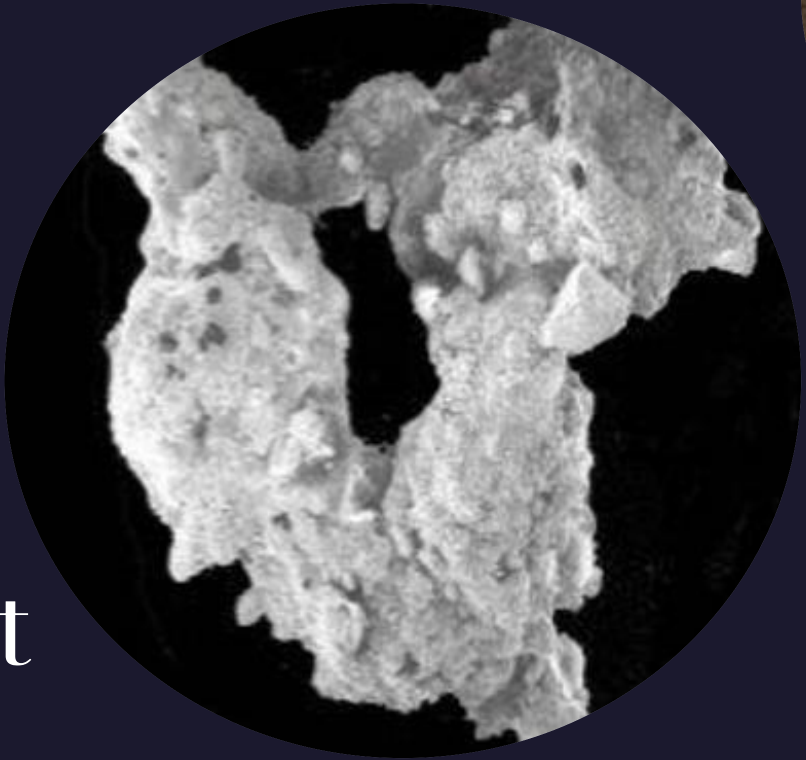
Agenda

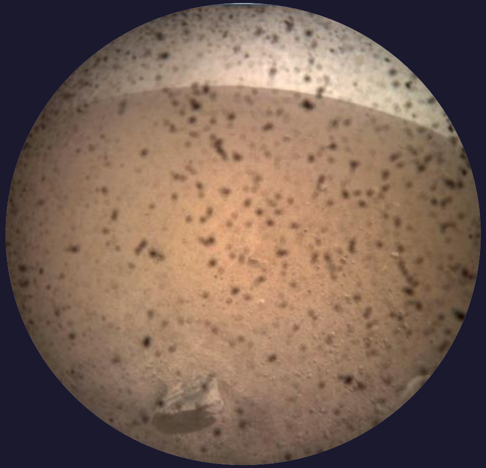
Dust, the dust problem, and dust mitigation

Defining “dust”

Adhesion experiment

Dust accumulation sensor

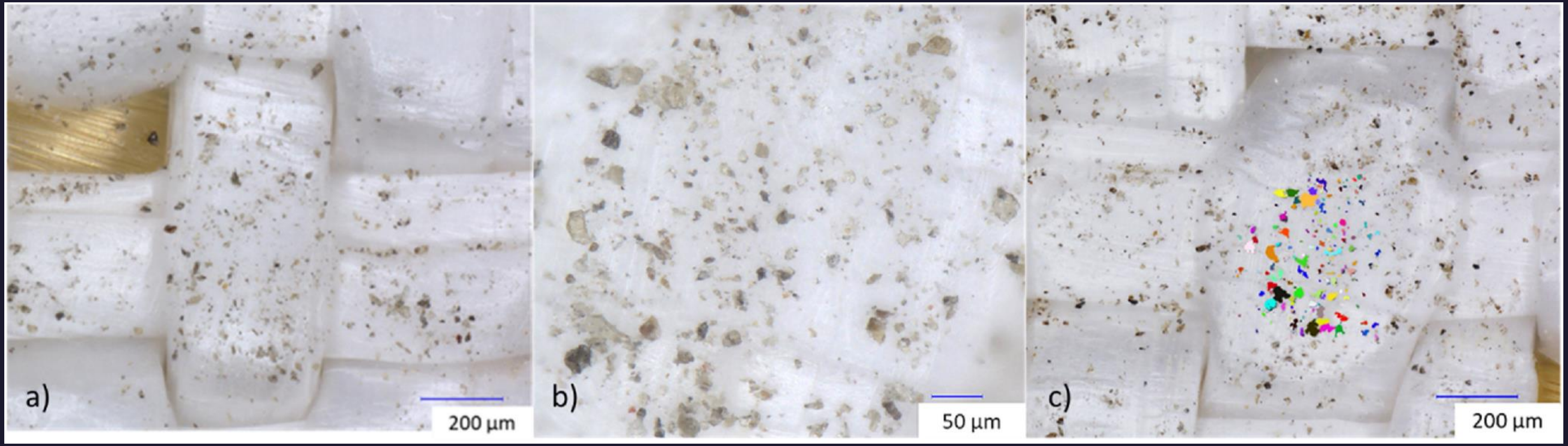




Adhesion Experiment

Goal: Measure adhesion properties of all materials desired to be used on the lunar surface.

Given Experimental Test Stand Success: Full up testing of materials in dusty-plasma chamber would result in a table of material adhesion values vs. simulant types (using multiple simulants).



Images a) and b) show dust that remained on the Ortho fabric after final 400 g rotation (No UV). Image c) shows an example of particle size identification and estimation.

Adhesion Experiment – Past

A semi-quantitative dust adhesion experiment measured <45 µm JSC-1/1A lunar simulant on four materials (bare aluminum, anodized aluminum, Ortho fabric and Z93P painted aluminum)

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Adhesion of lunar simulant dust to materials under simulated lunar environment conditions

Donald C. Barker [a], Andres Olivas [a], Ben Farr [b], Xu Wang [b], Charlie R. Buhler [c], Jeremy Wilson [a], John Mai [a]

Lunar dust adhesion was demonstrated using centripetal force measurement profile.

Measured material adhesion differences between just vacuum (~10^{-6} Torr) versus vacuum with UV light for all four materials.

A quadratic dependence of adhesion force with particle sizes remaining on final rotation was found in the range of 0.1 to 3 µm.

Finest of the fine dust will likely remain attached to all materials planned for use in the lunar environment.

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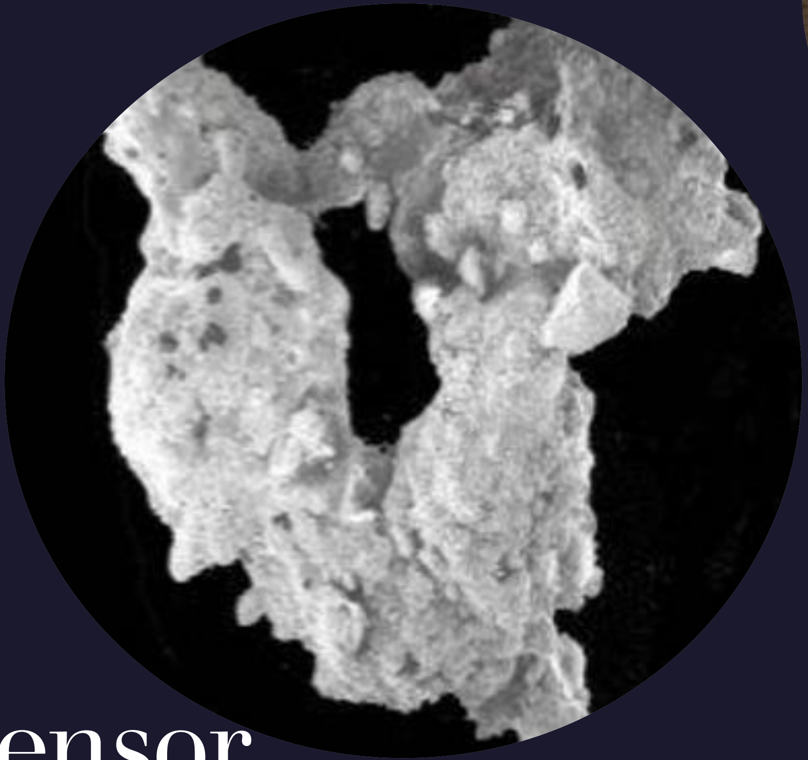
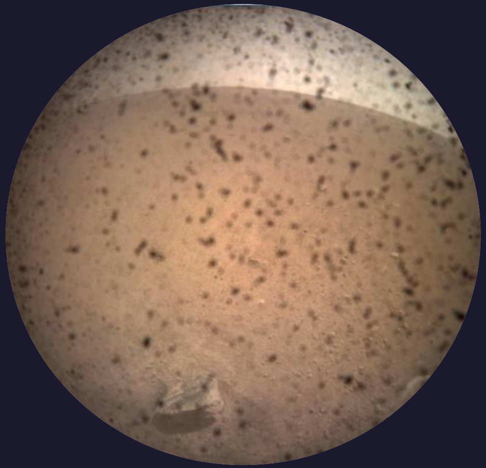
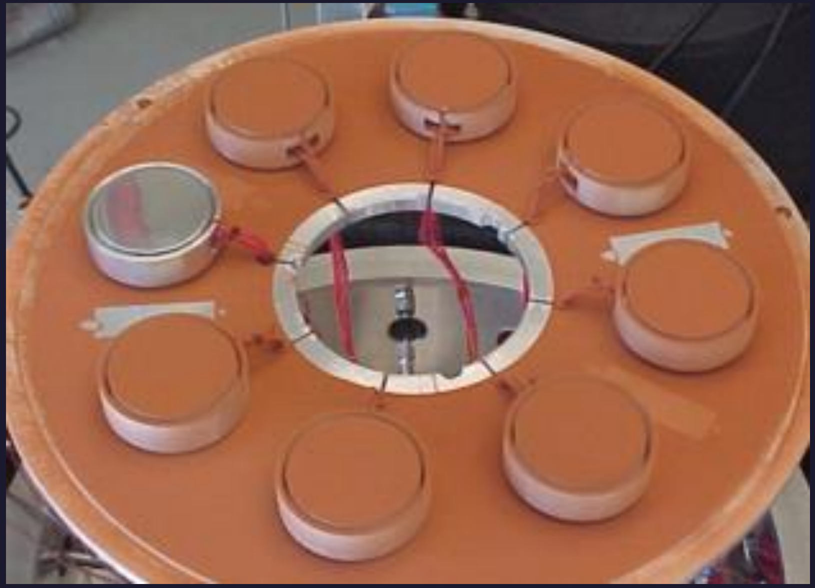
Dust accumulation sensor





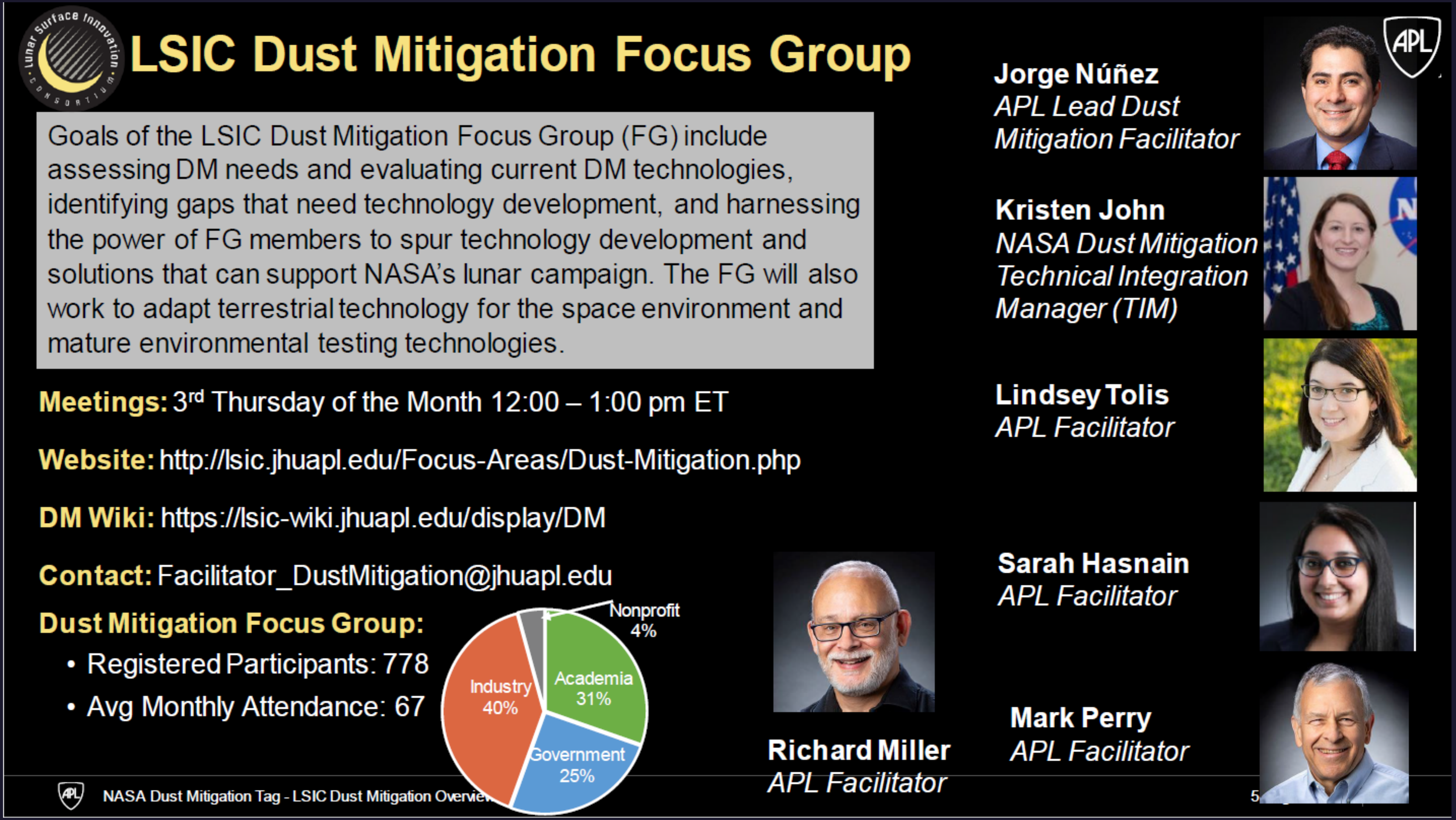
Lunar Dust Level Sensor & Effects on Surfaces (LDES)

- Quantify the effects of lunar dust on external surfaces, materials, and system performance (e.g. radiators); develop a sensor to measure in-situ local dust accumulation using reverse engineering.
- Perform ground testing to determine impacts of dust on radiator heat rejection.
- Test sensor on lunar surface to measure dust accumulation on key systems, study dust transfer on external surfaces, and assess material degradation.



LSIC

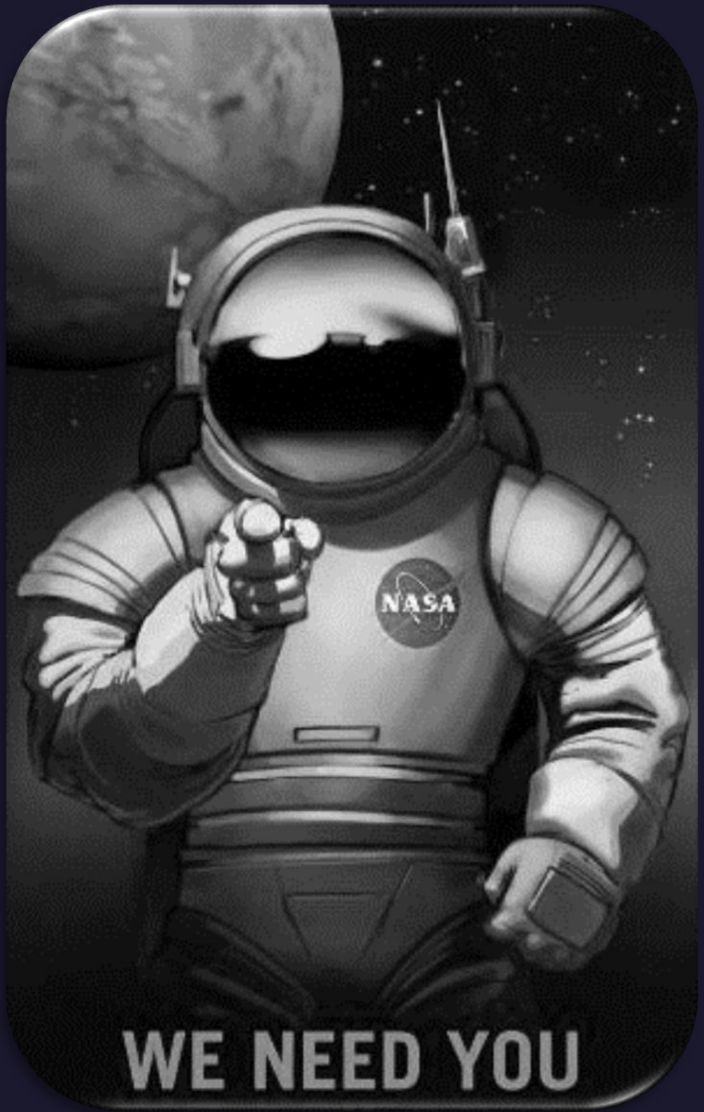
- Provides independent analysis/review of Dust Mitigation technology development.
- NASA's conduit to industry and academia.
- Provides Systems Engineering functions to help perform studies, address needs.



LSIC = Lunar Surface Innovation Consortium

What's next?

- Learn from the contamination control community
- A potential TIM to advocate for closure of these knowledge gaps
- Continue working with projects and programs on their dust mitigation strategies
- Thoughts? Please let me know!



Questions?

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