Survive the ~~Night~~ Dust

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Abstract # 2045 - Dust Mitigation Technology to Enable Survive the Night Capabilities

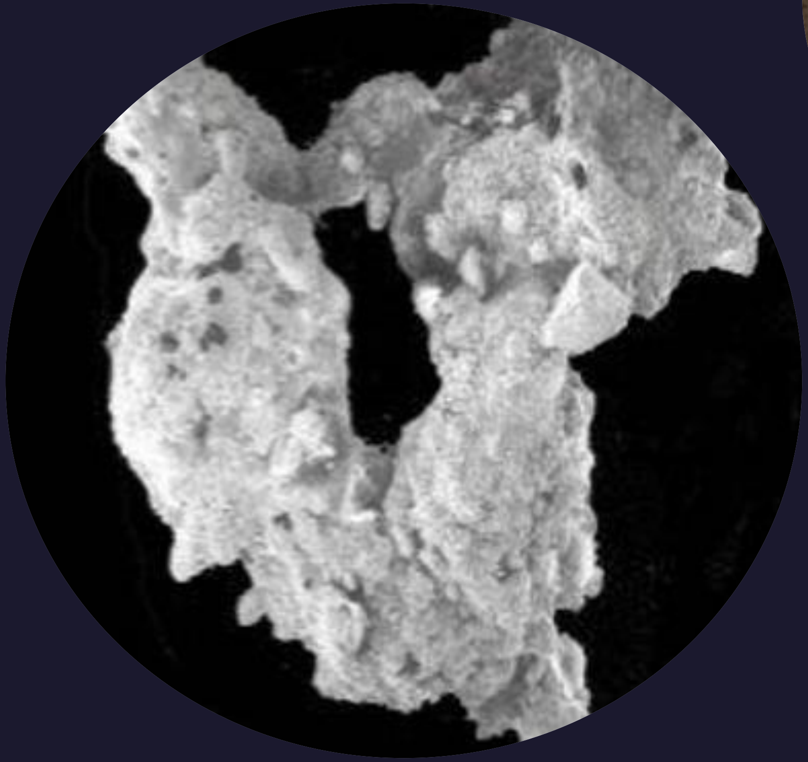

DUST
MITIGATION

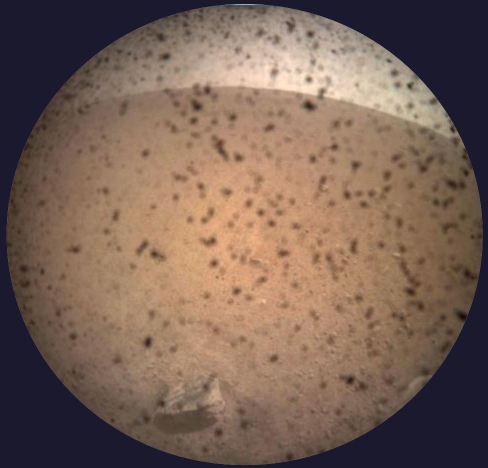
Agenda

The dust problem

Lunar surface failures

Mitigating the dust





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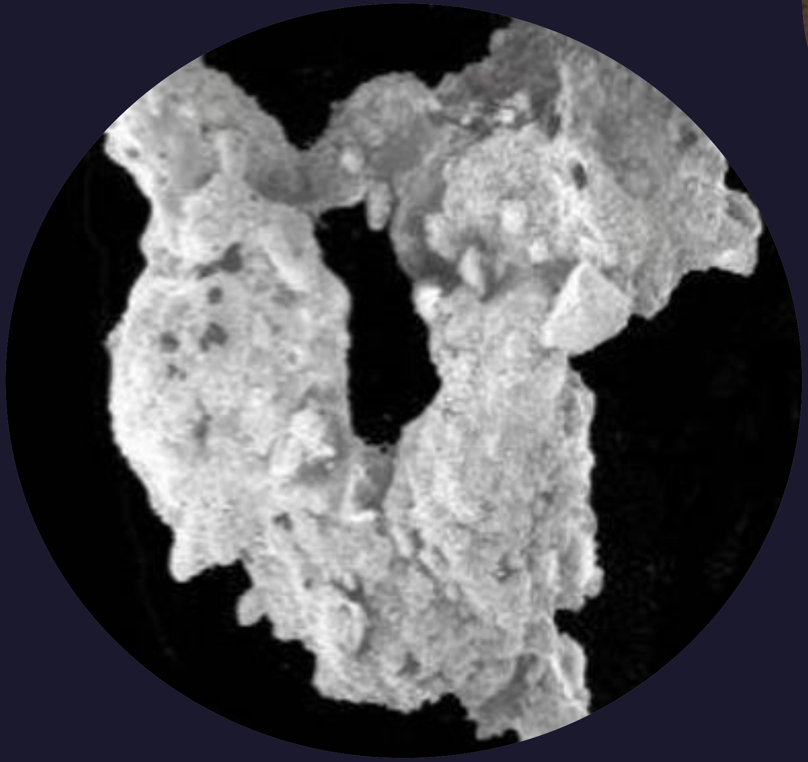
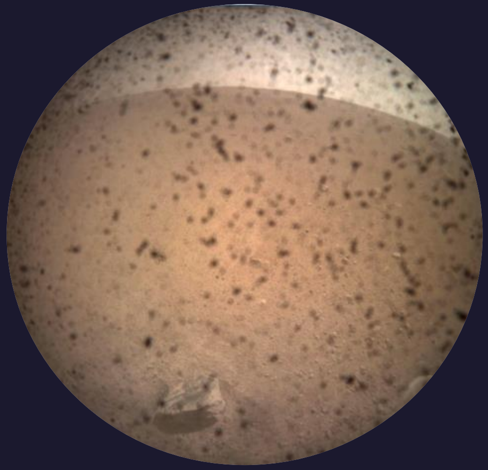
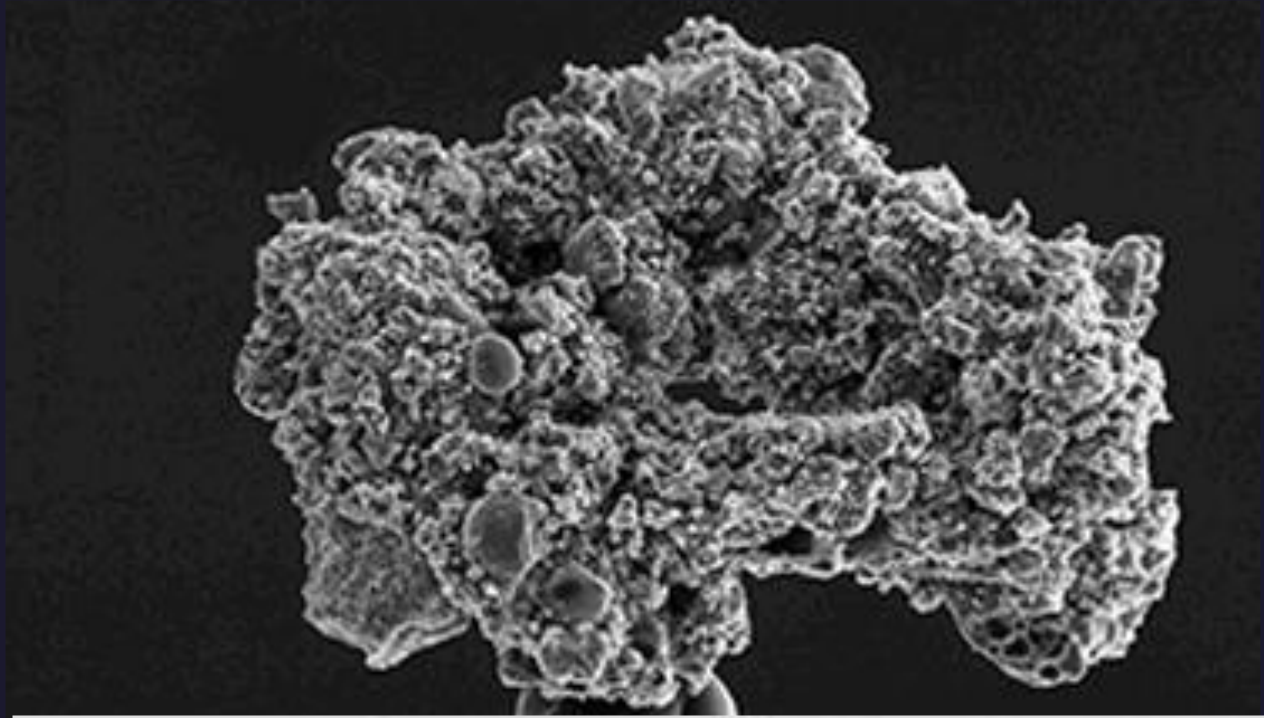
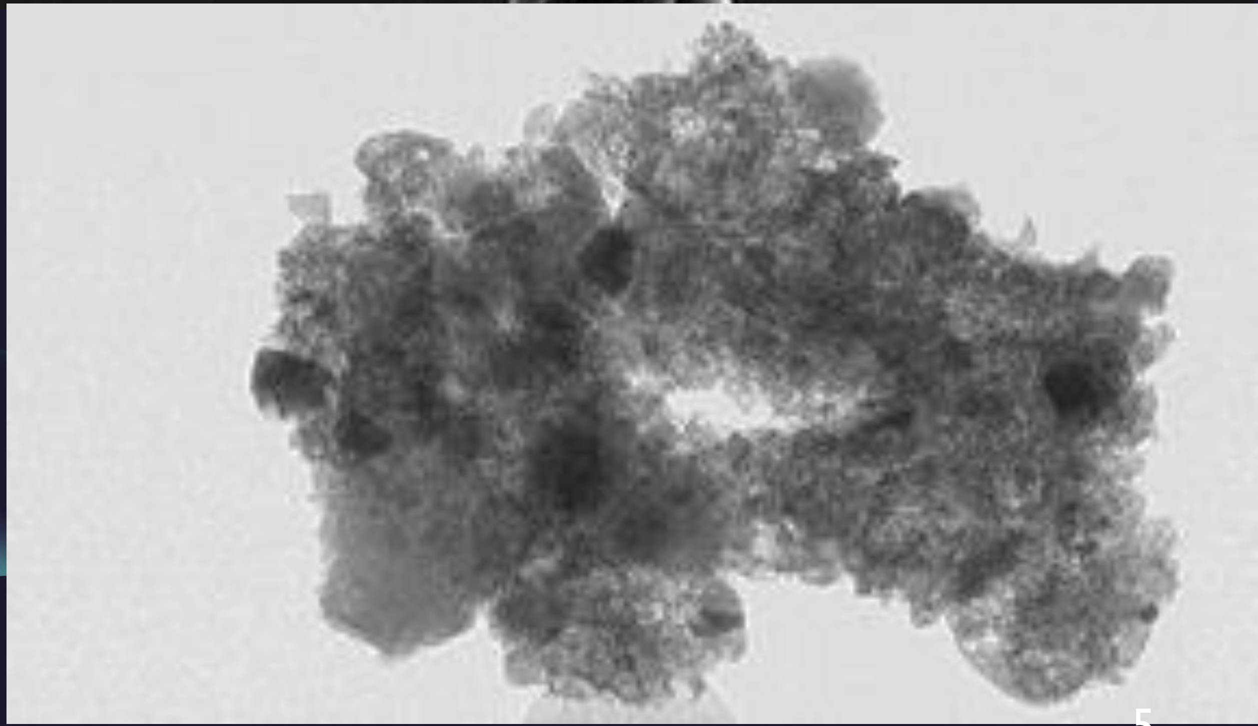




Assumption

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





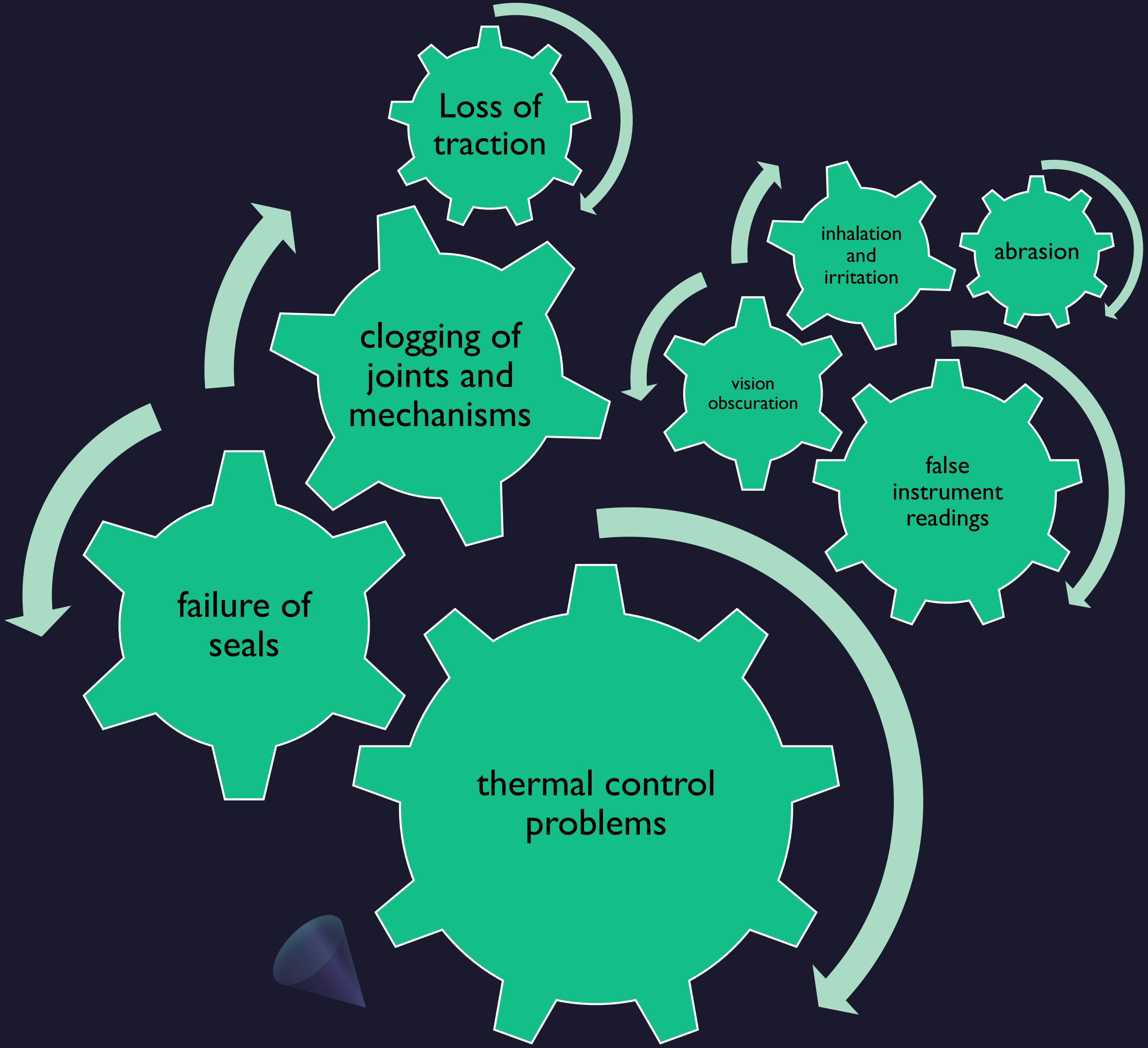
Courtesy of LeHigh University, Department of Materials Science and Engineering

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

Plume-surface interactions and science

- Plume-surface interactions (PSI) occur when a rocket engine exhaust (or other gas jet) interacts with a planetary surface
  - Examples include descent, ascent, or a sampling activity
  - Interactions are complex and an area of active research
- Relevant PSI effects
  - PSI effects will be a large contributor for lunar dust accumulation on any descending vehicle
  - Another effect is limited visibility during descent
  - Alteration of surface through a combination of erosion and diffusion
    - Cratering/erosion directly at the impingement point
      - Effects described in the introduction to Mehta et al. 2011
    - Material ejected away from impingement point
  - Plume heating
  - Exhaust products introduced to environment
    - Discussion of this and other effects in Watkins et al. 2021 (white paper, https://doi.org/10.48550/arXiv.2102.12312)

Ejecta streams visible during Apollo 11 landing.

https://ntrs.nasa.gov/api/citations/20200000979/downloads/20200000979.pdf
https://images.nasa.gov/details-Apollo%2011%2045th%20Anniversary%20Resource%20Reel.html

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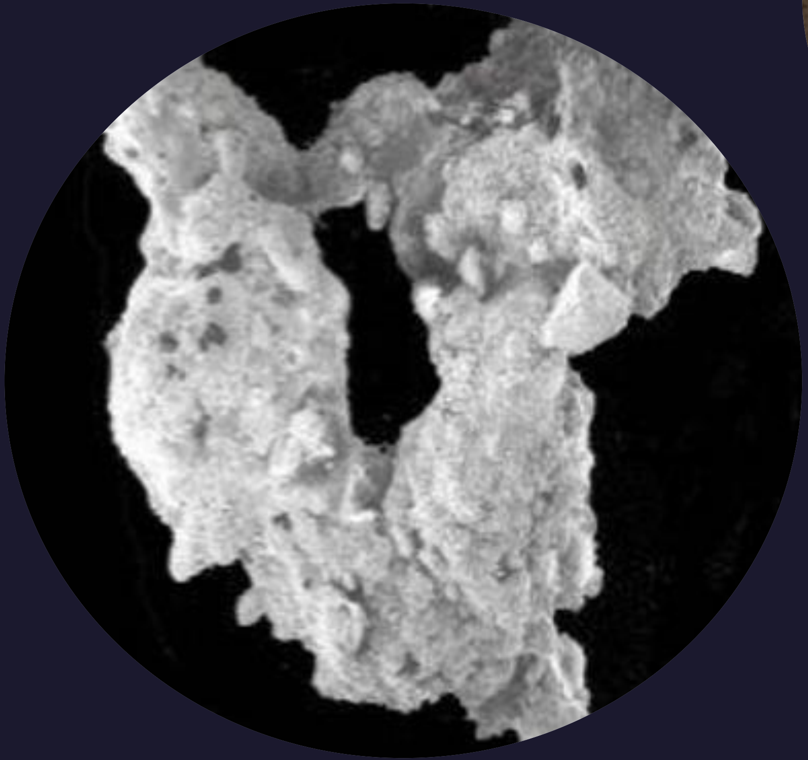
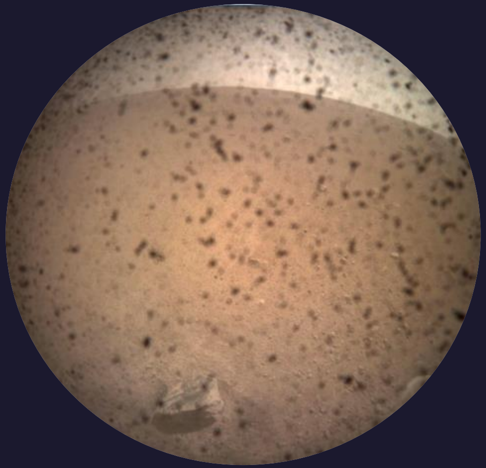




"When large systems fail, it is due to multiple faults that occur together in an unanticipated interaction, creating a chain of events in which the faults grow and evolve."

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 play into surviving the night?

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).

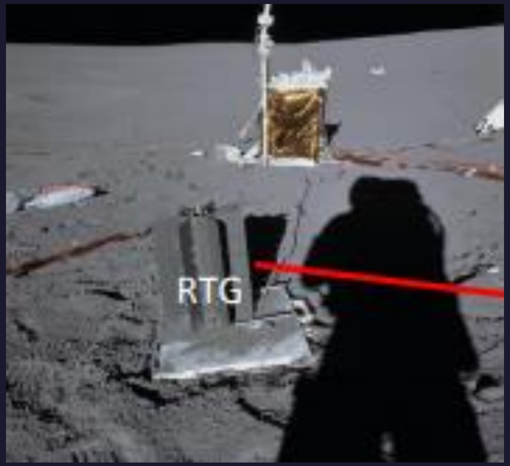
What to do about it?

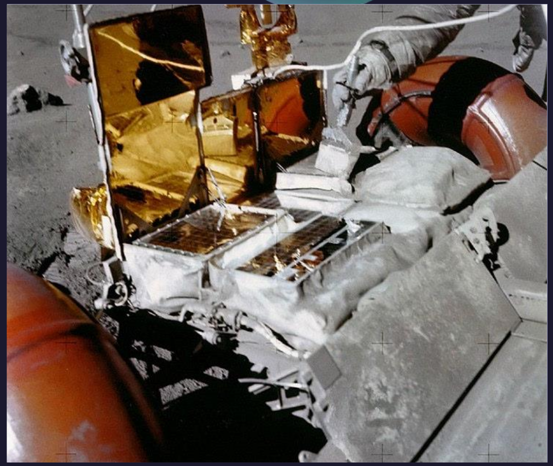
NASA-STD-1008 provides guidance on how to test for this. (Sections on dust testing for thermal & optical testing.)

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

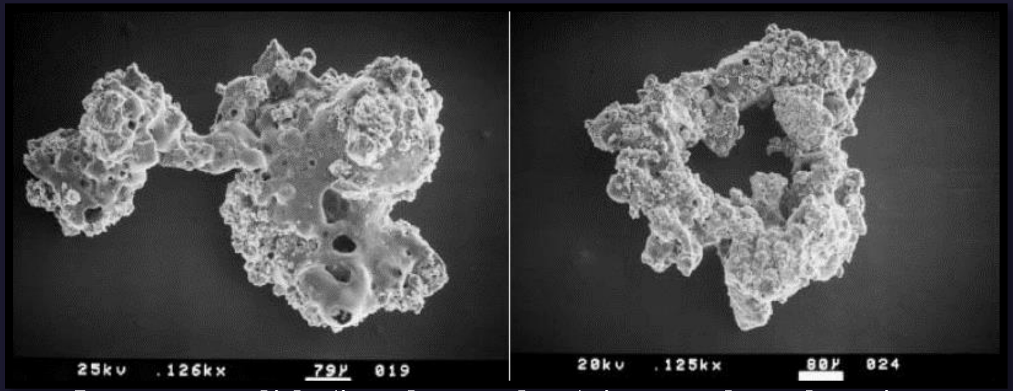
Dust was a problem on the space suits, communications, TV cameras, and other equipment

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

More lessons from Apollo

Apollo 14 Thermal Degradation Sample

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

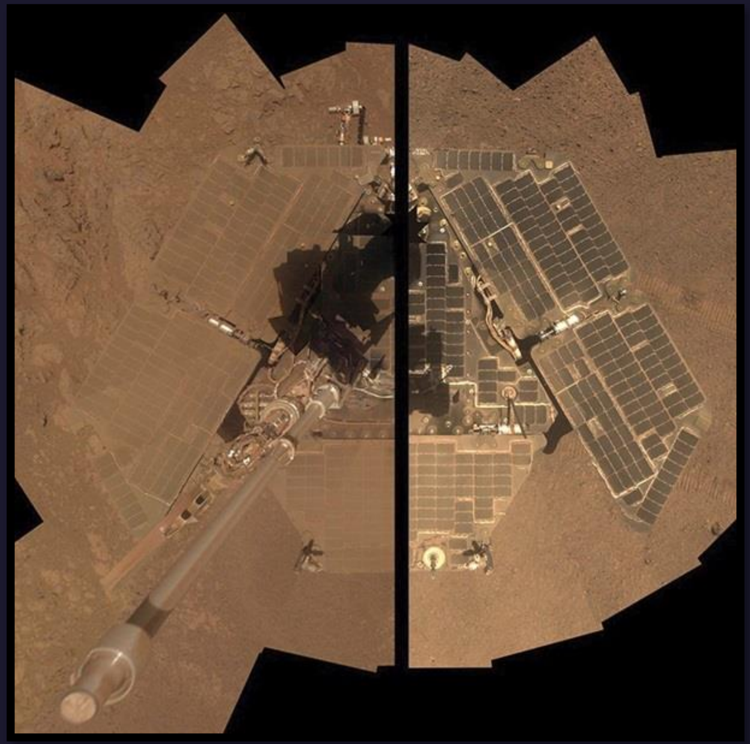


Lunar regolith (i.e. lunar dust) is angular, abrasive, irregular in shape, small in size, & adheres to surfaces

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)

The Story of Lunakhod 2 Rover

Lunokhod means Moonwalker - this was a series of Soviet robotic lunar rovers

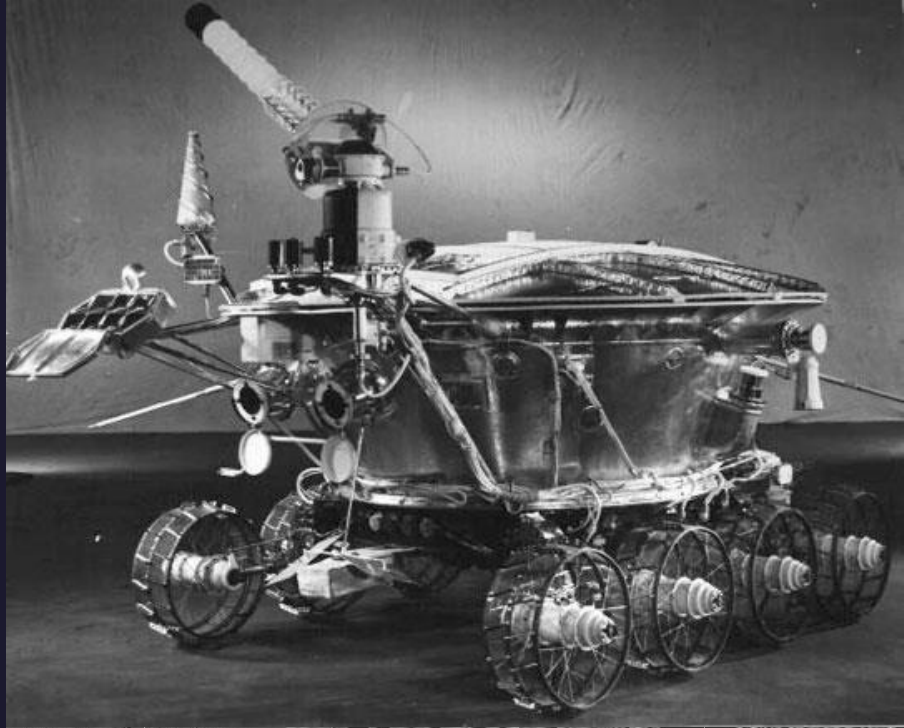
Source: https://www.nasa.gov/mission_pages/LRO/multimedia/lroimages/lroc-20100318.html
Source: https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1973-001A

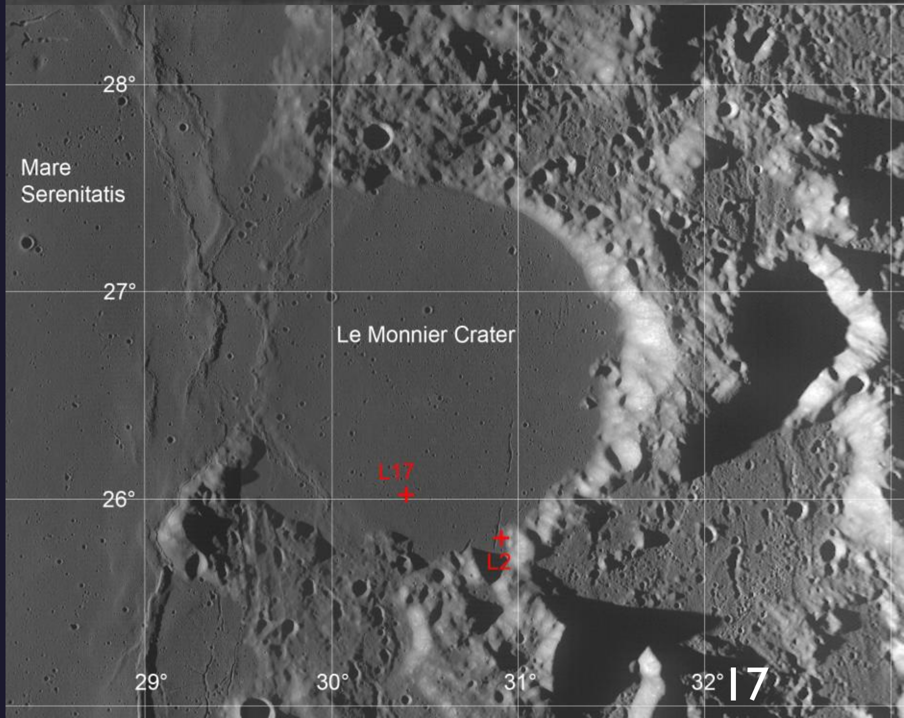
1970: LUNOKHOD 1

- In 1970, Lunokhod 1 landed.
- The rover was driven by solar power during the day; at night it parked and relied on thermal energy from a polonium-210 radioisotope heater to survive the cold (-150°C).
- Lunokhod 1 roved the lunar surface for 10 months.

1973: LUNOKHOD 2

- In 1973, Lunokhod 2 landed.
- It also roved the surface during the day, and parked at night.
- Lunokhod 2 roved the lunar surface for **just 4 months**.

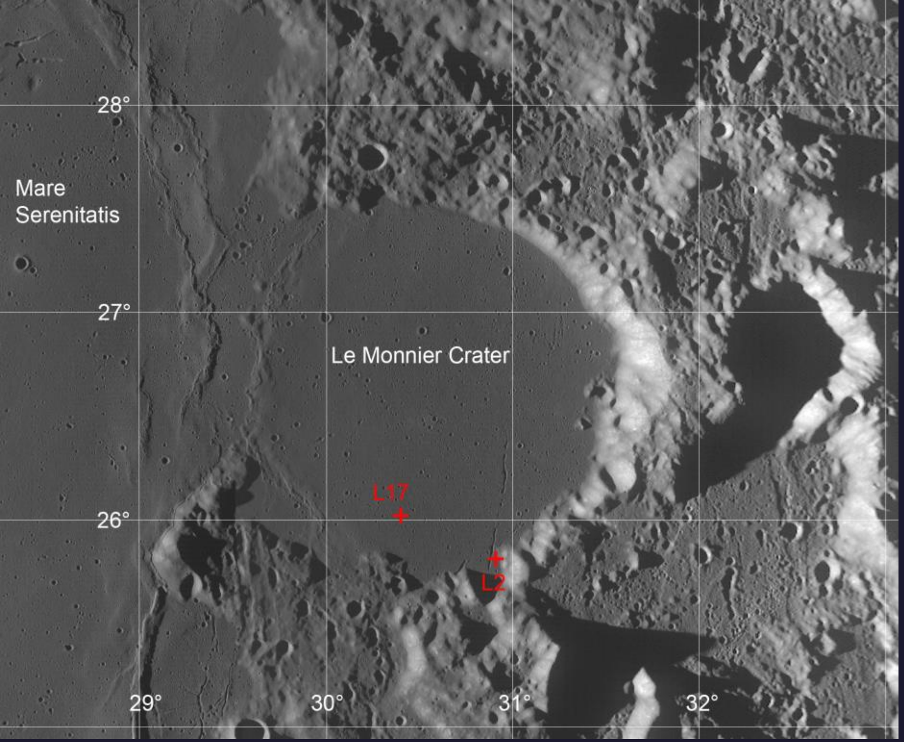




Lunokhod 2 had a collection of science instruments and cameras. Power was supplied by a solar panel on the inside of a round hinged lid which covered the instrument bay, which would charge the batteries when opened. A polonium-210 isotopic heat source was used to keep the rover warm during the lunar nights.

The rover would run during the lunar day, stopping occasionally to recharge its batteries via the solar panels. At night the rover would hibernate until the next sunrise, heated by the radioactive source. Lunokhod 2 operated for about 4 months, covered 37 km of terrain including hilly upland areas and rilles, and sent back 86 panoramic images and over 80,000 TV pictures. Many mechanical tests of the surface, laser ranging measurements, and other experiments were completed during this time.

Source: https://www.nasa.gov/mission_pages/LRO/multimedia/lroimages/lroc-20100318.html
Source: https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1973-001A

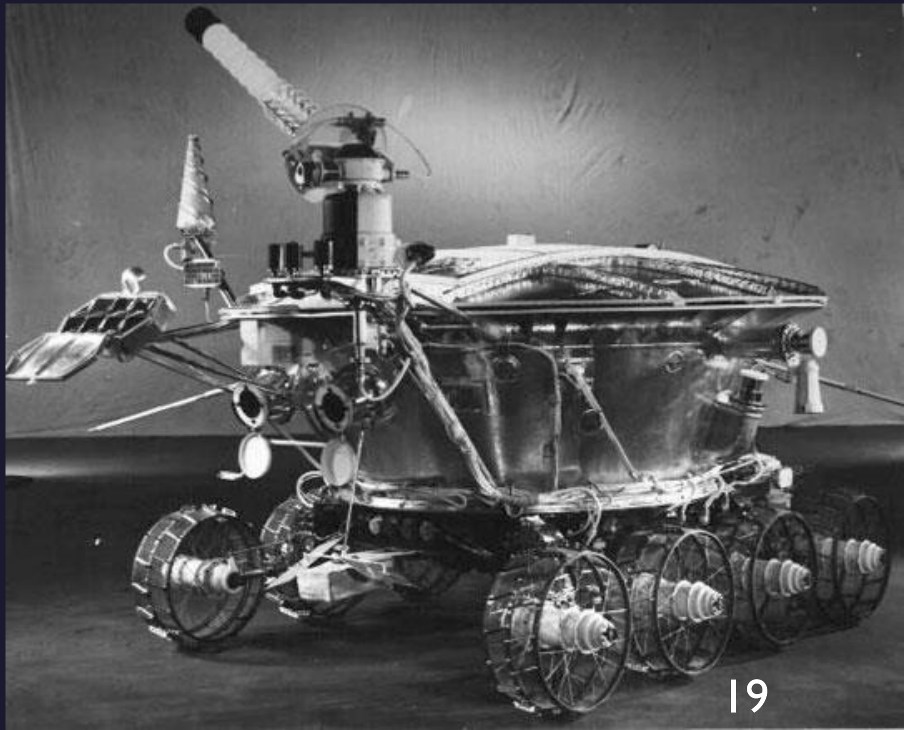


On 20 April 1973, Lunokhod 2 drove into a small crater. When it drove back out, it did not close the lid. Apparently the lid scraped the wall of the crater and deposited dust on its inner surface.

The lid was closed at the end of the lunar day, and the soil in the lid was dumped into the interior of the rover.

When the lid was opened for the next lunar day, the dust on the radiator caused the rover to overheat, and on 10 May communications ceased.

On June 4 it was announced that the program was completed.



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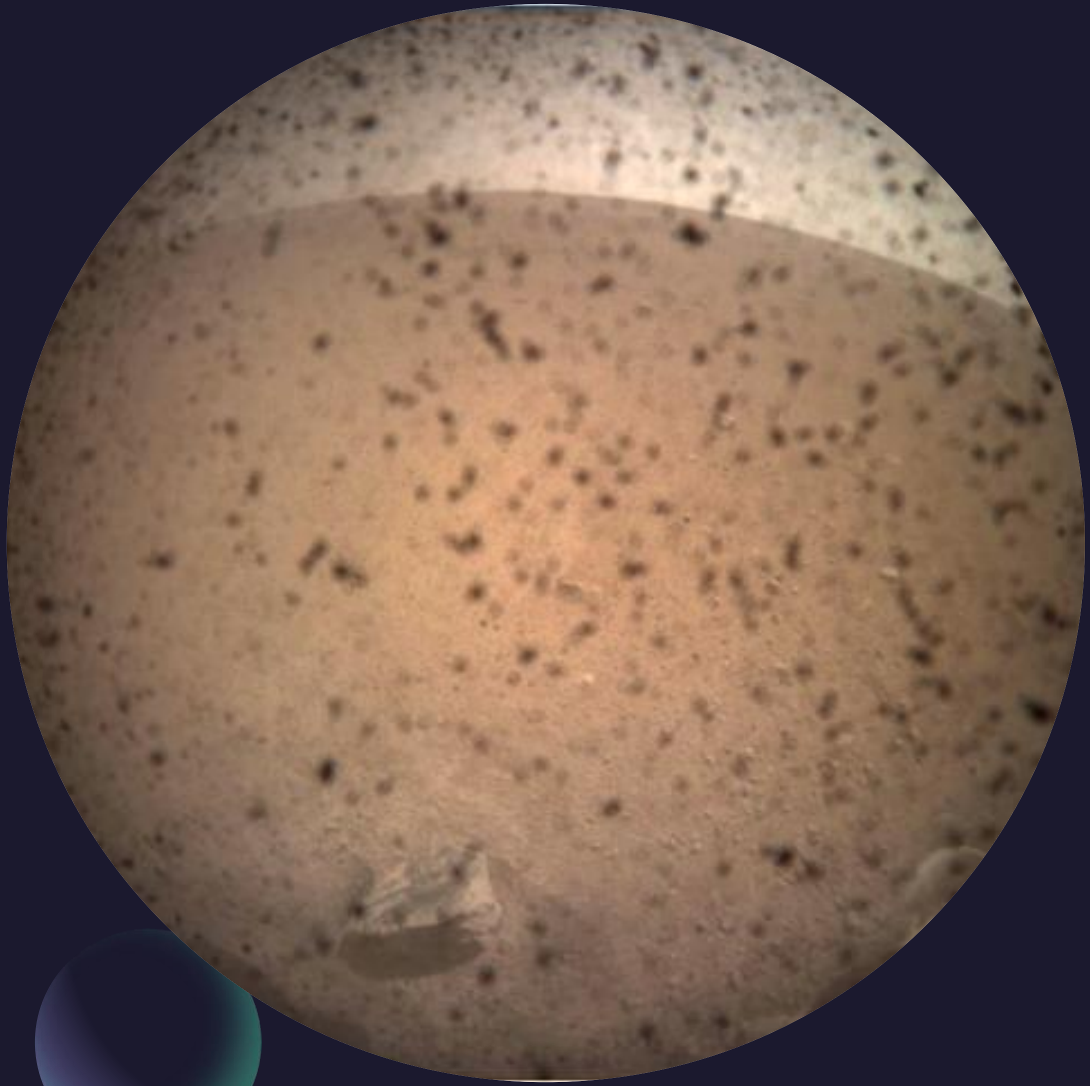
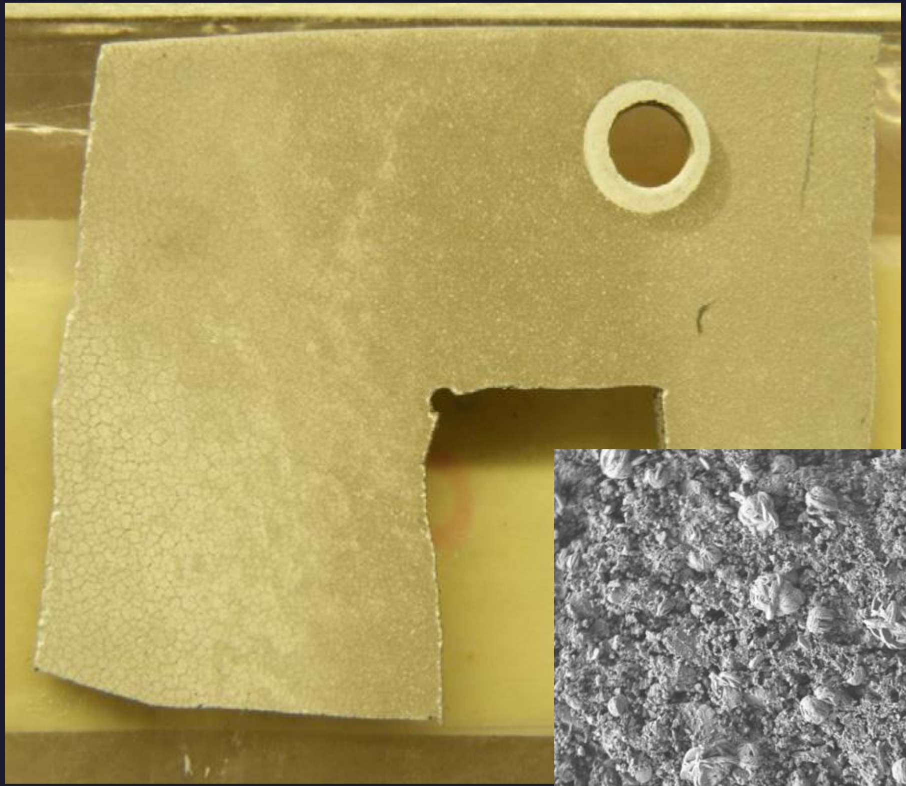
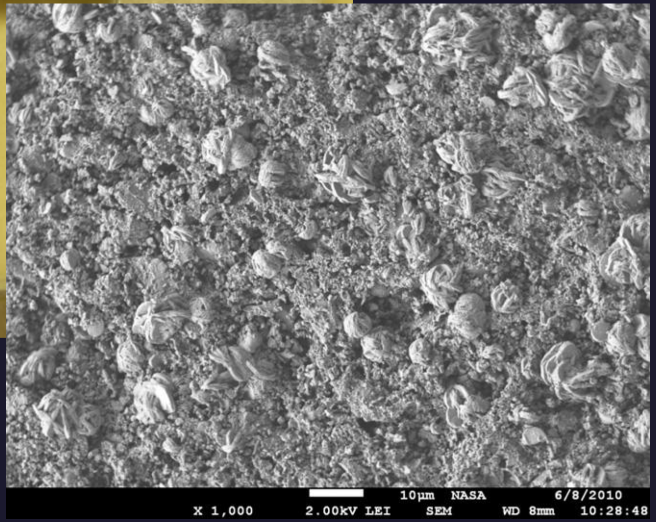
Impacts from PSI



Plume-surface interaction hazards

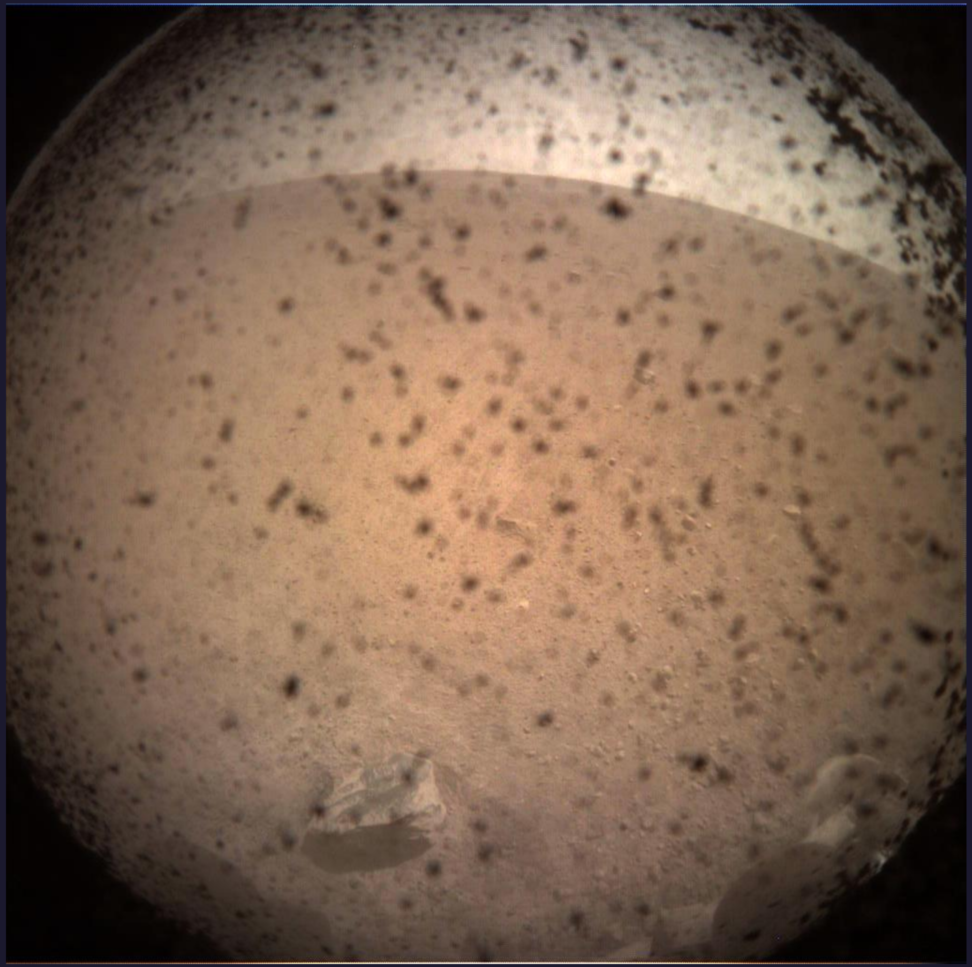
- Regolith ejecta poses a hazard to your spacecraft and to surrounding assets
- Examples
  - Apollo 12 landed near Surveyor 3
    - Scouring, pitting and cracking on Surveyor material coupons (See Immer et al. 2010)
  - Mars Insight
    - Material breached lens cover (see next slide)





A picture of Surveyor III coupon 2050 (top), and an SEM image of coupon 2051 (right). From Immer et al. 2010.

Mars Insight Instrument Context Camera



Images Credit: NASA/JPL-Caltech

Mars Insight's Instrument Context Camera (ICC) before and after lens cover was opened (left and right images, respectively). The ICC was mounted below-deck, and the cover did not prevent all dust from getting on the lens.

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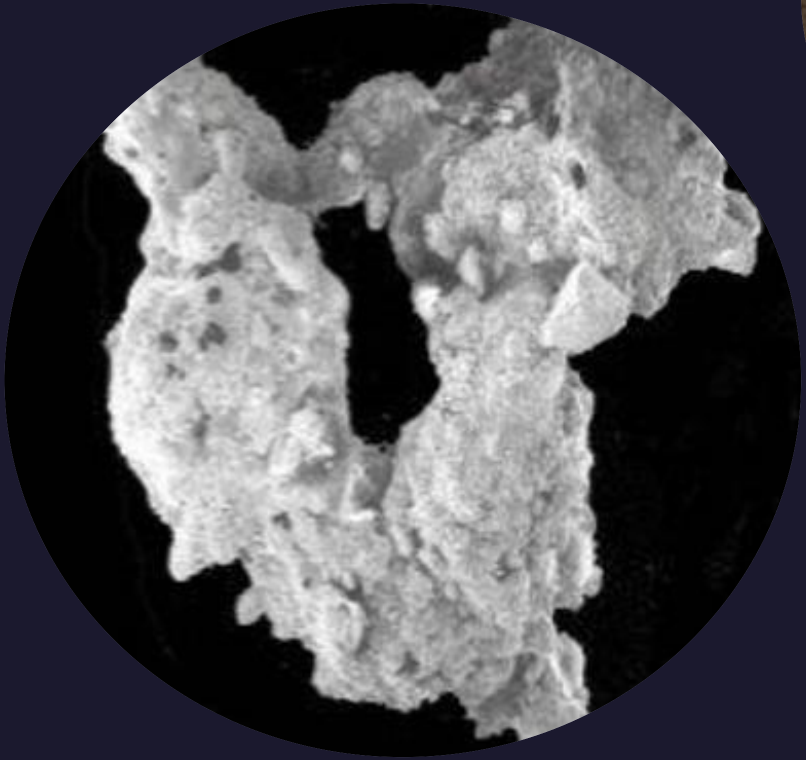
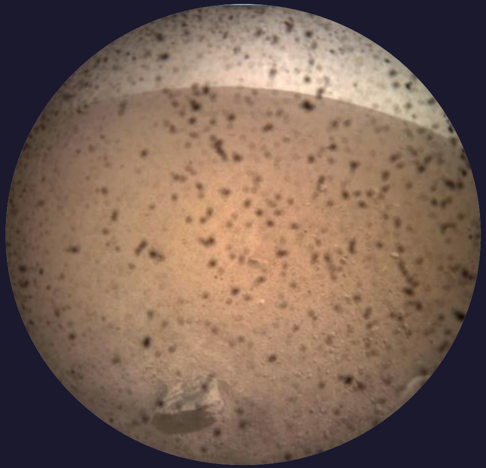
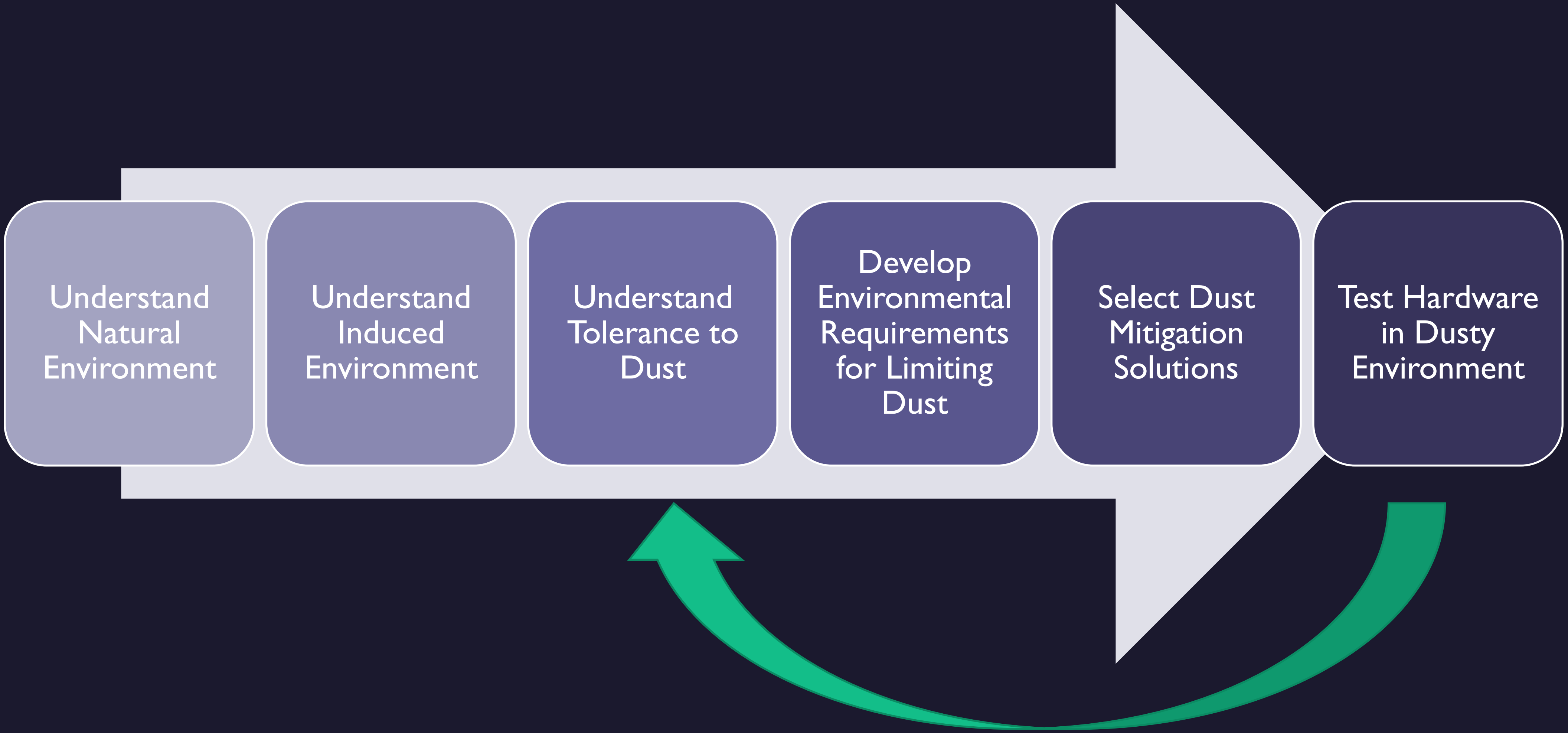




So you're going to the surface?

It sure would be nice if you had a…

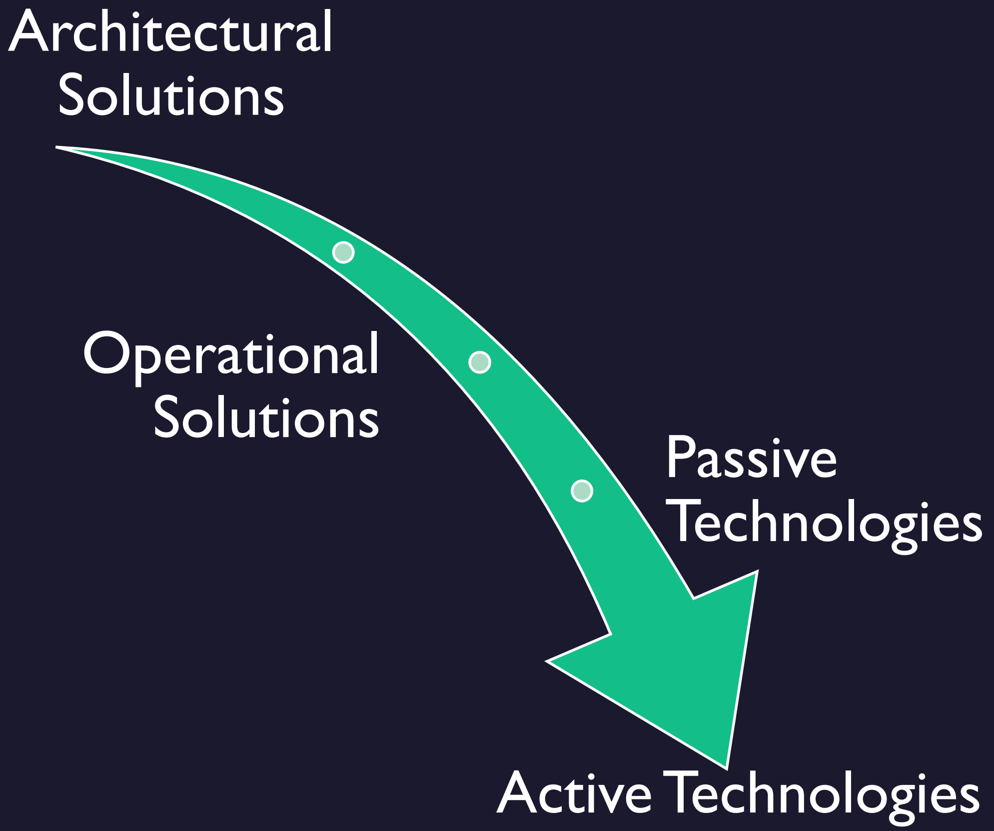
Dust Mitigation Strategy



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 (more on this later)

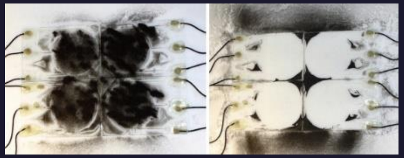
Architectural Solutions

Operational Solutions

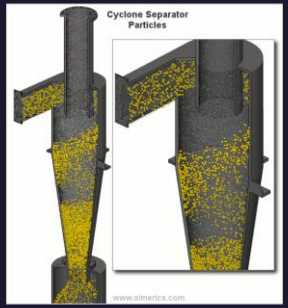
Passive Technologies

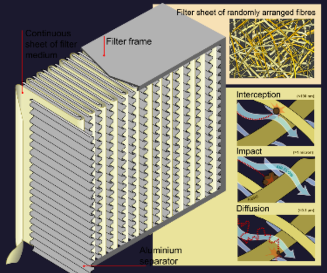
Active Technologies

- Active technology solutions:
- **Electrostatics**
- **Compressed air**
- Vacuums
- **Electrodynamic dust shield**



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





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

Dust mitigation solutions

that will help survive the extreme environment

Dust Mitigation Technology "Swimlanes"

Dust Tolerant Mechanisms

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

Passive Solutions

- Coatings
- Materials
- Filtration
- etc

Active Solutions

- Electrostatics
- Compressed air
- Vacuums
- etc

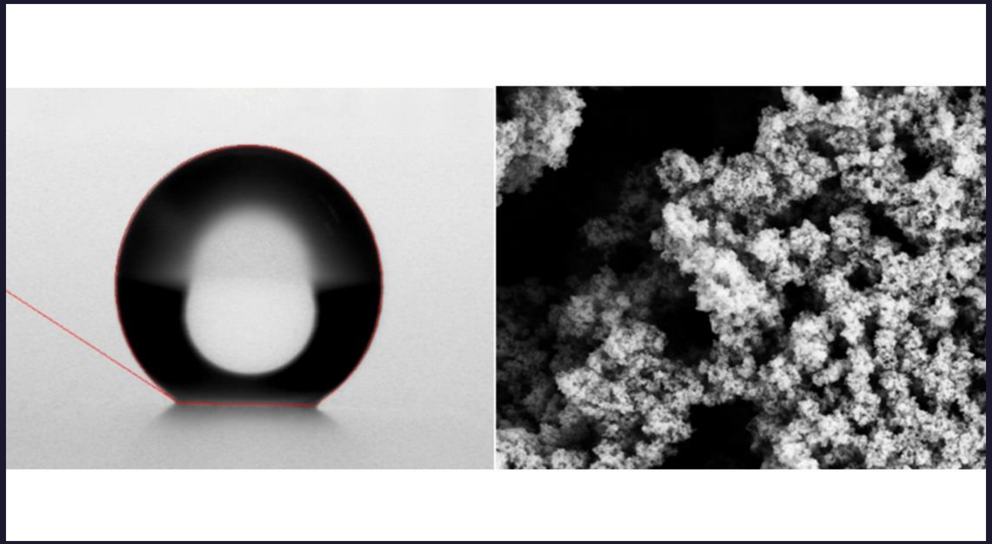
Dust Measurements

- 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)

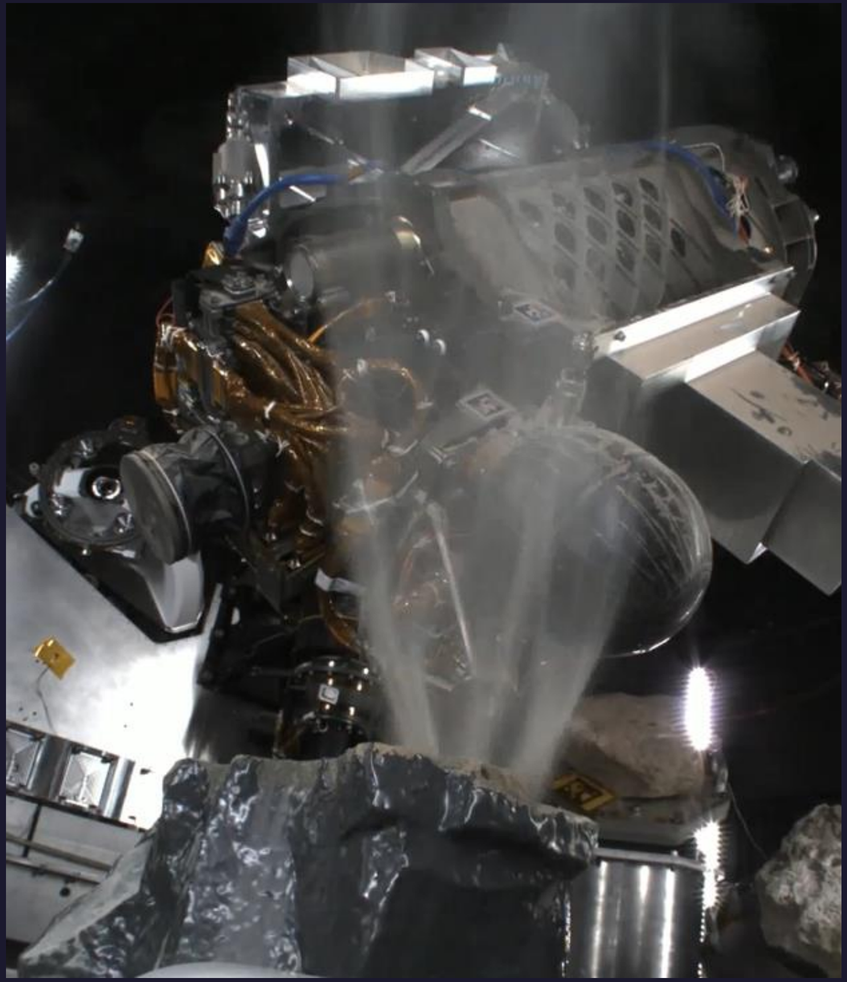
Low Surface Energy Coatings

- Super-hydrophobic coatings
- Can be included on radiators, flexible substrates, transparent surfaces
- Drastically reduced surface forces for easy particle removal



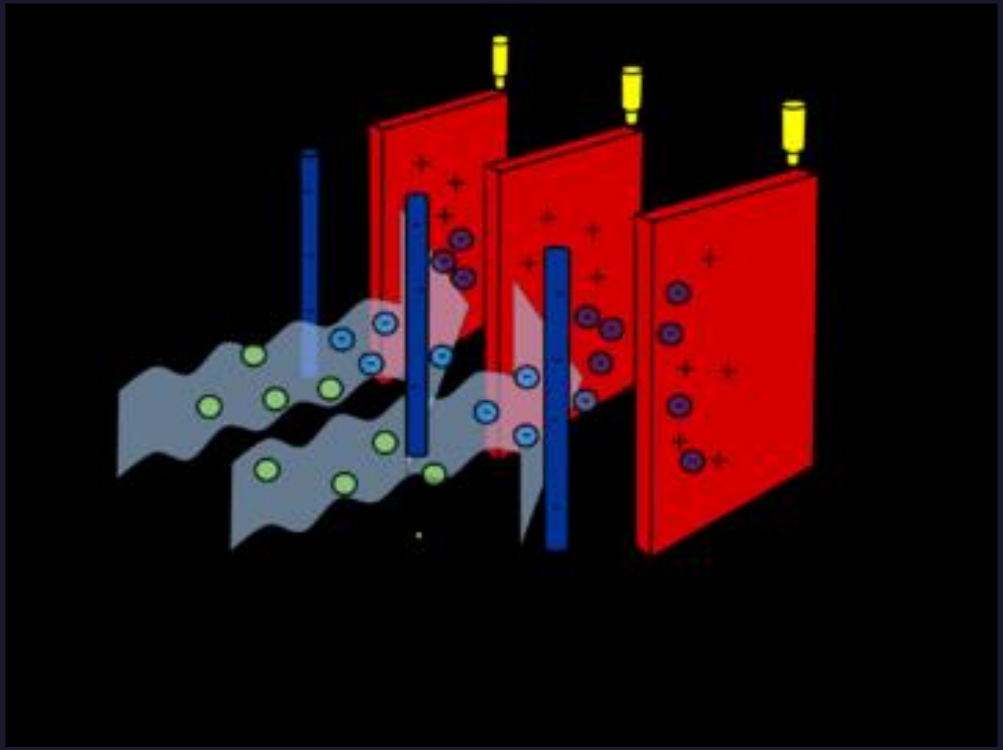
Compressed Gas

- Use spare commodities to blow dust from surfaces
- May require articulation of gas vents
- Can have little control over where dust lands



Electrostatic Precipitation

- Removes particulates from dusty gaseous flows
- ~95-99% clearing efficiency
- Terrestrial applications in cleaning fly ash from power plants
- Current projects for adaptation for ISRU and microbe collection in the upper atmosphere



Common Terrestrial Solutions for Mitigating Fine Particulate

- Brushes
- Wipes
- Tapes/Adhesives
- Filters
- Brushes
- Boot Scrubbers
- Coveralls/Aprons/Garments/Tarps
- Gels/putties
- Soil stabilization
- Coatings
- Monitors/sensors
- Electrostatically
- Vibrationally
- Mechanically

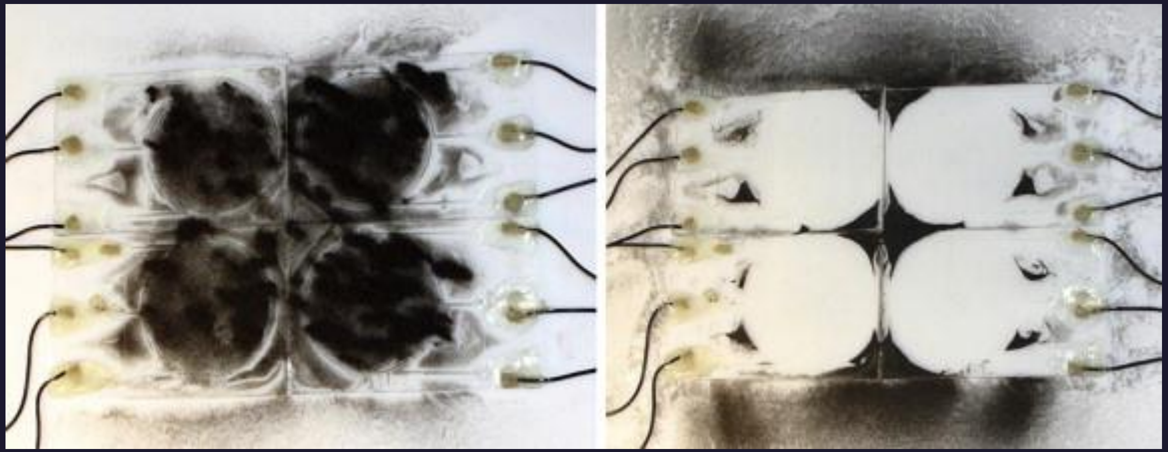
Relevant Industries/Applications: mining, cosmetics, food and baking (e.g. powdered sugar), pharmaceuticals, contamination control, clean rooms, household dust mitigation, living/working in deserts, military desert applications" exterior car cleaning, etc.

A Few NASA Dust Mitigation Solutions

that will help survive the extreme environment

Electrodynamic Dust Shield

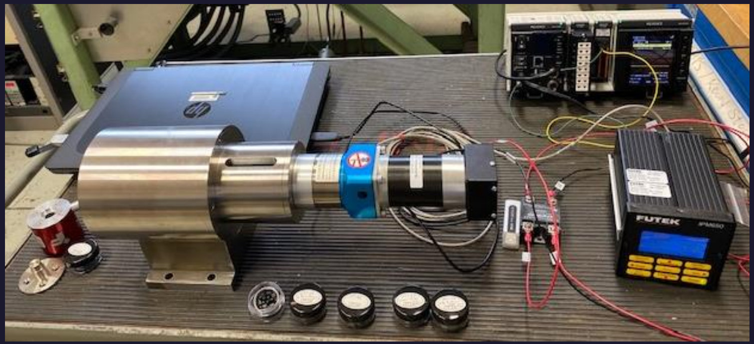
- High voltage pulses 'walk' particles from surfaces
- ~95-99% clearing efficiency
- Can be applied to a number of substrates
  - Camera lenses
  - Viewports
  - Thermal Radiators



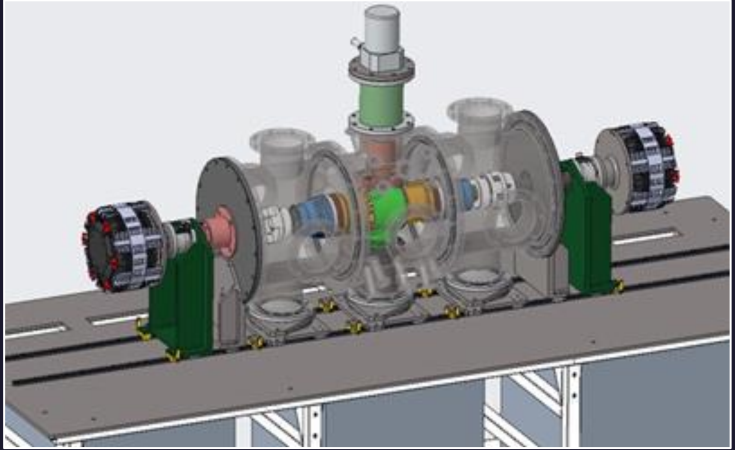
Buhler et. al. https://ntrs.nasa.gov/api/citations/20200000920

Dust Tolerant Mechanisms (DTM) Overview

- **Technology Product Capability**
  - Develop advanced actuator seals for rotary joints and rotary bearing technologies for long-term sustained operation in lunar dust environments
- **Technical Capabilities**
  - Identify candidate rotary seal technologies for a rotary joint
  - Test Volatiles Investigating Polar Exploration Rover (VIPER) Lunar Terrain Vehicle (LTV) rotary actuator seals in an environment
  - Identify and test rotary bearings in a lunar environment
- **Exploration & Science Applicability**
  - Applicable to mechanical rotary joints for space mechanisms
    - Rover wheels
    - Robotic arms
    - Antennas
    - Solar arrays
    - ISRU (drills, buckets, etc.)
  - Current test platforms
    - VIPER and LTV
  - Potential environments necessary
    - Lunar surface, Mars, and Gateway



Bearing Test Rig Benchtop Functional Check

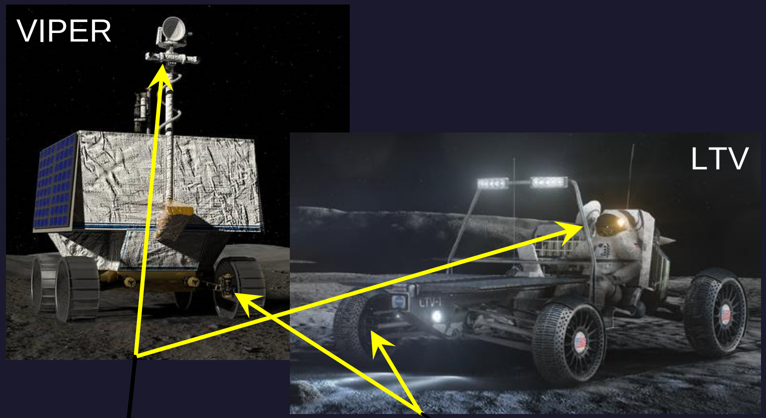


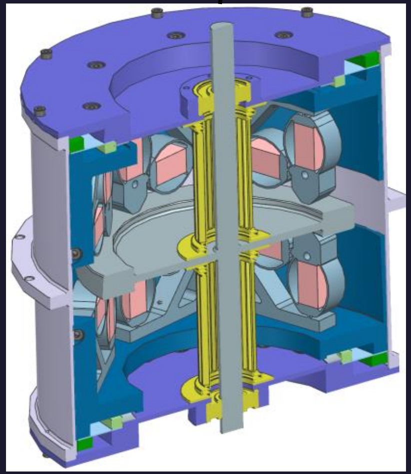
Large dusty, thermal vacuum chamber with dynameter CAD model

Motors for Dusty and Extremely Cold Environments (MDECE)

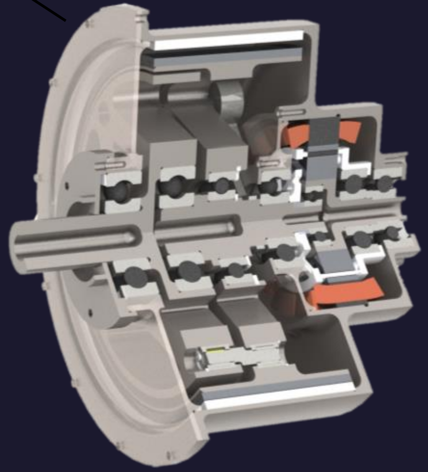
- **Technology Product Capability**
  - Develop an unheated magnetically-geared motor and an unheated piezoelectric motor that can operate continuously for a long duration at an ambient temperature of -243 °C (33 K)
- **Technical Capabilities**
  - Rotational actuators operate for long duration at -243 °C (50+ hours in a lunar permanently shadowed region)
    - Evaluate rotational actuators in controlled, reproducible, representative lunar dust environment
- **Exploration & Science Applicability**
  - Applicable to many space mechanisms
    - Driving & steering rovers
    - Robotic arm motion
    - Pointing of antennas & solar arrays
    - Gimbals
    - Actuating ISRU tools (drills, buckets, etc.)
  - Desirable or required for many high-interest environments
    - Lunar surface, Lunar Gateway
    - Mars, Titan, Europa, Enceladus

Example mechanisms for demonstrating prototypes (NASA KSC)





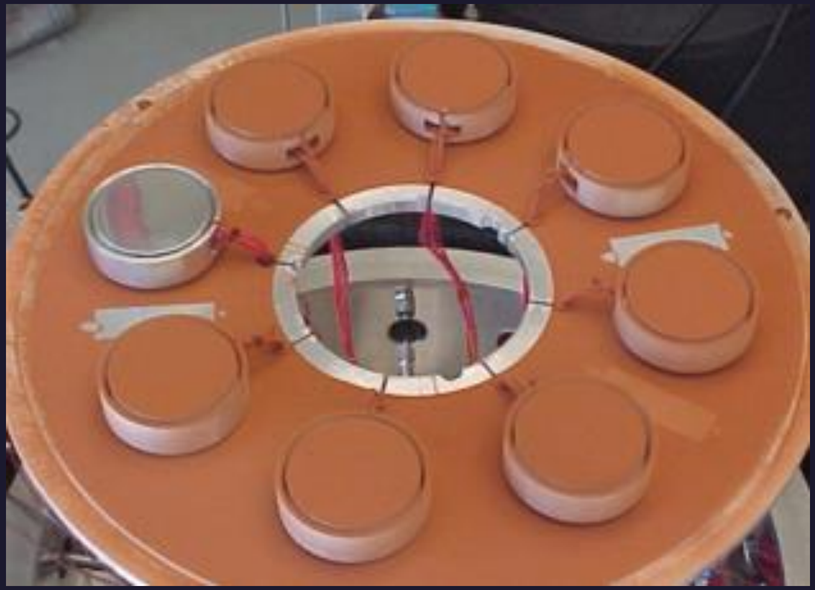
Piezoelectric actuator preliminary design (JPL)



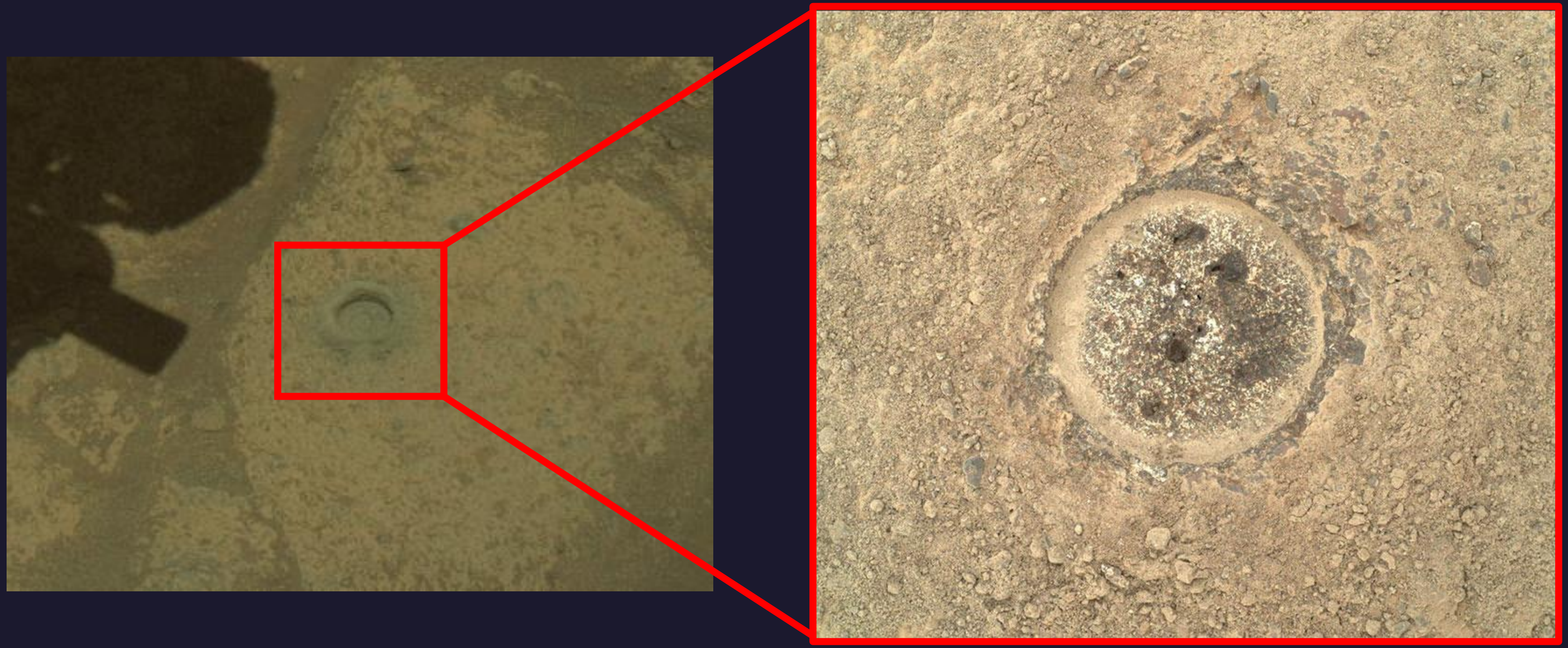
Magnetically-geared actuator preliminary design (NASA GRC & GSFC)

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.



Perseverance gas Dust Removal Tool (gDRT)



- Concept for lunar: design a Lunar Dust Removal Tool (LDRT) that can survive the lunar thermal environment and operate during a lunar surface mission
- The LDRT aims to extend the life of at-risk and sensitive surface equipment (e.g., articulating mechanisms, lenses, sensors, solar arrays) and mitigate the risk of electrostatic discharge due to uneven surface dust accumulation.
- The Lunar Dust Removal Tool (LDRT) is a self-contained and scalable tool that removes surface dust by a variable-strength flow of purge gas. It could be mounted on the tool side of an interchangeable end-effector of an articulating arm.
- See Jens (Design, Development and Qualification of a Gas-Based Dust Removal Tool for Mars Exploration Missions) 978-1-5090-1613-6/17/31.00c 2018 IEEE

Other NASA Dust Mitigation Projects

- Electrostatic Controlled Spray - Develop concepts to mitigate lunar dust hazards, enabling affordable, sustained operations both on the lunar surface and with transfers to and from Lunar Gateway or other orbital platforms.
- Dust Tolerant Seals - GRC Seal Team has extensive experience developing, testing, and characterizing seals for extreme environments including space-rated vacuum seals
- SCALPSS - Stereo imaging of plume surface interactions through CLPS lunar landing with high altitude stereo imaging prior to interactions onset. Data to be used to validate computational models needed for lander design nearby asset safety.
- Lo-DuSST – Lunar Occupancy Dust-Surface Separation Technology - Develop technologies for coupled passive and active methods for reducing lunar dust adherence to solar panel arrays, confined systems, drive shafts, and ISRU equipment.
- Patch Plate – Develop and demonstrate passive technologies for reducing the adherence of lunar dust to surfaces.
- DECT – Establish *NASA Lunar Dust Classification Standards* to address requirements, integration, architecture, and technology developer needs; perform integrated tests in relevant environments.
- Lunar Simulant Development – Simulant development; supply a variety of low, moderate, and high-fidelity simulants to projects for testing purposes; provide projects with lunar simulant expertise and advice.

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

Great Resources

Lunar Dust on Heat Rejection System Surfaces: Problems and Prospects by James Gaier

Thermal Optical Properties of Lunar Dust Simulants and Their Constituents by James Gaier

The Effect of Simulated Lunar Dust on the Absorptivity, Emissivity, and Operating Temperature on AZ–93 and Ag/FEP Thermal Control Surfaces by James Gaier et al

The Effects of Lunar Dust on EVA Systems During the Apollo Missions by James R. Gaier (to get a big picture feel of Apollo impacts)

The Impact of Dust on Lunar Surface Equipment during Apollo by James Gaier (to get a big picture feel of Apollo impacts in 10 minutes)

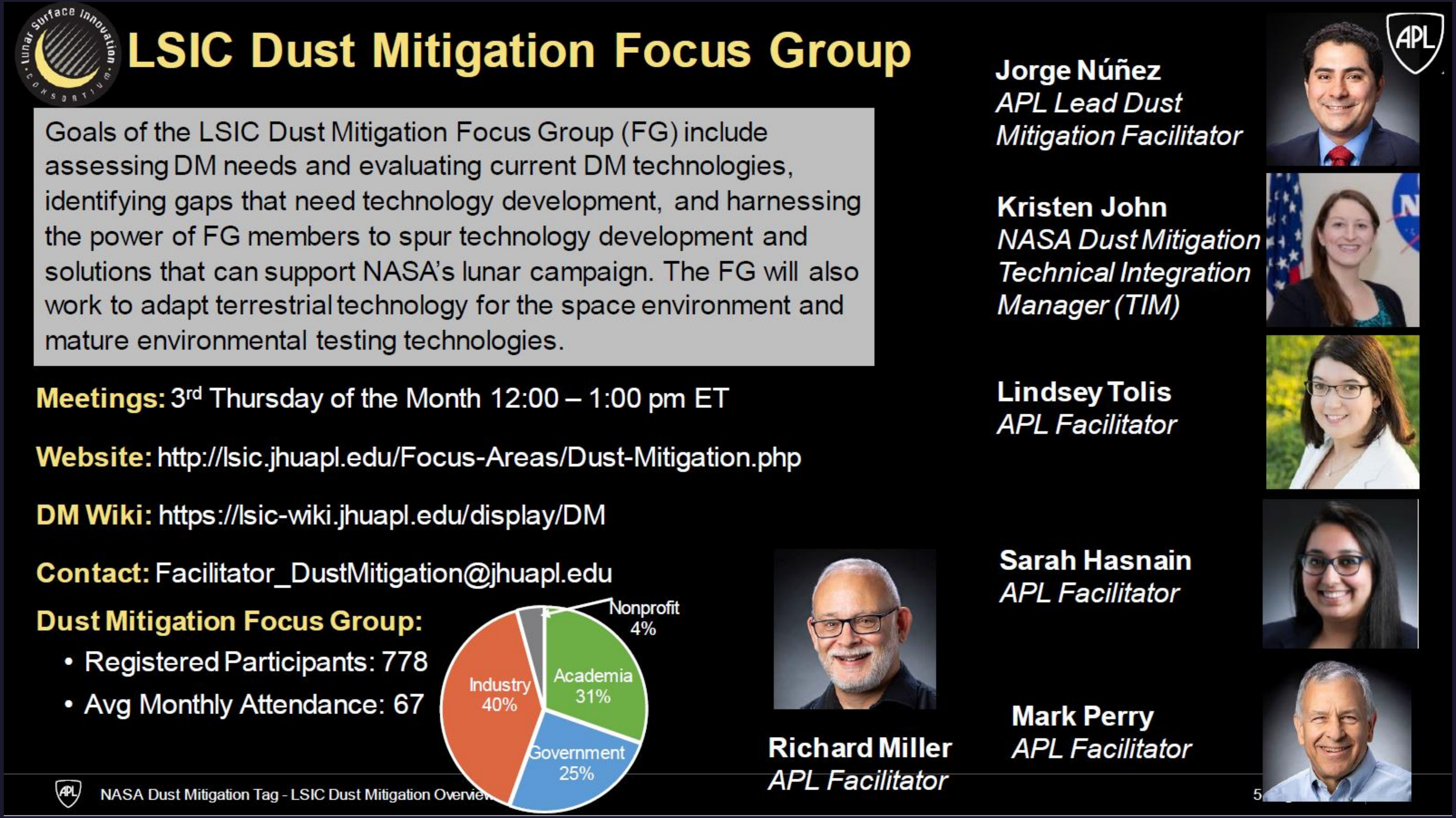
Dust Mitigation Gap Assessmen, ISECG, 2016

Lunar Dust Mitigation: A Guide and Reference, First Edition (2022) by Phil Abel et al (to get a feel for what to do about dust mitigation, specifically, for StN, look at the sections on Optical Surfaces & Radiators/Thermal Control Surfaces)

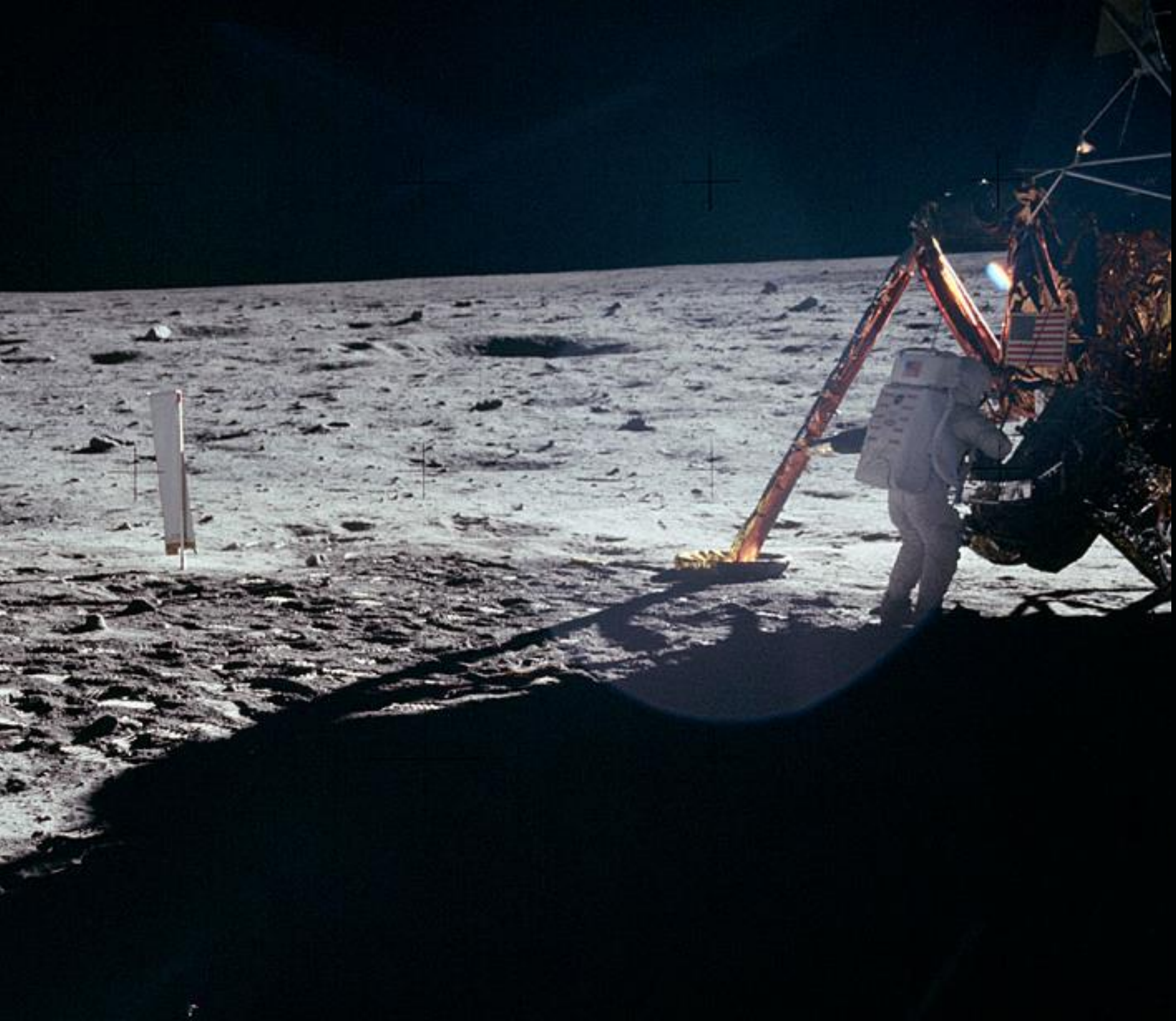
NASA-STD-1008 - Classifications and Requirements for Testing Systems and Hardware to be Exposed to Dust in Planetary Environments (if you will be

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



- Neil A. Armstrong Tranquility Base (Apollo 11), July 20, 1969

"I'm at the foot of the ladder. The LM [Lunar Module] footpads are only depressed in the surface about 1 or 2 inches, although the surface appears to be very, very fine-grained, as you get close to it, it's almost like a powder; down there, it's very fine.... I'm going to step off the LM now.

That's one small step for (a) man. One giant leap for mankind.

As the—The surface is fine and powdery. I can—I can pick it up loosely with my toe. It does adhere in fine layers like powdered charcoal to the sole and sides of my boots. I only go in a small fraction of an inch. Maybe an eighth of an inch, but I can see the footprints of my boots and the treads in the fine sandy particles."

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Questions?

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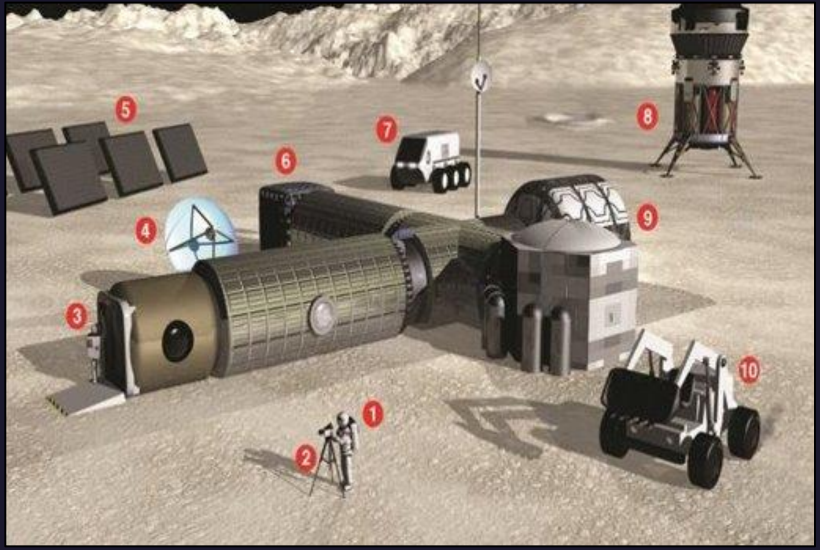
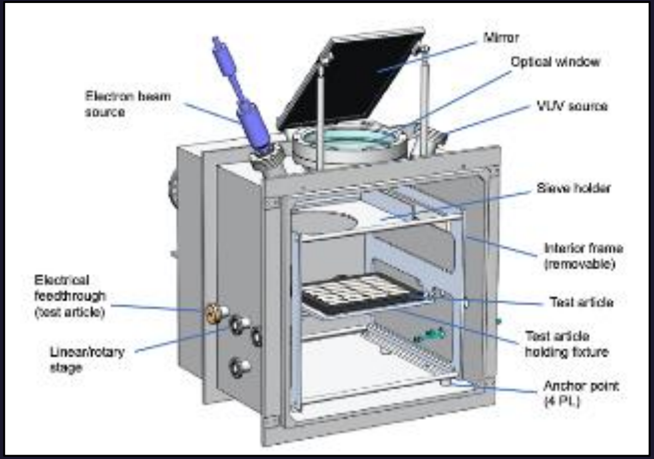
Back-up

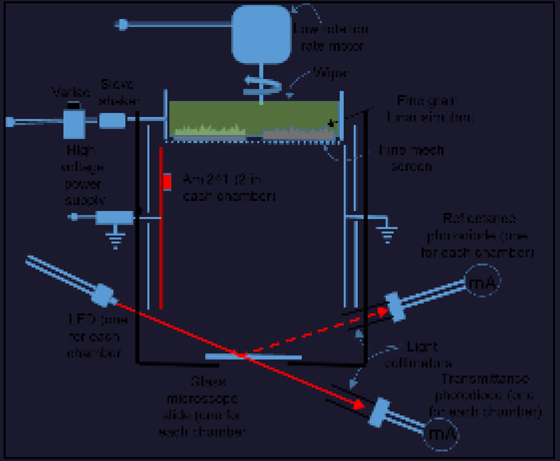
Lunar Occupancy Dust-Surface Separation Technologies (LO-DuSST) Overview

- **Technology Product Capability**
  - Technologies for coupled passive and active methods for reducing lunar dust adherence to solar panel arrays, confined systems, drive shafts, and ISRU equipment
- **Technical Capabilities**
  - Reduction in particle retention
  - Retention of power generation in solar arrays
  - Protection of equipment near landing sites
  - Reduce long term wear on surfaces
  - Robust coatings to reduce energy requirements for active dust mitigation technologies
  - Enabling mobile dust removal from various equipment
- **Exploration & Science Applicability**
  - Applicable to equipment surfaces
    - Solar arrays, power systems, radiators
    - Axels, bearings, drive shafts, rover wheels, rover arms
    - Space suit visors and fabric
    - ISRU (drills, buckets, etc)
  - Potential environments
    - Lunar surface, Lunar Gateway, Mars, Earth





Solar Panel Test Chamber



Initial concept design of attraction/repulsion chamber

Patch Plate Materials Compatibility Assessment Overview

- Technology Product Capability
  - Technologies for passively reducing lunar dust adherence to surfaces addresses the technology gap to efficiently and effectively remove lunar dust
- Technical Capabilities
  - Reduction in particle retention
  - Robust coatings
  - Demonstration and evaluation of saltation sensor (SALT) and optical microscope (OM)
- Exploration & Science Applicability
  - Applicable to equipment surfaces and extravehicular mobility units (EMU)
    - Power systems, Solar arrays, Sensor lenses
    - Rovers, Landers, Antennas, Radiators
    - Space suits, visors
  - Potential environments
    - Lunar surface
    - Lunar Gateway
    - Mars
  - NASA missions targeted
    - HEOMD, SMD, commercial landers


Lunar Dust Adhesion Bell jar at Glenn Research Center


Sample pair after exposure to nitrogen jet


Sample pair under nitrogen jets after dusting, prior to nitrogen jet

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."
- "Since this NASA Technical Standard was written to accommodate hardware and systems regardless of size or complexity, **the requirements leave considerable latitude for interpretation**."

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

Trade names and trademarks are used in this NASA Technical Standard for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by NASA.

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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.

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/

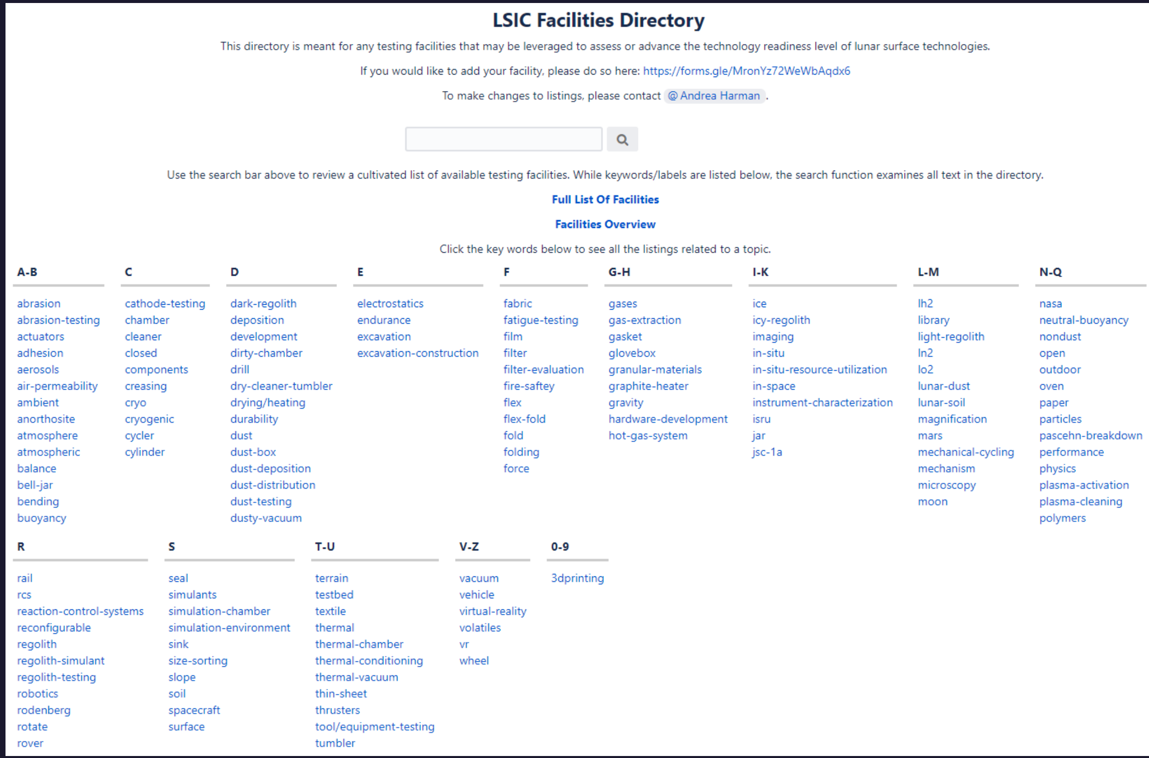
Facilities: What's out there now?

- LSIC Facilities Directory
  - [HTTPS://LSIC-WIKI.JHUAPL.EDU/DISPLAY/CD](https://lsic-wiki.jhuapl.edu/display/CD)

LSIC Operated

Anyone can add facilities (once you get a user ID)

Database of test facilities from NASA, academia, and industry



LSIC Facilities Directory

This directory is meant for any testing facilities that may be leveraged to assess or advance the technology readiness level of lunar surface technologies.

If you would like to add your facility, please do so here: https://forms.gle/MronYz72WeWbAqdx6

To make changes to listings, please contact @Andrea Harman .

Use the search bar above to review a cultivated list of available testing facilities. While keywords/labels are listed below, the search function examines all text in the directory.

Full List Of Facilities

Facilities Overview

Click the key words below to see all the listings related to a topic.

A-B
abrasion, abrasion-testing, actuators, adhesion, aerosols, air-permeability, ambient, anorthosite, atmosphere, atmospheric, balance, bell-jar, bending, buoyancy

C
cathode-testing, chamber, cleaner, closed, components, creasing, cryo, cryogenic, cycler, cylinder

D
dark-regolith, deposition, development, dirty-chamber, drill, dry-cleaner-tumbler, drying/heating, durability, dust, dust-box, dust-deposition, dust-distribution, dust-testing, dusty-vacuum

E
electrostatics, endurance, excavation, excavation-construction

F
fabric, fatigue-testing, film, filter, filter-evaluation, fire-saftey, flex, flex-fold, fold, folding, force

G-H
gases, gas-extraction, gasket, glovebox, granular-materials, graphite-heater, gravity, hardware-development, hot-gas-system

I-K
ice, icy-regolith, imaging, in-situ, in-situ-resource-utilization, in-space, instrument-characterization, isru, jar, jsc-1a

L-M
lh2, library, light-regolith, ln2, lo2, lunar-dust, lunar-soil, magnification, mars, mechanical-cycling, mechanism, microscopy, moon

N-Q
nasa, neutral-buoyancy, nondust, open, outdoor, oven, paper, particles, pascehn-breakdown, performance, physics, plasma-activation, plasma-cleaning, polymers

R
rail, rcs, reaction-control-systems, reconfigurable, regolith, regolith-simulant, regolith-testing, robotics, rodenberg, rotate, rover

S
seal, simulants, simulation-chamber, simulation-environment, sink, size-sorting, slope, soil, spacecraft, surface

T-U
terrain, testbed, textile, thermal, thermal-chamber, thermal-conditioning, thermal-vacuum, thin-sheet, thrusters, tool/equipment-testing, tumbler

V-Z
vacuum, vehicle, virtual-reality, volatiles, vr, wheel

0-9
3dprinting

Full Dust Facility Overview

Created by Andrea Harman, last modified on Sep 28, 2021

Site	Location	Facility	Size	Configuration	Vacuum (Torr)	Temperature Range	Cryo	Primary Use	Contact	Volume (ft^3)	Volume (m^3)	Notes
ARC	Mountain View, CA	SSERVI Regolith Test Bin	4m x 4m x 0.5m testbed	Testbed, filled with 8 tons of JSC-1A regolith simulant	Ambient	Ambient	N/A	Lunar Polar Lighting, Stereo Vision Characterization	Joe Minafra (joseph.minafra@nasa.gov)	8	0.23	Tribochar advancem sensor tes
ARC	Mountain View, CA	Regolith Test Bin	24' x 14' x 1'	Testbed, filled with 20 tons of Anorthosite	Ambient	Ambient	NA	Lunar Polar Lighting, Stereo Vision Characterization	Joe Minafra (joseph.minafra@nasa.gov)	336	9.364	They have independ research r any upgra
GRC	Cleveland, OH	Mechanism Exposure to Regolith Simulator	Overall dimensions: Approx. 15" wide x 15" deep x 20" tall. Inside (test chamber): Approx 8" wide x 8" depth x 8" height	Acrylic and aluminum sealed test chamber inside acrylic sealed vacuum cabinet (low level vacuum).	Low level vacuum (i.e. not high vacuum) ~ 10 Torr in current config ~10^{-7} Torr in future	Currently room temperature only	No	Small vacuum-capable facility for exposing mechanism concepts to lunar regolith environments for durability testing, advanced technology development, and other performance evaluations in simulated surface operations	Adam Howard (howard@nasa.gov)	0.3	0.008	Operation
GRC	Cleveland, OH	Gases and Aerosols from Smoldering Polymers (GASP) Lab	326 liter	Repurposed glovebox, now an aerosol test chamber	Atmospheric pressure only	Ambient tests with lab-generated aerosols and smoke from a furnace (25 to	N/A	Smoke experiments for spacecraft fire safety, proving gas and aerosol sensor and	Ben Sumlin (benjamin.sumlin@nasa.com) Marit Meyer (marit.meyer@nasa.gov)	11.5	0.326	The GASP particles/ environm calibration chamber

(Some) Facilities @ NASA

Regolith Test Bed @ KSC Swamp Works

Lots of Dirty Gloveboxes

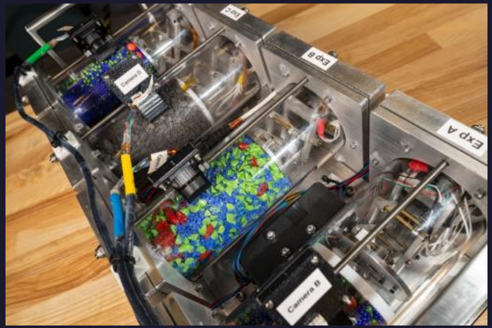
Lunar Environmental & ISRU Test Facility @ JSC

Rock Yards @ JPL & JSC

ARGOS @ JSC

Regolith Test Bin @ ARC

SLOPE Lab @ GRC



Hermes LunarG Testbed for Microgravity & Suborbital Testing