Unique Science from the Moon in the Artemis Era

The Challenge of Lunar Dust

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June 8th, 2022

With Contributions from Wesley Chambers, Charles Buhler, and Marit Meyer


DUST
MITIGATION

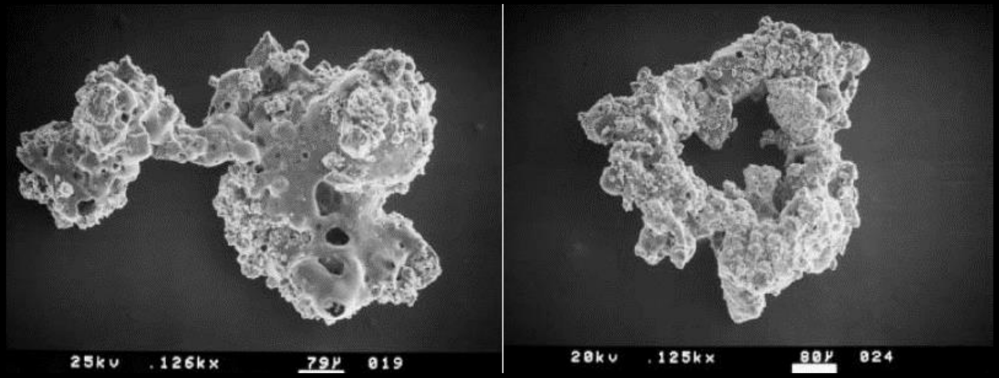
Outline

- The Dust Problem
- (Some) Lunar Dust Considerations
  - Electrostatics
  - Aerosols
  - Plume Surface Interactions (PSI)
- Dust Mitigation Testing

The Dust Problem

Lunar Regolith

Regolith is the fragmental layer covering the lunar surface, independent of rock size or composition.

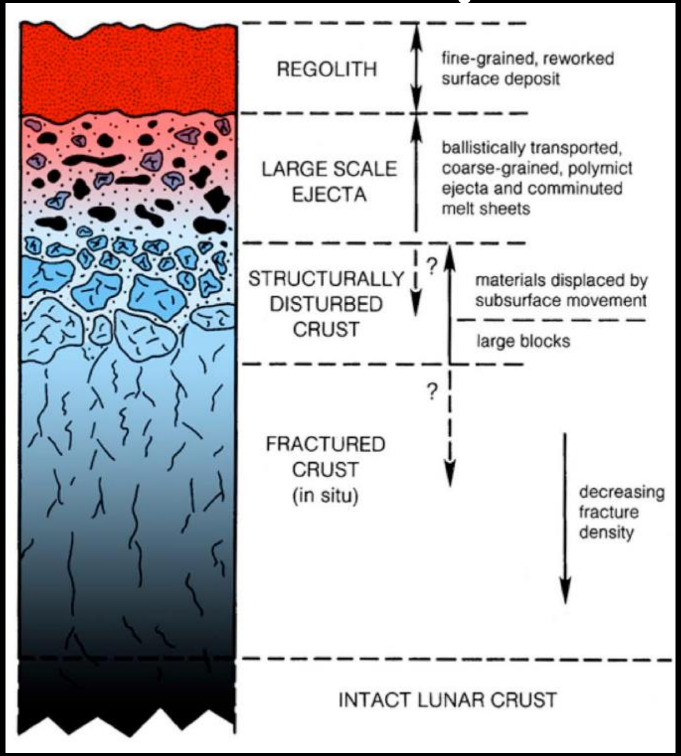


Angular; abrasive; irregular in shape

Created by **bombardment** of the solid lunar crust by meteoroids, solar UV flux, solar wind, radiation, etc. over billions of years.

Agglutinates are fused particles of **impact glass**, rock, and mineral fragments (<1 mm in size) formed by micrometeorite impacts.

Schematic cross-section of the regolith structure



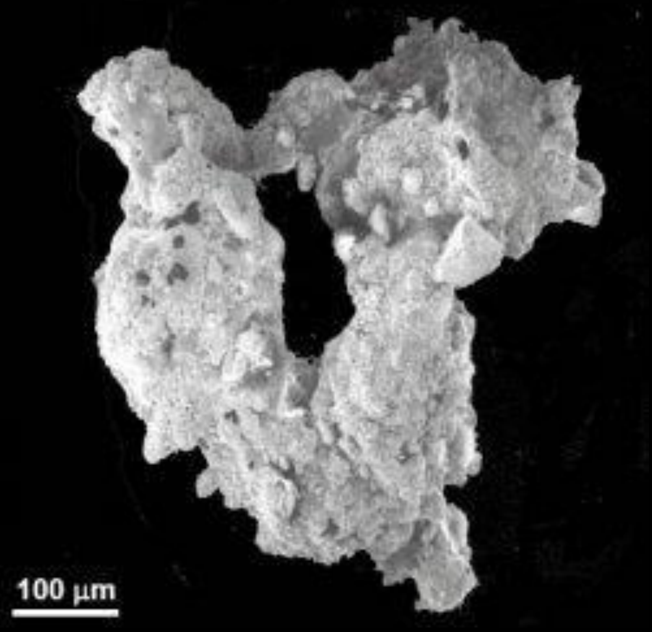
Close-up of a boot print from Apollo 12. Note the cohesiveness of the regolith.

Definition of Dust

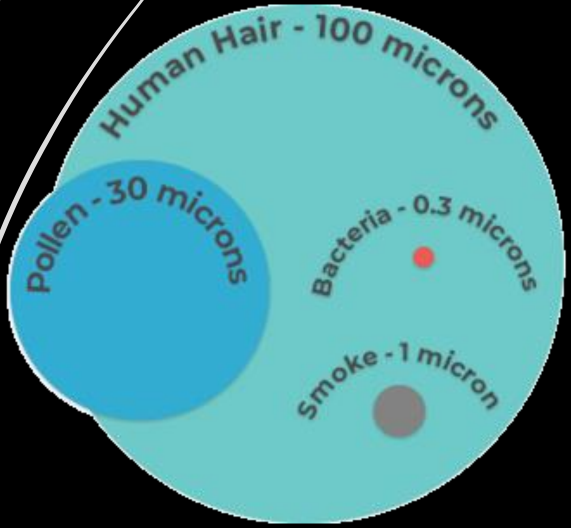
Geologic definition: <20 μm

Dust mitigation definition:

All lunar particulate that will need to be mitigated.



Electrostatic Properties, Magnetic Properties



The average particle size of lunar dust is 72 μm.

Rule of thumb:

50% of the regolith (by weight) is less than 50 μm

20% of the regolith is less than 20 μm

1% of the regolith is less than 1 μm

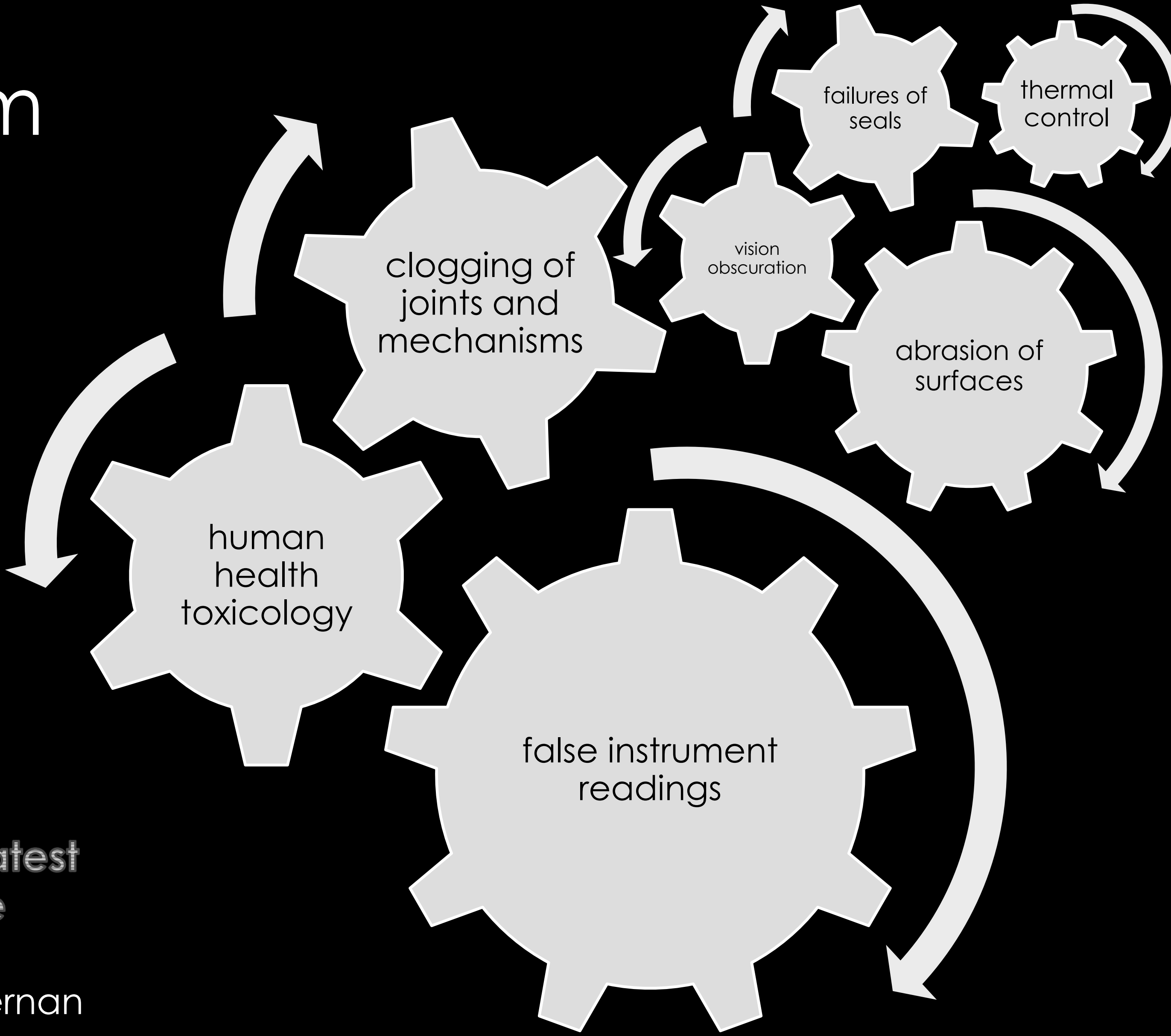
We don't talk about dust.

Actually…we talk about it a lot!

But, how should we talk about dust?

- The problems it will cause?
- The hardware/systems it will impact?
- The solutions?
- How to test against it?

The Dust Problem
& Insight from Apollo



"I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon"

-Apollo 17 Commander Gene Cernan

The Dust Problem

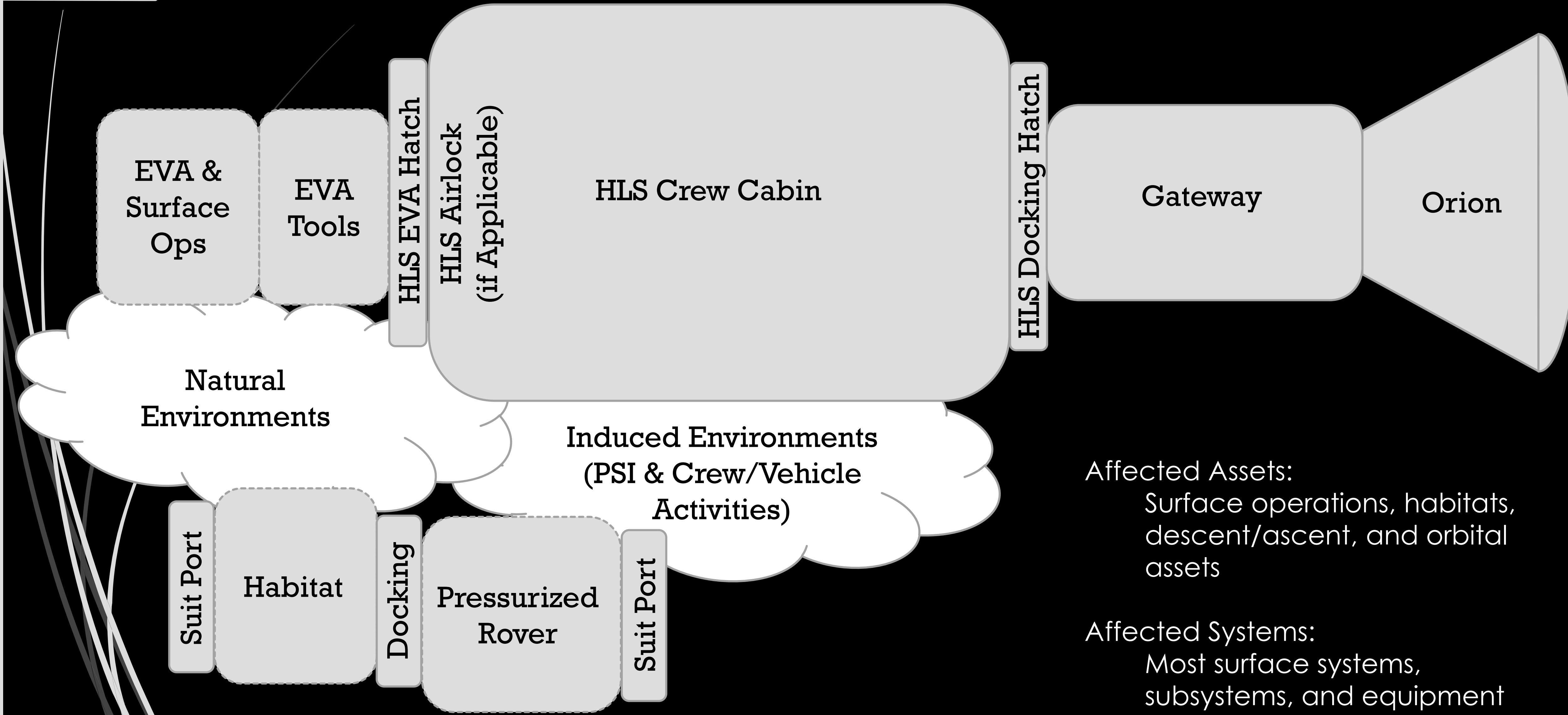
- Lunar dust is inevitable.
- Dust mitigation is not a new concept.
- Mitigating dust is critical for the success of lunar surface science investigations.

Lunar dust will be a feature of all lunar surface science investigations, whether welcome or not.

Dust poses challenges for:

- Mechanisms
- Electronics & Connectors
- Seals
- Softgoods (Fabrics)
- Filtration
- Crew Health & Monitoring
- Thermal Systems (property changes)
- Power Systems (degradation)
- Optical Systems
- Plume Surface Interaction & Landing Pads

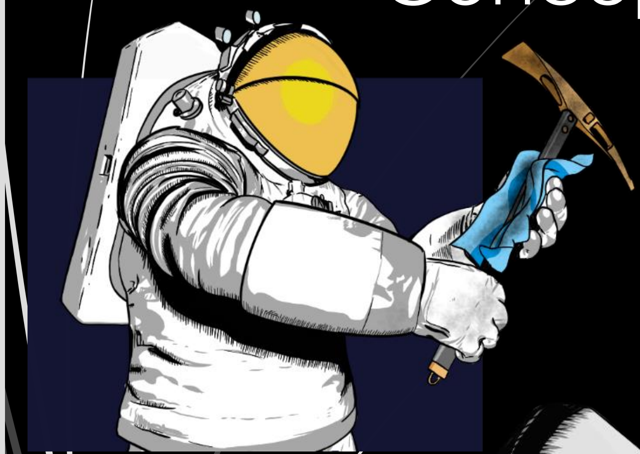
The Dust Problem
An Integrated Architecture

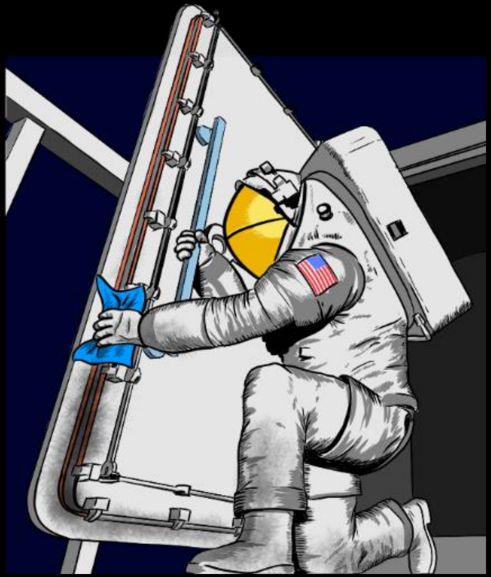


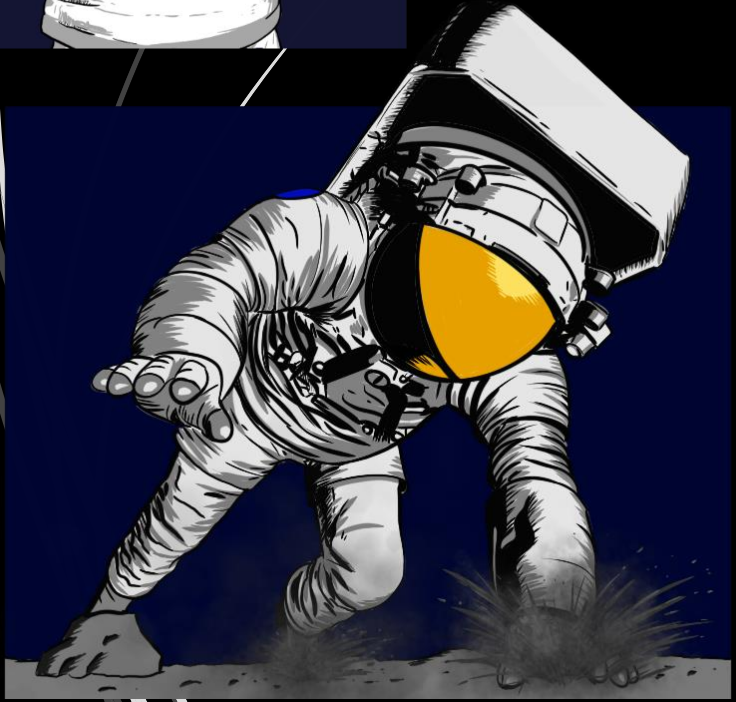
Affected Assets:
Surface operations, habitats, descent/ascent, and orbital assets

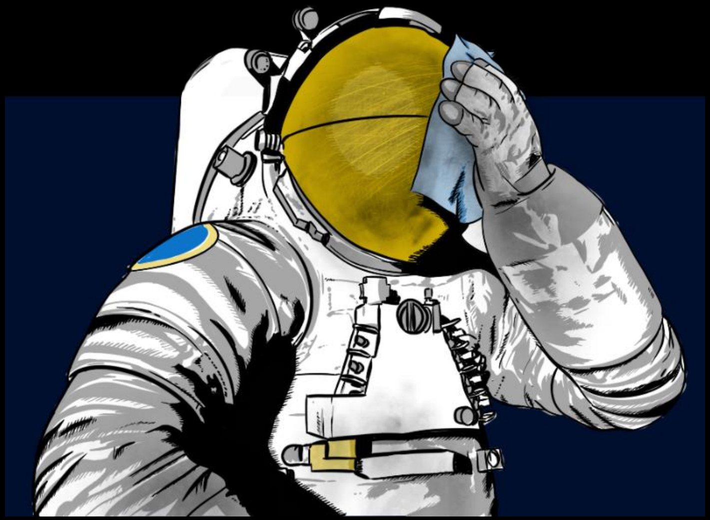
Affected Systems:
Most surface systems, subsystems, and equipment

The Dust Problem
Concept of Operations







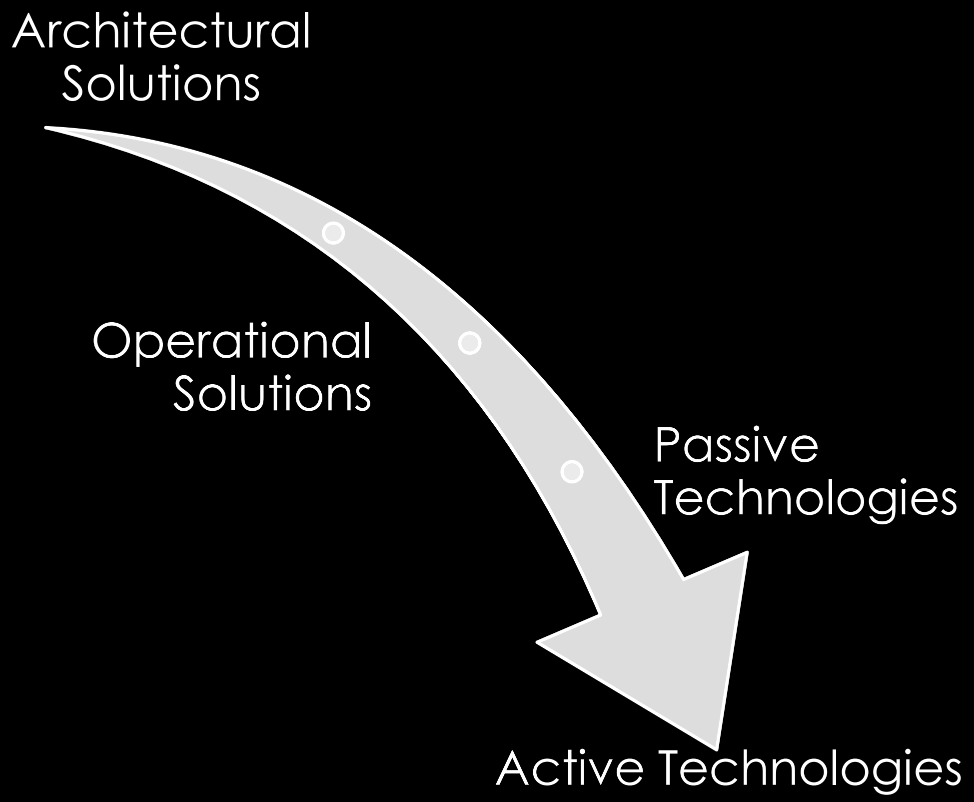


Current EVA timelines book-keep 30 minutes (or less) of the EVA for Dust Mitigation Activities (includes cleaning suits, hatch seals, sample containers, etc). This is tool/suit agnostic and does not include any IVA time. (We need testing/verification to balance the overall timeline.)

The Dust Problem
An Integrated Dust Mitigation Strategy

<u>Dust management</u>

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



Dust Management

- Tolerate Dust Exposure
  - Minimize reliability/performance impacts on
    - Gas handling and processing systems from dust
    - Connectors and sealing surfaces from dust
    - Monitoring components from dust
    - Exposed surface materials from dust
    - Mechanical systems from dust
    - Optical systems from dust
    - Electrical and electronic systems from dust
    - Information and communication systems from dust
- Detect and Monitor Dust
  - Maximize accuracy/reliability of dust level monitoring
    - Uninterrupted sensor function is critical for astronaut safety and mission success and cannot be compromised by exposure to dust
    - Dust could interfere with sensor performance, by chemical interaction, attenuation of molecular ionic transport, mechanical restriction of the sensing membrane.
- Control Entry of Dust
  - Minimize dust exposure to the astronaut during EVA
    - Mechanical components of vents, intakes, filters, louvers may be compromised by dust exposure. Dust may increase contaminant load to the point it would seriously affect system performance or astronaut health.
  - Minimize dust contamination of human habitable environments
    - If a high volume of dust is transferred, then the interfacing systems could be overloaded, reducing performance, or requiring frequent maintenance.
    - Airlock, rovers, tools, water handling/processing, thermal control systems, etc. can all be affected
- Remove Dust
  - Minimize dust deposition on critical surfaces
    - Dust accumulation may degrade reliability and impact crew safety
  - Minimize human effort required to conduct dust mitigation operations
    - Cleaning dust from equipment can take an excessive portion of astronaut time

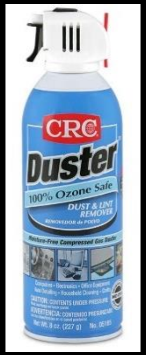
Dust Mitigation Solutions

Architectural Solutions

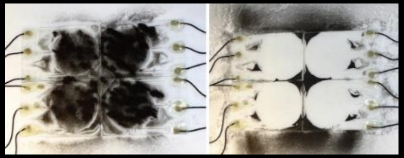
Operational Solutions

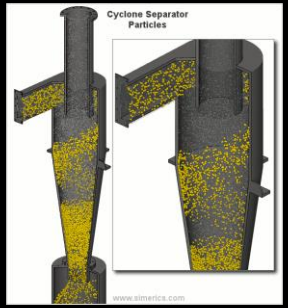
Passive Technologies

Active Technologies

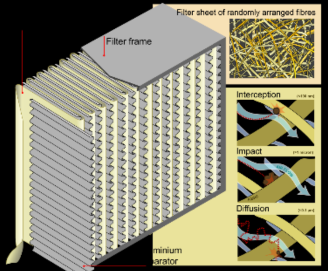


- <u>Active technology solutions:</u>
- Electrostatics
- Compressed air
- Vacuums
- Electrodynamic dust shield





- <u>Passive technology solutions:</u>
- HEPA filters
- Cyclone separators
- Softwalls
- Low-energy surface coatings
- Coveralls/aprons
- 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 Strategy

1. Understand Natural Environment
2. Understand Induced Environment
3. Understand Tolerance to Dust
4. Write Dust Requirements
5. Select Dust Mitigation Solutions
6. Test Hardware in Dusty Environment

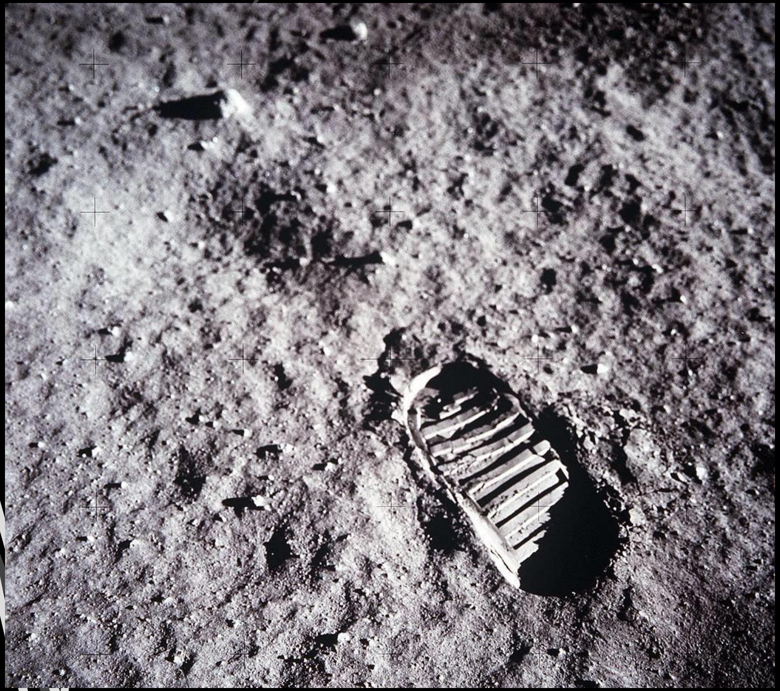
The Dust Problem is Cross-cutting

- Lunar → Exploration
- Dust → Science
- Mitigation → Technology

The Role of Dust Mitigation in Lunar Science

- Dust mitigation enables successful science on the surface.
- Ground testing of future instruments against the effects of lunar dust.
  - Rovers that may carry scientific payloads need to provide mobility as the wheels traverse through the regolith.
  - Investigations that involve mechanisms (e.g. drill or arms transporting samples to instruments) need to understand how to mitigate dust to improve reliability and extend operations.
  - Imagery, optics, or solar panels need to protect their surfaces from the abrasiveness of lunar dust.
- Incorporating certain technologies into the design of future investigations may be necessary.

The Scientific Value of Lunar Dust



- Lunar dust is not just an obstacle to performing science on the Moon. It is the dust itself, collected during Apollo, which unveiled some of the mysteries of the Solar System.
  - Countless discoveries since Apollo (and still on-going, e.g. ANGSA)
  - The images of bootprints on the surface showed that the top layer of regolith is easily compressed, giving insight into the porosity of the regolith
  - Apollo 17 Lunar Ejecta And Meteorites (LEAM) Experiment, part of the Apollo Lunar Surface Experiments Package (ALSEP) aimed to measure the speed, direction, and total kinetic energy of particles impacting the surface

Lunar Dust Considerations

Electrostatics, Aerosols, Plume Surface Interactions (PSI)

Lunar Dust Considerations

Mobility

Thermal

Reactivity

Electrostatics

Aerosols

Sensors & Instrumentation

Adhesion

Optical

Simulants

Abrasion

Surfaces/Coatings/Surface Modification

Plume Surface Interactions (PSI)

Toxicity & Health Concerns

Dust Deposition

- POCs for each of these available if needed.

Electrostatics

Courtesy of Charles Buhler (KSC)

What do we know about the electrostatics environment on the moon?

- The particles are good dielectrics (permittivities between 2-3) and resistivities (ρ above 10^{13} Ωm) and are most likely charged (positive and/or negative) or net zero total charge (bipolar).
- The surface of the moon is also a dielectric (no electrical ground)
- Very, very dry – no moisture to allow charge decay ($\tau = RC = \rho\varepsilon\varepsilon_o$)
- The allowed electric field is much higher than the Earth and Mars

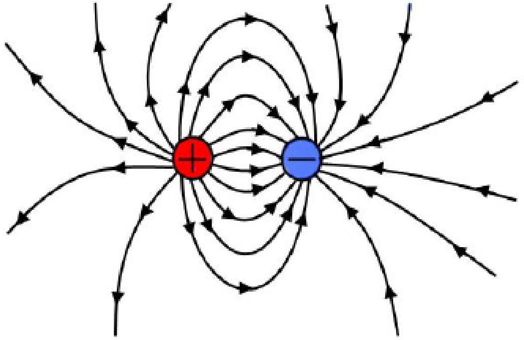
  - E_Moon >> E_Earth >> E_Mars
  - 10^8 V/m >> 10^6 V/m >> 10^4 V/m
  - Field Emission >> Air Breakdown >> CO2 at Paschen minimum
  - **Thus particle charges can be a lot higher than on Earth**

Operation	Mass charge density (charge-to-mass ratio) μC/kg
Sieving	10^{-3} to 10^{-5}
Pouring	10^{-1} to 10^{-3}
Scroll feed transfer	1 to 10^{-2}
Grinding	1 to 10^{-1}
Micronizing	10^{2} to 10^{-1}
Pneumatic conveying	10^{3} to 10^{-1}

Are any of these configurations free for forces of adhesion?

- **Insulator surfaces?**
- **Charged insulators?**
- **Antistatic or Statically Dissipative materials?**
- **Grounded metals?**
- **Ungrounded metals?**
- **Fabrics?**
- **Rough surfaces?**
- **Smooth surfaces?**

$$F = q\,E_1 + qE_2 + ..$$



Common Electrostatics Misconceptions

- Non-stick surfaces do not attract dust (Teflon)
- Metals do not tribocharge
- Like materials do not tribocharge
- Disturbed dust is uncharged
- There’s only one sign of charge on the dust particles
- Insulator-insulator contact charging is well understood

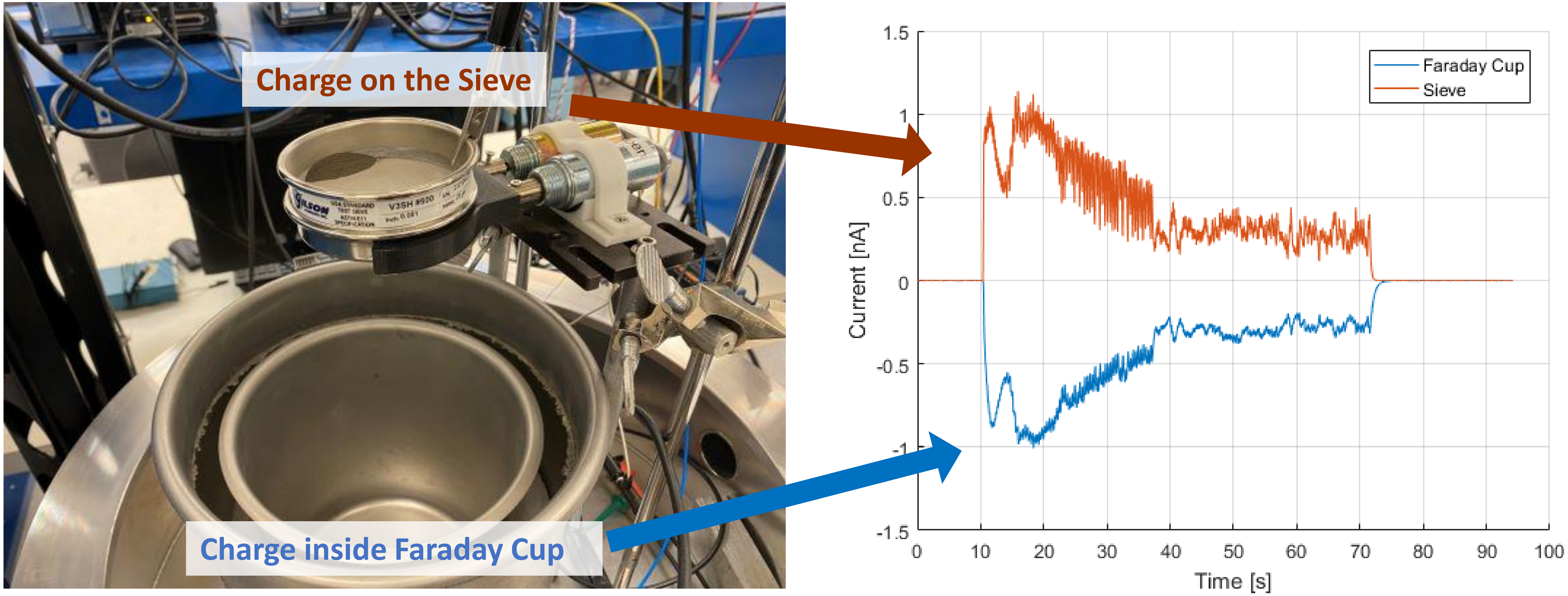
$$F=qE$$

$$\iint E\, dA = \frac{q}{\varepsilon_o}$$

Force	Equation	Magnitude (N) (for a 10 μm particle)	Mitigation Strategy
Gravity	$F = \frac{4}{3}\pi\rho a^3 g$	10^{-10}	Steep angle of incidence Vibrations
Van der Waals	$F = aA/6z^2$	$10^{-5} - 10^{-6}$	Keep surfaces rough Disallow contact
Capillary	$F = 2\pi\gamma d$	$10^{-5} - 10^{-6}$	Keep RH < 65% Nonexistent outside habitat
Chemical	$F = \frac{\partial W}{\partial x} = -\frac{\partial}{\partial x}(f n \Delta H)$	$>10^{-5}$	Possibly significant within habitat Unknown outside habitat
Mechanical	$F \sim d$		Vibrations Disallow particle interlocking
Electrostatic Image (point charge)	$F = q^2/16\pi\varepsilon_0(a+z)^2$	10^{-7}	Make surface more conductive to remove *q* Inside habitat increase RH Match dielectric constant of surface and particle Disallow contact
Electrostatic Image (solid sphere)	$F = \frac{q^2}{\left[16\pi\varepsilon_0 az(\psi + \frac{1}{2}\ln 2a/z)^2\right]}$	$10^{-5} - 10^{-6}$	Make surface more conductive to remove *q* Inside habitat increase RH Match dielectric constant of surface and particle Disallow contact
Electrostatic Charge Exchange	$F = \pi\varepsilon_0 a\varphi^2/z$	10^{-7}	Minimize work function difference between particle and substrate Disallow contact
Electrostatic Layers	$F = qE_{bk}$	10^{-7}	Minimize dust layer thickness Minimize surface charging Disallow contact

KSC Sieve Dust Deposition Tests

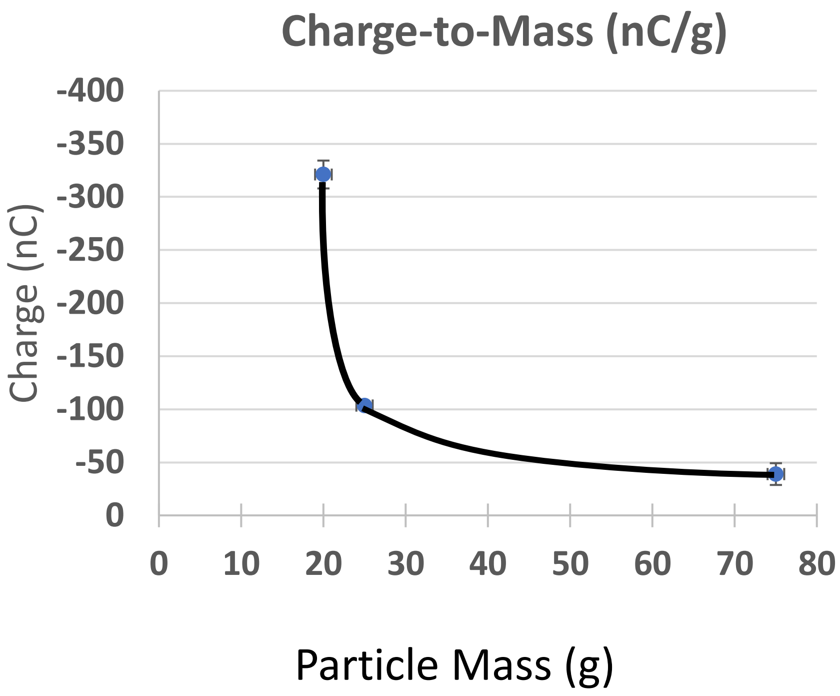
Objective: Deposit dust simulants in a high vacuum environment and measure the charge on these particles in a consistent way in accordance with NASA-STD-1008 (2021).



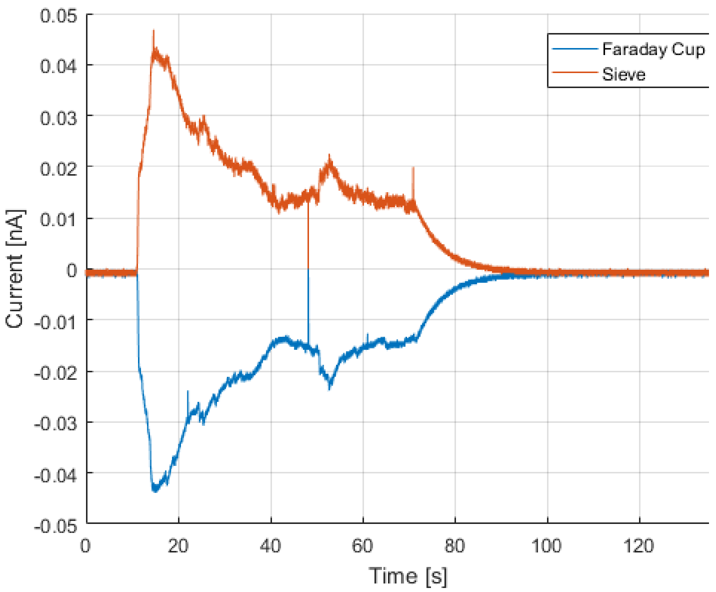
Result: The acquired charge value are normalized by the total mass deposited during each test case.

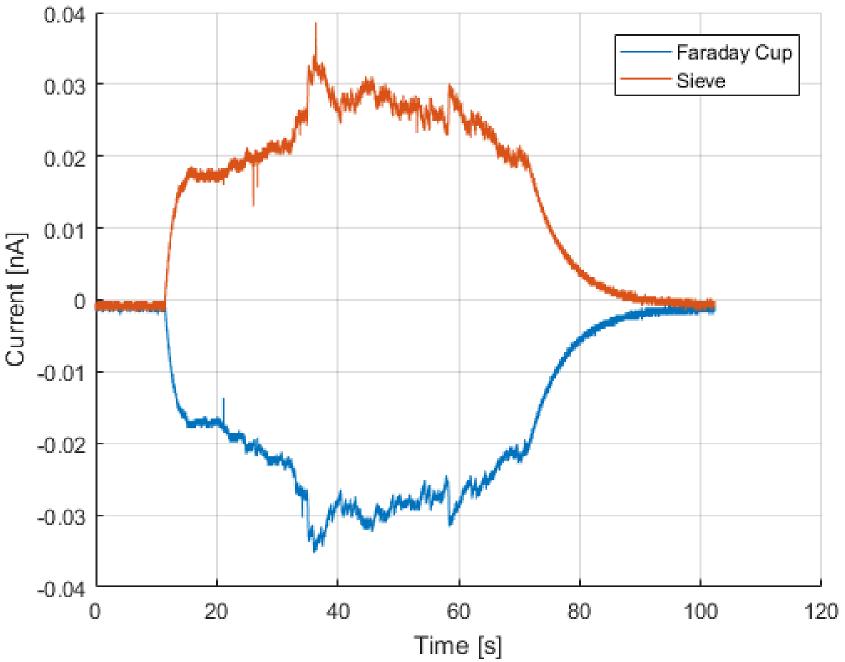
The charge-to-mass ratio $\frac{Q}{m}$ can then be used for engineering analysis, modeling and simulation.

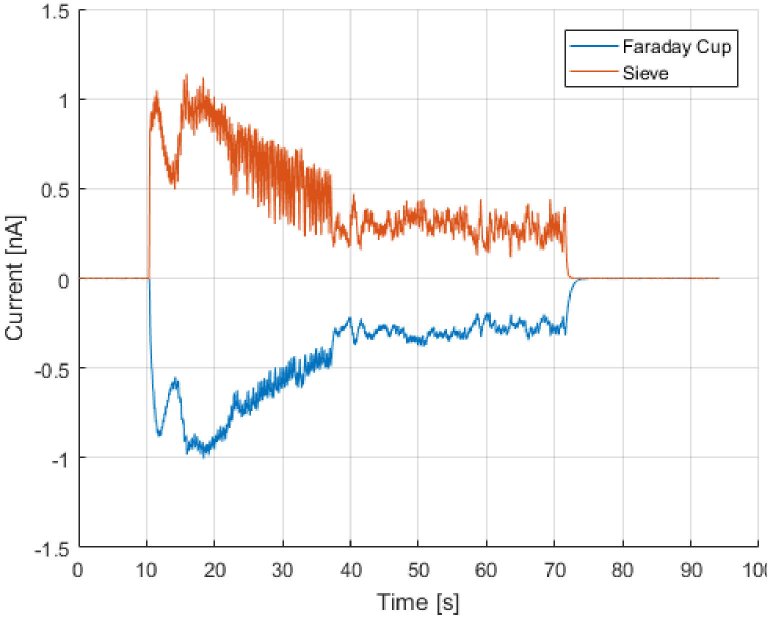
POC:
jerry.j.wang@nasa.gov
charles.r.buhler@nasa.gov

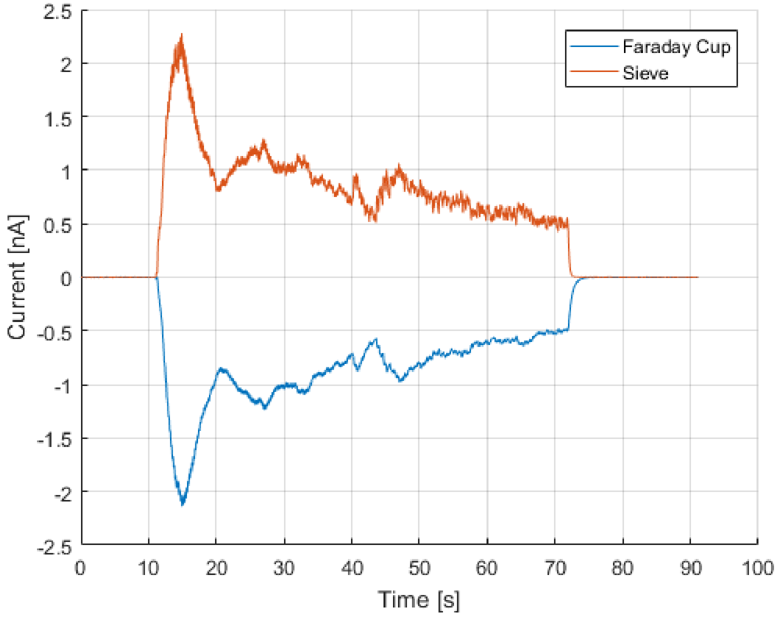


Particle Diameter Range	Q/m cup (nC/g)	Q/m sieve (nC/g)
25 um to 45 um	-99.4	
25 um to 45 um	-205.65	
25 um to 45 um	-106.32	100.59
25 um to 45 um	-104.9	106.7
Average	**-103.54**	**103.65**
STDEV	**3.65**	**4.32**
20 um to 25 um	-74	71.7
20 um to 25 um	-330.5	308.7
20 um to 25 um	-311.8	295.9
Average	**-321.15**	**302.30**
STDEV	**13.22**	**9.05**
75 um to 90 um	-46.35	46.73
75 um to 90 um	-31.8	31.8
Average	**-39.08**	**39.27**
STDEV	**10.29**	**10.56**









Note: Runs to date are for a 1-minute shake at 10 Hz at <9E-5 Torr using JSC-1A. More to come.

Aerosols

Courtesy of Marit Meyer (GRC)

Lunar Dust from the Aerosol Perspective

- Aerosols are particles in air, therefore only in pressurized/habitable environments
  - Particles of concern are less than 10 µm (inhalable) and less than 2.5 µm (respirable)
  - Sizes not visible to the human eye
- Lunar dust concentration limits in the cabin protect crew from harmful exposure
  - Lunar dust requirement is more stringent than limits for typical cabin dust (e.g. on ISS)
  - Equipment can be exposed to even higher dust concentrations in areas where initial contamination occurs
    - After EVA, before and during cleaning operations

Lunar Dust from the Aerosol Perspective

Example of a mass concentration aerosol instrument, DustTrak DRX (cal factor required)

- Test hardware in a chamber with aerosolized simulant to determine if performance is affected by the allowable lunar dust concentration
  - Requirement: NASA Standard 1008 Section 5.3.1
  - Particularly any device that ingests air
- Use specialized facility and instruments
  - Purge chamber first
  - Generate a stable simulant aerosol with uniform spatial concentration for test duration
    - *NASA TM with 'how to' instructions coming soon*
  - Measure concentrations with appropriate aerosol instrument(s)
    - *NASA TM coming soon with material-dependent instrument calibration factors for several available simulants*
  - Additional testing best practices and guidelines are in the Dust standard document

Plume Surface Interactions (PSI)

Courtesy of Wesley Chambers (MSFC)

Plume-surface interactions and science

- Plume-surface interactions (PSI) occur when a rocket engine (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
  - 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.

Regolith reflectance altered at landing sites

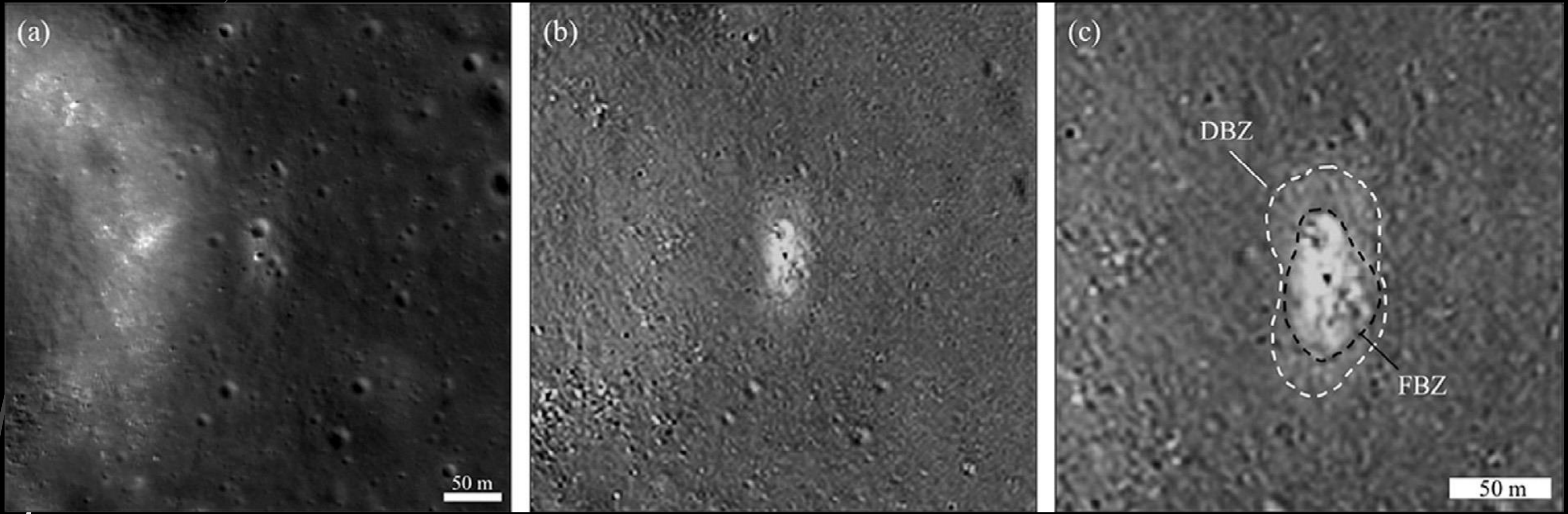
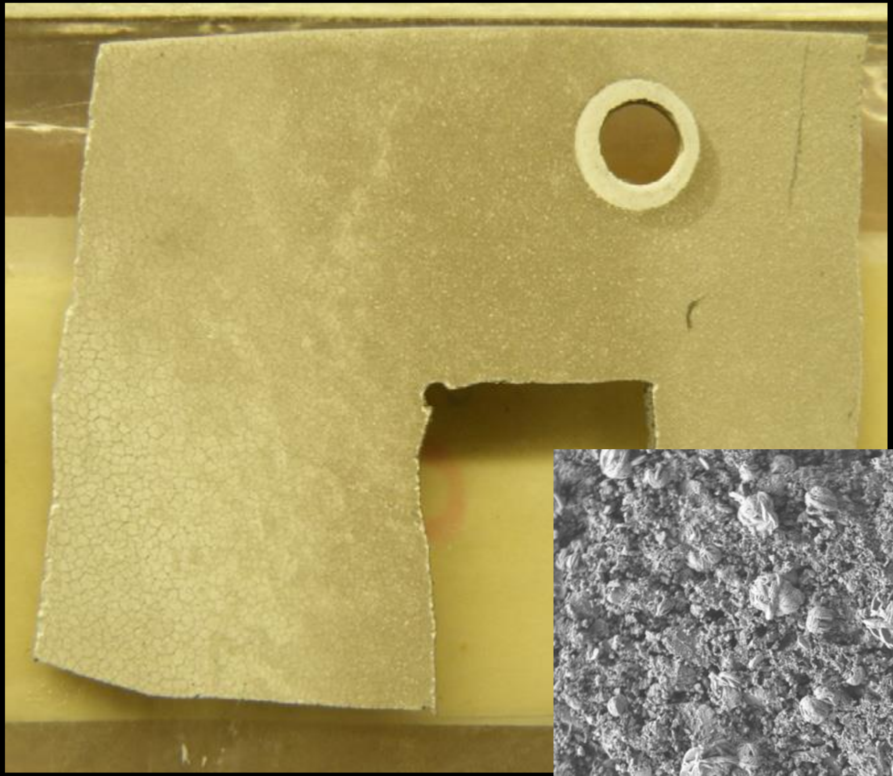
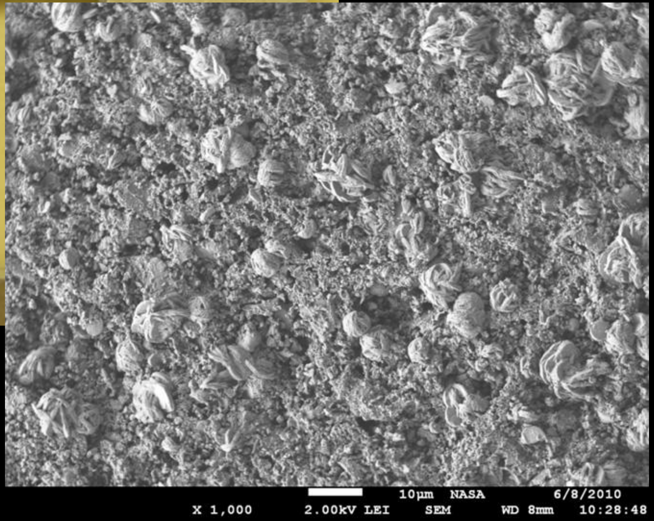


Figure from Clegg-Watkins et al. 2016, showing the Chang'e 3 landing site in (a), the same image divided by a pre-landing image in (b), and the "diffuse blast zone" and "focused blast zone" in (c).

Plume-surface interaction hazards

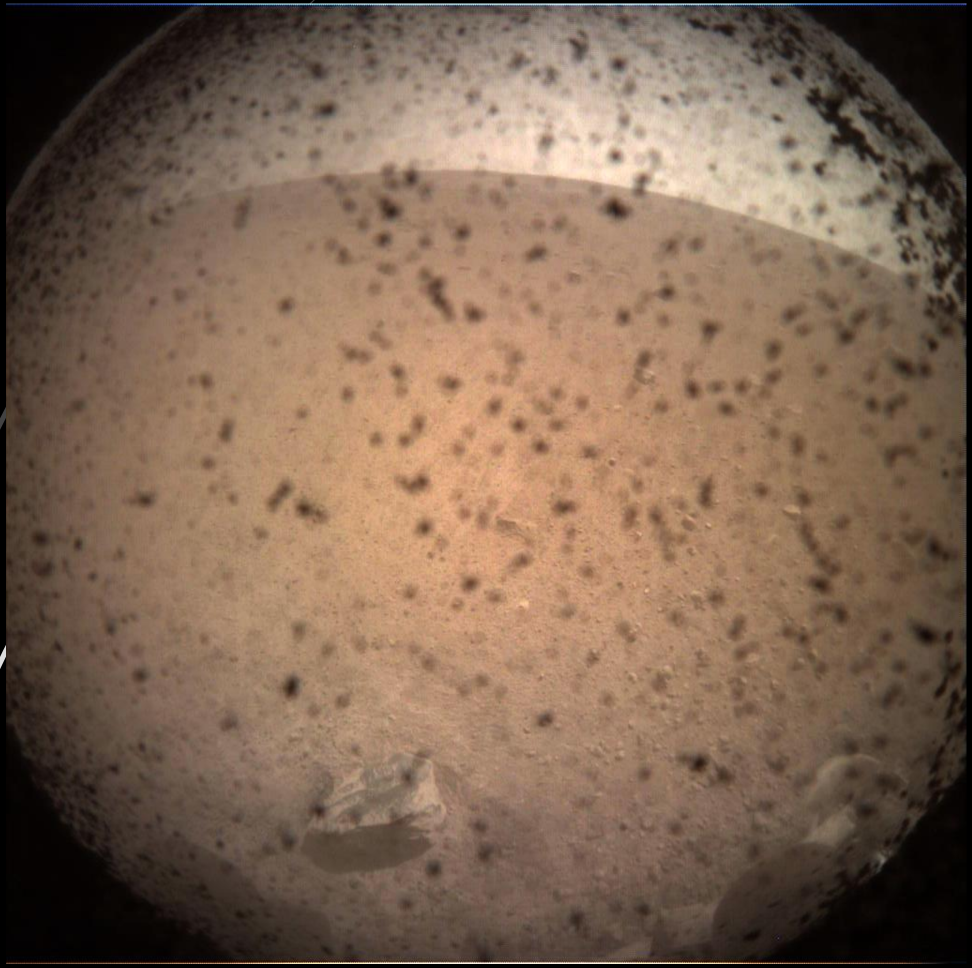
- Regolith ejecta poses a hazard to your spacecraft and to surrounding assets
- Examples
  - Apollo 12 landed near Surveyor 3
    - Scouring, pitting and cracking on Surveyor material coupons
      - See Immer et al. 2010
  - Mars Insight
    - Material breached lens cover





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.

Lunar Dust Considerations

Mobility

Thermal

Reactivity

Electrostatics

Aerosols

Sensors & Instrumentation

Adhesion

Optical

Simulants

Abrasion

Surfaces/Coatings/Surface Modification

Plume Surface Interactions (PSI)

Toxicity & Health Concerns

Dust Deposition

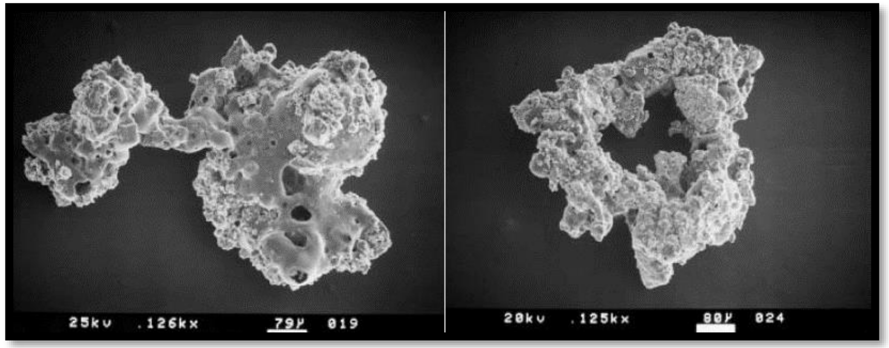
- POCs for each of these available if needed.

Dust from a system perspective…

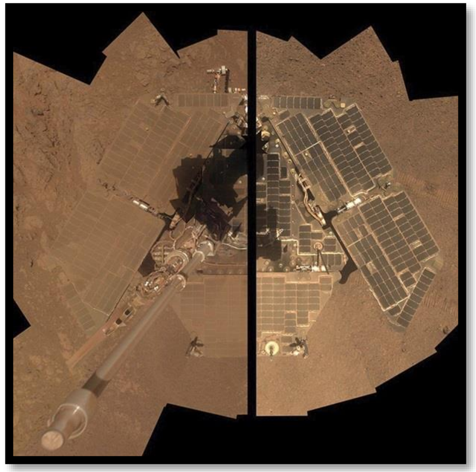
LUNAR DUST ON POWER SYSTEMS

- What could go wrong?
  - 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.

Apollo 14 Thermal Degradation Sample



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



Mars Opportunity Rover

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

"I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon"
-Apollo 17 Commander Gene Cernan

Dust Mitigation Testing

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

Purpose

- Establish the minimum requirements for testing with dust
- Provide general guidance for testing methodologies and best practices
- Provide developers and end-users with information that will guide testing of systems and hardware for exposure to dusty environments
- Facilitate consistency and efficiency in the testing of space systems, subsystems, or components with operations and missions in dusty environments

Document Overview

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)

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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SECTION 5.

Testing Methodologies & Best Practices

5.1 Simulant Prep & Storage

5.2 Simulant Loading Definitions

5.3 Testing Practices & Categories

5.4 Simulants

5.5 Facilities

Document Overview

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Dust Requirements & Standards

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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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SECTION 5.

Testing Methodologies & Best Practices

5.1 Simulant Prep & Storage

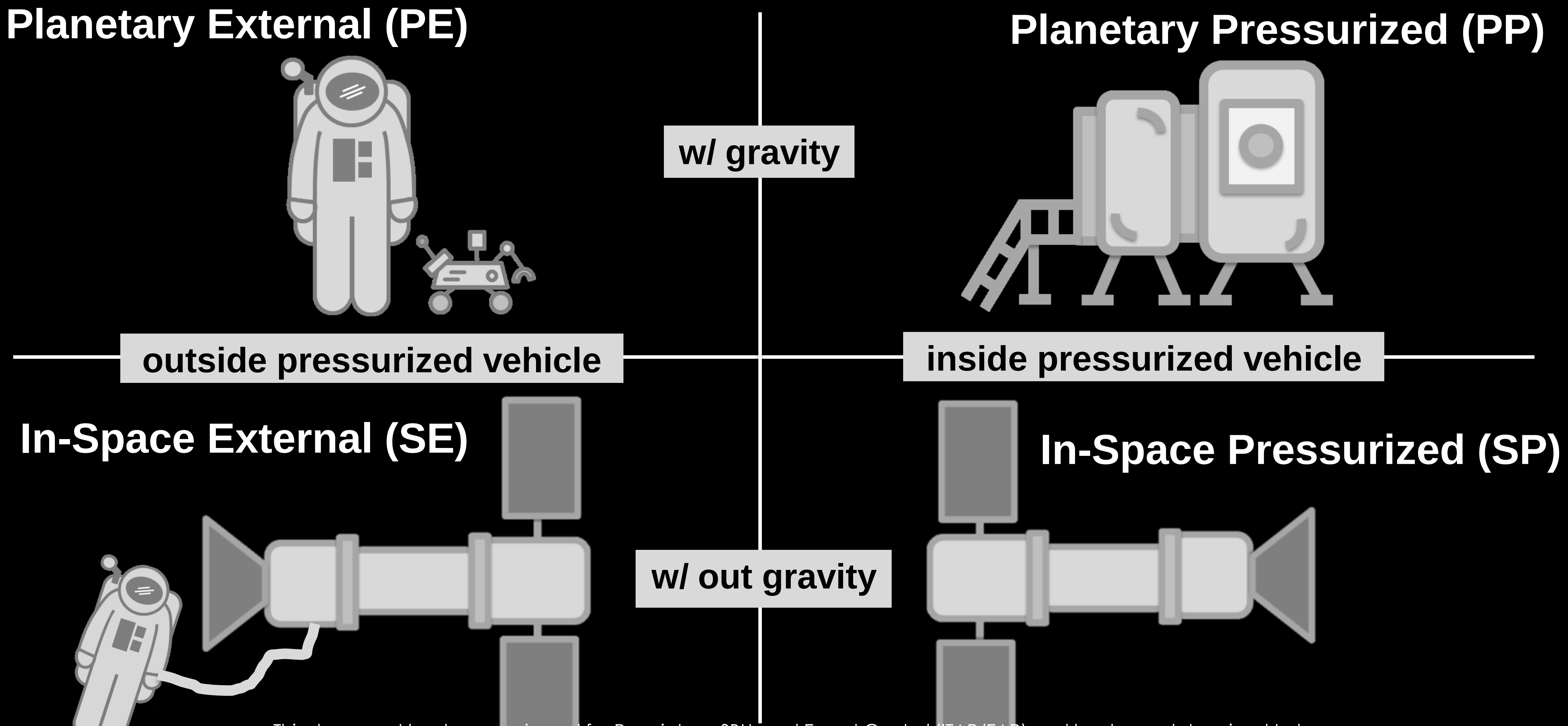
5.2 Simulant Loading Definitions

5.3 Testing Practices & Categories

5.4 Simulants

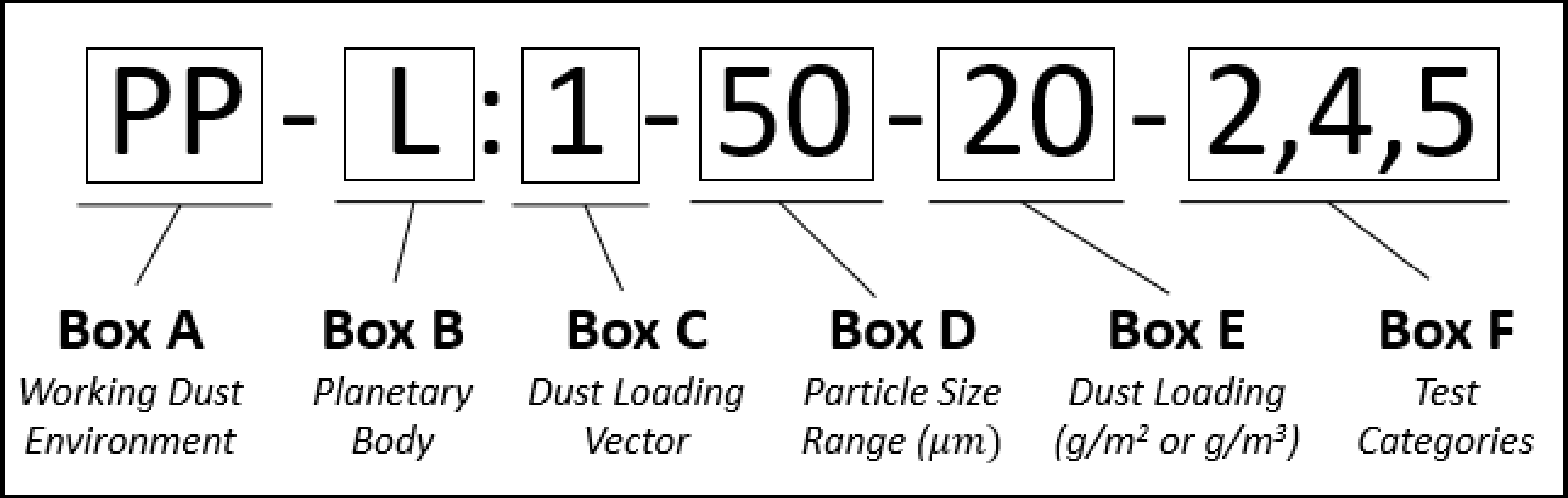
5.5 Facilities

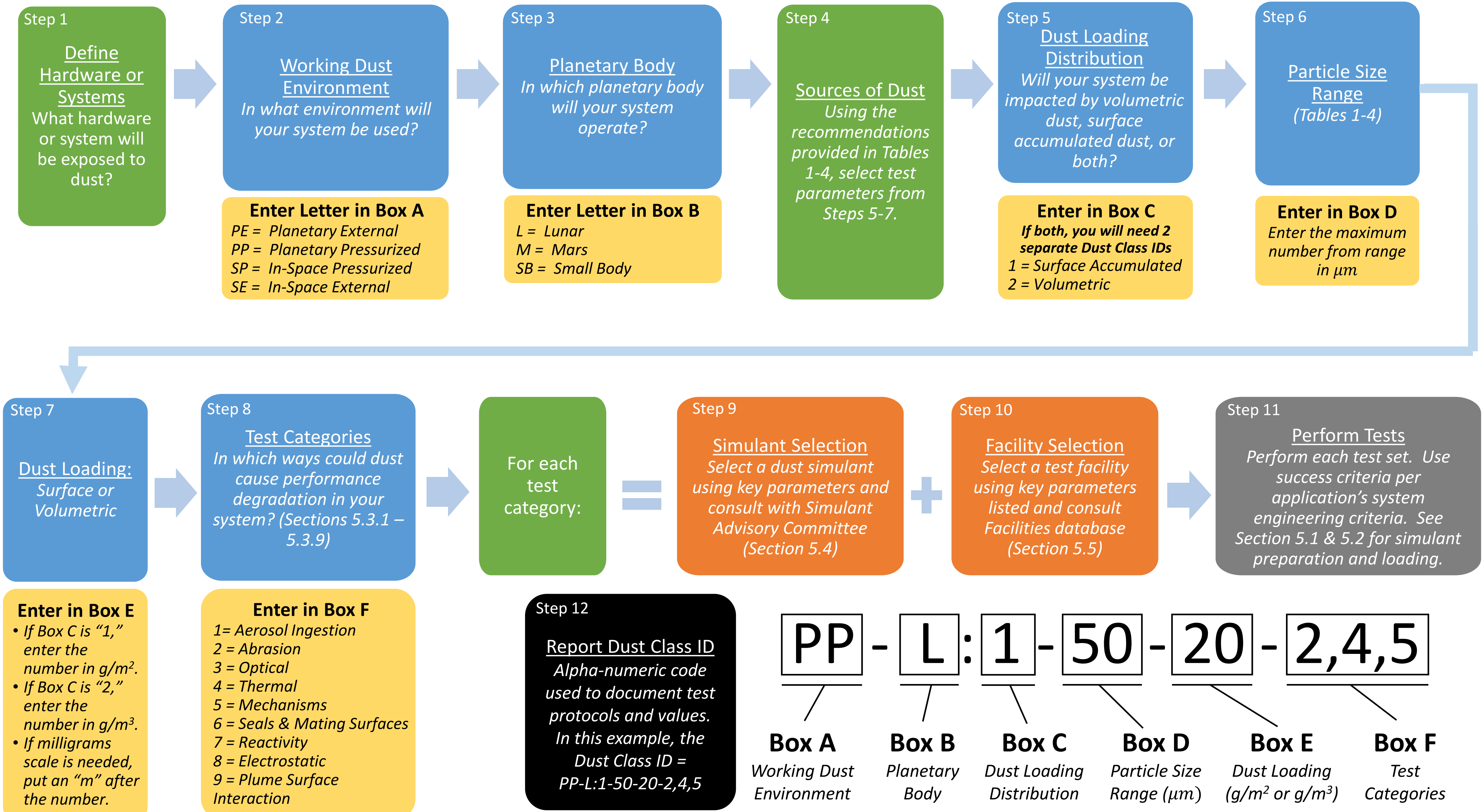
Working Environments Classification



Dust Class ID

User may assign alpha-numeric code to identify protocol to which they validated their hardware




Step 1
Define Hardware or Systems
What hardware or system will be exposed to dust?
Step 2
Working Dust Environment
In what environment will your system be used?
Enter Letter in Box A
PE = Planetary External
PP = Planetary Pressurized
SP = In-Space Pressurized
SE = In-Space External
Step 3
Planetary Body
In which planetary body will your system operate?
Enter Letter in Box B
L = Lunar
M = Mars
SB = Small Body
Step 4
Sources of Dust
Using the recommendations provided in Tables 1-4, select test parameters from Steps 5-7.
Step 5
Dust Loading Distribution
Will your system be impacted by volumetric dust, surface accumulated dust, or both?
Enter in Box C
If both, you will need 2 separate Dust Class IDs
1 = Surface Accumulated
2 = Volumetric
Step 6
Particle Size Range
(Tables 1-4)
Enter in Box D
Enter the maximum number from range in μm
Step 7
Dust Loading:
Surface or Volumetric
Enter in Box E
• If Box C is "1," enter the number in g/m².
• If Box C is "2," enter the number in g/m³.
• If milligrams scale is needed, put an "m" after the number.
Step 8
Test Categories
In which ways could dust cause performance degradation in your system? (Sections 5.3.1 – 5.3.9)
Enter in Box F
1= Aerosol Ingestion
2 = Abrasion
3 = Optical
4 = Thermal
5 = Mechanisms
6 = Seals & Mating Surfaces
7 = Reactivity
8 = Electrostatic
9 = Plume Surface Interaction
For each test category:
=
Step 9
Simulant Selection
Select a dust simulant using key parameters and consult with Simulant Advisory Committee (Section 5.4)
+
Step 10
Facility Selection
Select a test facility using key parameters listed and consult Facilities database (Section 5.5)
Step 11
Perform Tests
Perform each test set. Use success criteria per application's system engineering criteria. See Section 5.1 & 5.2 for simulant preparation and loading.
Step 12
Report Dust Class ID
Alpha-numeric code used to document test protocols and values. In this example, the Dust Class ID = PP-L:1-50-20-2,4,5
PP - L : 1 - 50 - 20 - 2,4,5
Box A
Working Dust Environment
Box B
Planetary Body
Box C
Dust Loading Distribution
Box D
Particle Size Range (μm)
Box E
Dust Loading (g/m² or g/m³)
Box F
Test Categories

Document Overview

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)

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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

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Section 5. Testing Methodologies & Best Practices

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SECTION 5.

Testing Methodologies & Best Practices

5.1 Simulant Prep & Storage

5.2 Simulant Loading Definitions

- 5.2.1 Surface Accumulated Loading
  - 5.2.1.1 Method 1: Pre-Load the Dust
  - 5.2.1.2 Method 2: Vacuum Chamber Dust Loading
- 5.2.2 Volumetric

5.3 Testing Practices & Categories

5.4 Simulants

5.5 Facilities

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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

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.)

Testing Categories

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.

Testing Categories, con't

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).

Questions?

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