Lunar and Planetary Dust Mitigation Design

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November 6-7, 2019

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Lunar and Planetary Dust

- The Moon and Mars are dusty environments
- The dust contaminates surfaces causing impacts on systems
  - Surface obscuration, thermal effects, abrasive impacts
- Dust properties and environmental effects
- Mitigating dust
  - Historical approaches
  - Minimizing Size, Weight and Power of dust mitigation
  - In-situ resource utilization

Dust is there, how do we mitigate the impact?

Lunar and Planetary dust problems

- Surface coating- thermal, optical obscuration, mobility
- Mechanisms- abrasive activity
- Airborne- respiratory effects
- Skin contact- abrasion and irritation

This sounds really familiar!

Lunar and Planetary dust knowledge

- Lunar dust
  - Apollo program dust impacts
  - Apollo program dust mitigation attempts
  - Samples returned
  - Various research programs

- Mars Dust
  - Degradation of solar array and thermal radiator performance on Mars

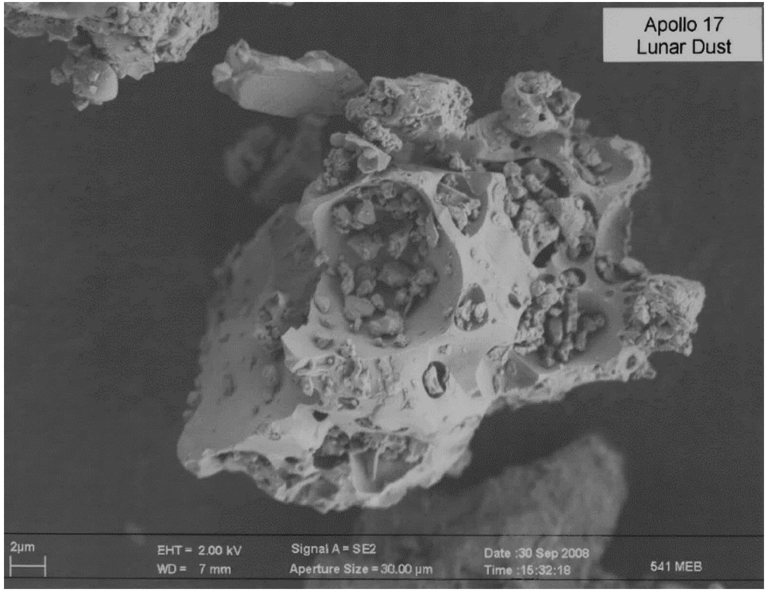
- Planetary dust

Wait, Earth is a Planet, we've been dealing with dust for thousands of years!

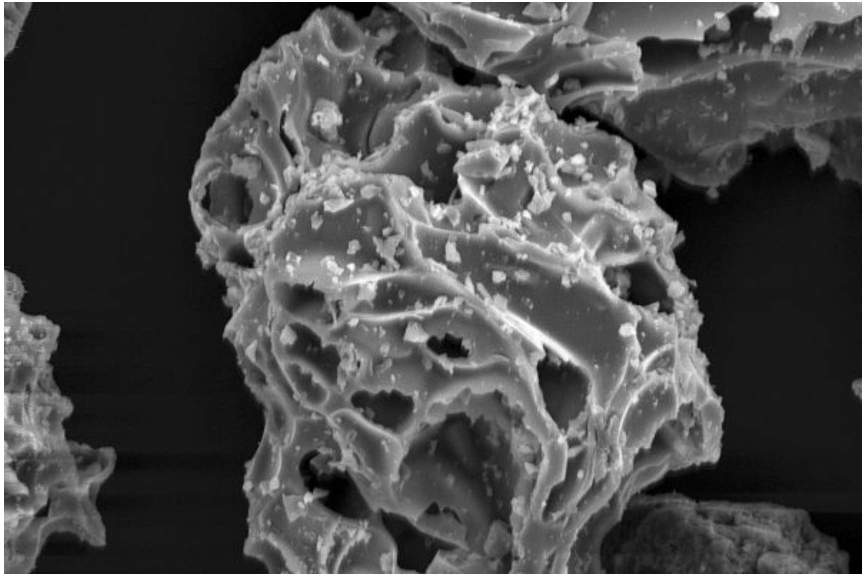
Removing dust is not a new problem, why are we starting with a blank piece of paper?

Dust is Dust!

Apollo 17 Lunar Dust and Volcanic Ash



SEM micrograph provided by Doris Jallice NASA GSFC Code 541Materials Engineering Branch



Mount Redoubt Volcanic ash NSF Science360 picture of the day Pavel Izbekov and Jill Shipman, University of Alaska Fairbanks

Lunar and Planetary Dust Properties

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- Dielectric- Both Lunar and Mars dust are dielectric, (silicon and metal oxides), no contact charge neutralization
  - A lot of Tellurian dust is dielectric
- Particle sizes from nanometers to microns
  - Tellurian particulates fall in this range
- Lunar dust contains iron nanoparticles (magnetic)
  - Some Tellurian dust is magnetic
- Relatively sharp and abrasive particles
  - A number of Tellurian dust particle types are sharp and abrasive
- Agglutination of smaller articles into larger stuck together particles
  - Tellurian dust agglutinates, often with handling

There are general and specialized dust mitigation schemes

Environmental effects

- Lunar terminator plumes
  - At the lunar terminator there are plumes of dust
  - At the lunar terminator there are rapid swings in the electric field
  - Similar swinging potentials are used for coating abrasives industrially
- Low humidity increases surface retention of particles, higher triboelectric charging, higher surface energy, longer charge decay
- Atmospheric particle saltation rates are primarily dependent upon medium viscosity and particle size
- Triboelectric charging- separating, dragging
- Radiative charging
  - Ionizing particles
  - Photoelectric

Many of these issues are common in Tellurian systems

Dust Retention

- Van Der Waals forces
  - Surface molecular electronic field interactions, permanent and induced multipole effects
  - Range of interaction 0-<1 nm
- Embedding
  - Caused by reduction of surface energy by causing distortion into the surface, perhaps chemical bonding
  - 0 meters
- Electrostatic Effects
  - Triboelectric and total charge effects
  - 0-meters in-vacuo

Break particle surface contact, minimize return

Dust removal requirements

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- It is neither necessary nor possible to remove all dust,
- Remove dust that is suspended, will slough off or is otherwise problematic
- Remove more adherent dust, to what level?
- Minimize damage to surfaces being cleaned
- Minimize size, weight, power and risk
- Be simple and easy to use

Remove what is necessary in the least complicated manner

Mitigating ISO 12103-2 and non-standard road dust

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- Road dust in desert areas is similar to Planetary dust with respect to abrasive, electrostatic properties and composition
  - Non-conductive, leading to triboelectric charging
  - Abrasive, composed of hard glassy or crystalline material
  - A wide particle size distribution
- Mitigation Concepts in use
  - Surfaces- minimize charge differences
  - Abrasion- Isolate, minimize force in removing/isolating particles
- Tellurian Approaches
  - Electrostatics- Grounding
  - Triboelectric charge generation- ionizers
  - Air guns/ blow off
  - Abrasion- Low force removal and isolation

These issues are critical to the automotive industry

Historic removal of Lunar dust

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- Apollo used a brush outside of the LM to reduce dust transfer
  - Effective to some degree
  - Issues: differential charging, triboelectric and radiation
- The remaining dust was then tracked into the LM prior to repressurization
- Apollo used vacuum cleaners to some effect in minimizing dust mitigation
  - Limited efficacy due to size, weigh and power limitation on vacuum cleaner
  - Velcro, screw holes and gaps were problematic

Learning from the past

Twisting the knobs to mitigate dust

- Suspended dust
  - Dust settles out at a rate slowed by gas viscosity and possibly electrostatic charge
  - With an airlock, if the air pressure is near zero, the dust will fall out of suspension
- Electrostatic charge effects
  - Particles can be captured using electrostatic fields
  - Electrostatically adhered particles and suspended particles can be neutralized with an air ionizer
- Isolating particles
  - Use simple engineering solutions to isolate removed dust
    - Open grid flooring
    - Centrifugal separators (Cyclonic)
    - Magnetics for largely magnetic dust

Knowing the physics then use what you have

Air lock mitigation

- Elevated lift up open grate floor -Separate dust and crew
- Ionizing air knife at low air lock pressure- Connect umbilical for space suit, Use ionized repressurization air for local non-contact dust blow off, (At low airlock pressure dust settling will be faster)
- Recirculating ULPA filter unit from about 10 kPa up, Pre filtration could include passive or active electrostatics, Moisture to aide in agglutination
- Adhesive tape dust/lint roller
- In-situ resource utilization
  - After donning the suit the next trip out, using a controlled venting through a vacuum cleaner hose, clean and vent the airlock, including below the lift up floor.
  - Ionizer in brush head for mitigating triboelectric charging
  - Dust proof throttle valve at pick up nozzle, KF style vacuum cap and valve to external environment.
  - Potentially use exhausting vacuum during repressurization, additional resources required

Make use of the different environments

Crew environment design

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- Design for cleaning as much as possible
  - Minimize/mitigate surface gaps
  - Keep surface as smooth as possible
  - Minimize the number of small internal radii (internal corners)
  - Minimize exposed cloth or porous surfaces
  - Tacky mat at entrance

- Isolate dust- Airlock (mud room), Air cleaner isolation

- Utilize common high load dust separation techniques in air recirculation as needed (Magnets, Electrostatics, volume filtration)

- Variable ULPA air filtration

The usual techniques for clean systems

Crew Environment cleanliness

- Variable rate air flow filtration, entry high flow, maintenance lower flow
- Elevated removable open grid floor
- Tacky rollers
- Soft low force Wipe- Drag wipe, “California Car Duster”, Swiffer
- Damp wipe
- Central Vacuum dust separator isolated multistage filtration

Simple robust known technologies

Mitigation approaches External Environment

- Solar Arrays, Sealing surfaces, Thermal surfaces
  - Ionizing air knife- minimize gas usage versus air shear rate with electrostatic neutralization
  - Soft low force Wipe- Drag wipe, “California Car Duster”
  - Adhesive lint rollers

- Mechanisms
  - Remove gross dust contamination
  - Soft wipe seals- Felt seals (no gaps, compliant, minimize impact embedded dust)
  - Elastomeric boots- nearly hermetic

Simple known technologies

Conclusions

- Lunar and Planetary dust are not anomalous materials
- Mitigating Lunar and Planetary dust is much the same as any dust
- There have been millennia of dealing with planetary dust on Earth
- There are additional mitigation mechanisms that can and should be designed in Lunar and Planetary Hardware to utilize in-situ resources

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