Dust charging issues

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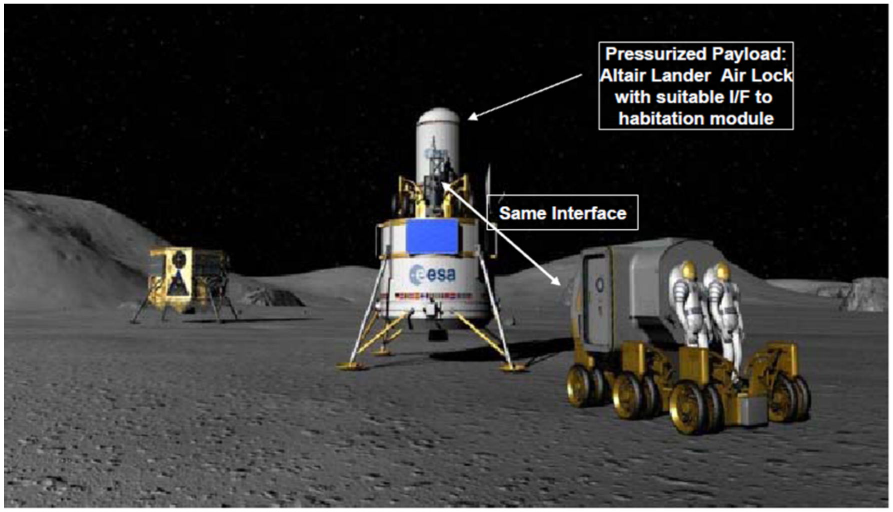
SPINE Meeting, ESTEC, 19/03/2013

Dust issues in the context of Human and Robotic Exploration

“I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust.”

Gene Cernan
Apollo 17 Technical Debrief

Alan Bean’s spacesuit (Apollo 12)



Dust issues in general

- *highly abrasive : friction with surfaces can wear down materials (e.g. astronauts suits), reduce material lifetimes*
- *highly sticking: contamination of habitats following EVA with dust loaded suits (including materials within the habitat, atmosphere quality, potentially astronaut's health)*
- *seal degradation, leaks, increased spares and maintenance of bearings, mechanisms blocking*
- *degradation and loss of coatings, especially optical elements (windows, solar panels, wiring)*
- *altered thermal properties of equipment surfaces, thermal control of habitat elements*
- *mechanical degradation of systems by penetration into mechanical moving parts*
- *degradation of astronaut's suits (e.g. visor surface scratches, dust accumulation), leaks*
- *potential health issues (lungs, nervous and cardiovascular systems) due to dust inhalation.*
- *reduction in visibility/optical depth due to dust levitation and transport,*
- *contamination and efficiency reduction of solar panels,*
- *complex sampling and handling characteristics for payloads due to unique electrostatic behaviour*

Effects on Systems – EVA example

Sub-system	Effects due to dust exposure
Outer Garment	Dust accumulation /transfer to airlock habitat/ materials degradation
Bearings	Seal degradation/leaks/increased spares/maintenance
Visor coatings	Scratches/Severe abrasion/loss of coatings
Lighting	Reduced illumination due to dust coating illumination source

Sandra Wagner, JSC

A large number of systems are affected -> reliability and performance of optical/mechanical/electrical (including life support and astronaut health) systems

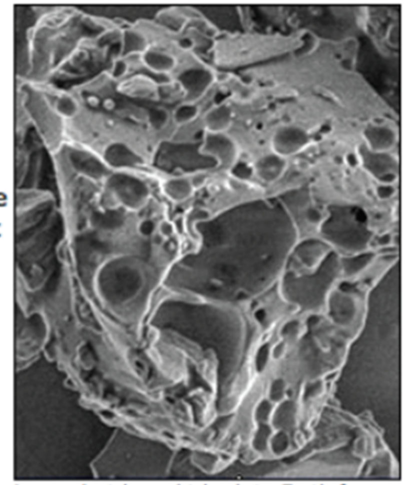
Health Hazards

„**Fine particles**
The team at the University of Tennessee has shown that about one percent by weight of lunar soil comprises particles less than one micron in size. A smaller - but still significant - fraction is less than 100 nanometres (billionths of a metre) in size.
They determined that most of the fine particles in lunar dust are composed of glass formed through the impact of micrometeorites on the surface of the Moon. But the glass also contains metallic iron grains, much like that in a carpenter's nail and measuring just 10-20 nanometres in size.
These grains, called "nano-phase iron", are so small that, if inhaled, some would pass directly from the lungs into the blood circulation.“

Lunar dust 'may harm astronauts'

By Paul Rincon
Science reporter, BBC News, Houston

Scientists are investigating the possible threat posed to astronauts by inhaling lunar dust.


Lunar dust brought back to Earth from the Apollo 17 mission

A study suggests the smallest particles in lunar dust might be toxic, if comparisons with dust inhalation cases on Earth apply.

Teams hope to carry out experiments on mice to determine whether this is the case or not.

Nasa has set up a working group to look into the matter ahead of its planned return to the Moon by 2020.

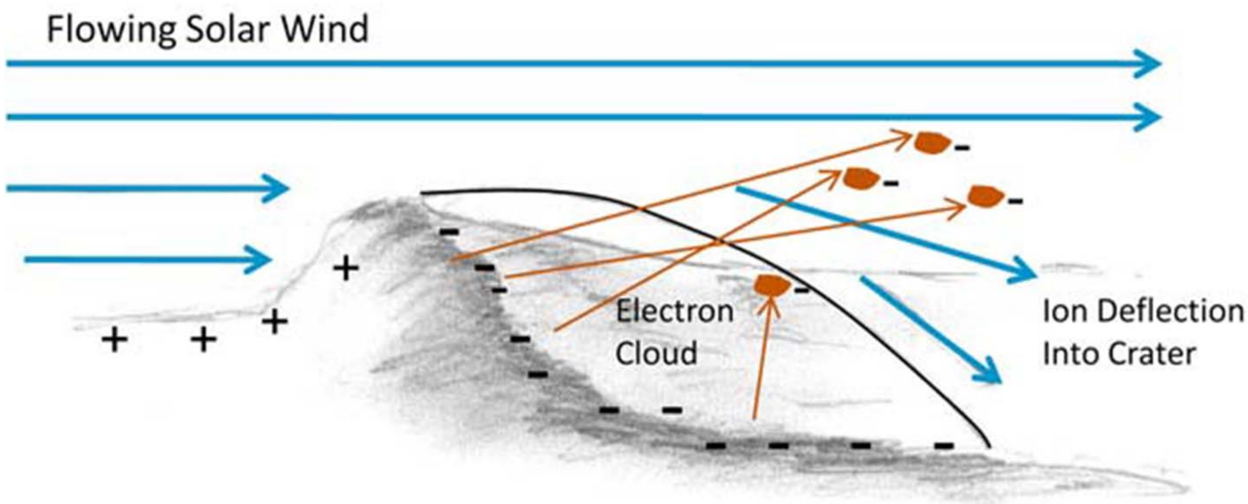
A team at the University of Tennessee (UT) in Knoxville is also looking at ways of using magnets to filter dust from the living environments of lunar bases and spacecraft.

See how the US plans to return to the Moon in 2020

The health effects of inhaling lunar dust have been recognised since Nasa's Apollo missions.

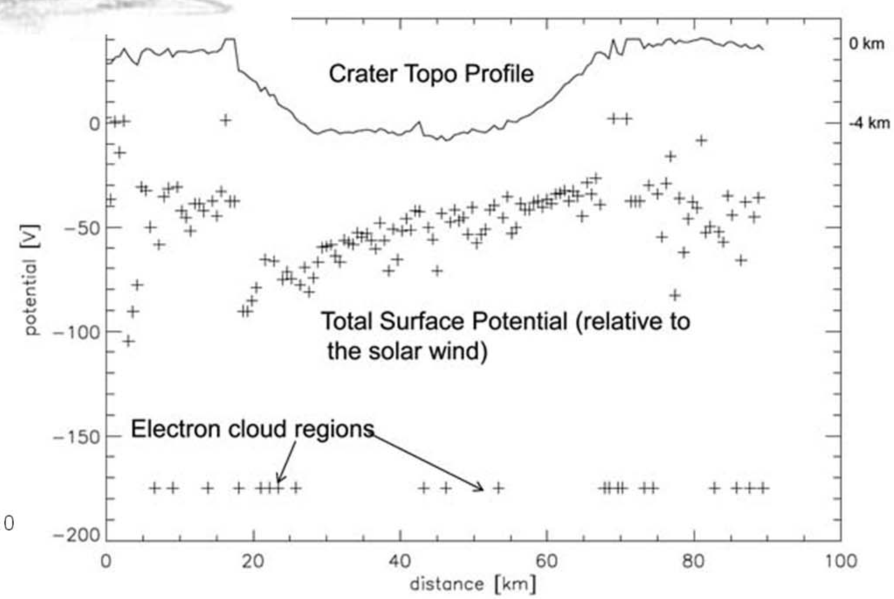
Astronaut Harrison H (Jack) Schmitt, the last man to step on to the Moon in Apollo 17, complained of "lunar dust hay fever" when his dirty space suit contaminated the habitation module after an energetic foray on the lunar surface.

Surface / Triboelectric charging



Farrell et al, 2008

Moving objects at the surface of shadowed areas / craters floor might accumulate a large amount of charge – dissipative time very large (~minutes) → ESD risk during operations in such areas.



Mitigation Techniques

- Strippable Coatings
- CO2 Snow Cleaning
- Ice Blasting
- Laser Cleaning
- Dynamically Switchable Surfaces
- Airflow Cleaning of Surfaces
- Work Function Matching Thin Film Coatings
- Dense-phase CO2 Cleaning
- Compressed Waste Gas for Dust Removal
- Magnetic Self-Cleaning Connectors
- Electrodynamic Screen for Removal of Dust from EVA Suit and Visors
- Magnetic Brush
- Plasma Cleaning of Surfaces
- Fiber, Textiles and Non-wovens Technologies
- Electrospinning
- Integrated Wear/Damage Monitoring
- Surface Modification of Space Suit Fabric (e.g. Nano-Tex Technology)
- Electronic Textiles to Facilitate Dust Removal by Dielectrophoresis
- Recycled Electrospun Protective Layers
- Thin Film Coatings
- Advanced Filters to Capture Planetary Dust and Indoor Dust
- Gecko-Inspired Fiber Adhesive Arrays
- Contacting Type Metal Face Seal
- Dust Monitoring Particle Counters
- MEMS-based sensors for Particulate Detection and Characterization
- Discrete Particle Simulation Tool for Fine Cohesive Particulates

To be tested in Lab

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AEVA Dust Focus Group, 2005

GSP / TRP associated studies

GSP : ***Modelling of Dusty plasma Near surface Environments***
TRP : ***Dust Electrostatic Charging, Transport and Contamination for Lunar Lander and Human Exploration Missions***

- **Specifications of charged dust environments at objects of interest in the context of future exploration missions : the Moon and asteroids (GSP)**

→ Improve current modelling capability for such environments in Europe

- **Develop a charged dusts / exploration units interactions diagnostic tool for future missions risks assessment (TRP)**

→ Where and what will be the exploration systems surfaces mostly affected by dust ?

Modelling of Dusty plasma Near surface Environments

- ❑ Parallel studies, Kicked-Off Oct. 1st 2012
- ❑ Studies duration is 1 year
- ❑ Consortia:

- FMI (prime), IRF-K, UoB, Arquimea
- ONERA (prime), IRS, Lancaster University, Leuven University

Objectives : specify distributions of dust size, mass, velocity, charging levels, fluxes and densities, etc … usefull to assess harmful effects on explorations systems. Variations of these distributions with location, as well as global circulation of dust is addressed.

→ Provides a near surface environmental description and at project level environmental specification, to be used as input in charged dusts assessment risk tool.

PM1	PM2	PM3
- Modelling Requirements - Model Preliminary Architecture	- Near Surface Dusty plasma Model	- Environment Specifications - Gaps analysis

Dust Electrostatic Charging, Transport and Contamination for Lunar Lander and Human Exploration Missions

- ❑ Kicked-Off Feb. 1st 2013
- ❑ Studies duration is 18 monthes (excluding maintenance)
- ❑ Consortia:

- ONERA (prime), IRS, Lancaster University, Leuven University

Objectives : modelling the processes of charging, transport and charged dust deposition in the vicinity of and at exploration units surfaces.

→ Provide diagnostics on dust contamination of surface exploration systems (e.g. planetary probes/payloads/vehicles/habitat and astronauts) in order to support the design of planetary exploration missions and systems.

SPIS-Dust requirements - 1

- model the 3D geometry of a surface exploration system
- model a 3D planetary surface with a complex (e.g. crater like) topology
- input s/c and planetary materials physical and electrical characteristics
- input dust grains material characteristics, deviation from spherical shape (e.g. through a fudge factor) and user defined dust mass and size distributions
- define global dusty plasma environment, including surface dust grains launching velocity distributions
- parameterize interactions between dust grains and landed/surface platform surfaces materials, as e.g. dust fractionation ratio under impact, dust penetration ratio, sticking, albedo change etc …

SPIS-Dust requirements - 2

- simulate charged dust dynamic (surface separation, levitation and transport) in the vicinity of surface exploration units.
- model interactions (e.g., triboelectric charging, adhesion, implantation, shattering, etc …)of charged dust with the surfaces of equipment on the lunar surface,
- simulate charging mechanisms of exploration units surfaces due to the combined effect of charged grains, electrons and ions currents, and photoemission
- model charged grains/surface separation conditions.
- calculate the electrostatic charging behaviour of limited e.g. lunar surface areas.

Outputs :

- Surface current due to the charged dust
- Density, energy, velocity, mass, charge and size distributions of dust grains in volume and at impact on a surface
- Dust contamination levels, based on dust fluxes at a surface, velocity distributions of impacting grains, grains surface coverage, implantation rates etc …