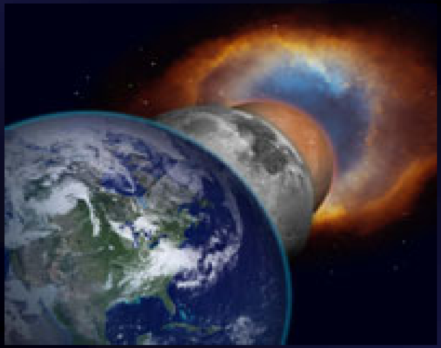
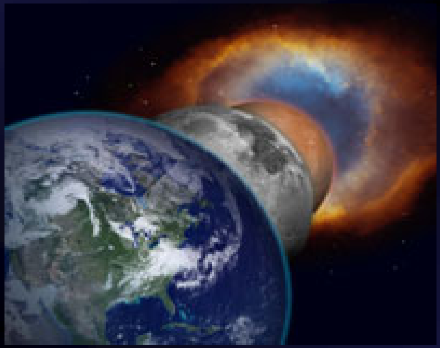


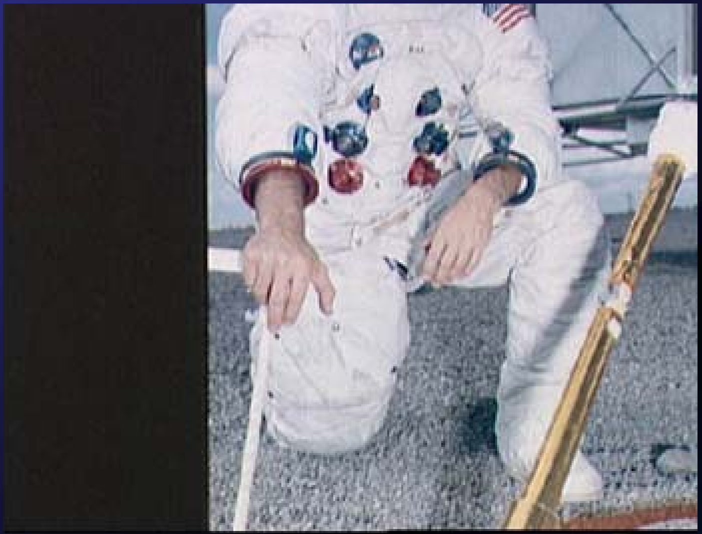
Planetary Dust: Cross-Functional Considerations

Presented by
Sandra Wagner
JSC, Crew and Thermal Systems Division

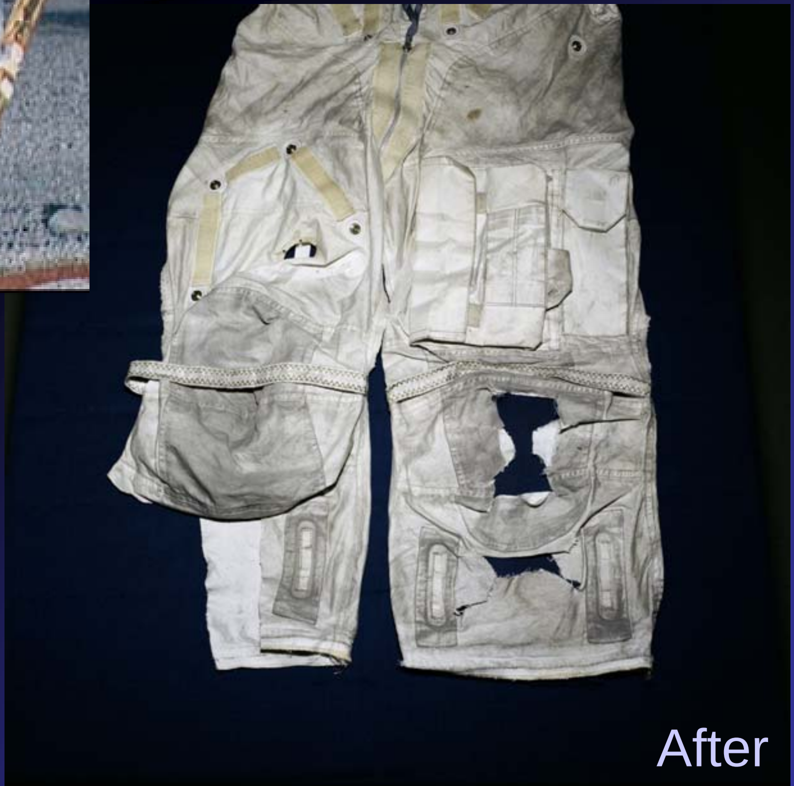
Habitation 2006
Orlando, Florida
February 6-8, 2006

Apollo 12:
Alan Bean’s Spacesuit





Before



After

Advanced Integrated Matrix (AIM) Dust Assessment

What Information is Needed to Develop Lunar and Martian Dust Requirements?

ABSTRACT

Apollo astronauts learned first hand how problems with dust impact lunar surface missions. After three days, lunar dust contaminating on EVA suit bearings led to such great difficulty in movement that another EVA would not have been possible. Dust clinging to EVA suits was transported into the Lunar Module. During the return trip to Earth, when micro gravity was reestablished, the dust became airborne and floated through the cabin. Crews inhaled the dust and it irritated their eyes. Some mechanical systems aboard the spacecraft were damaged due to dust contamination. Study results obtained by Robotic Martian missions indicate that Martian surface soil is oxidative and reactive. Exposures to the reactive Martian dust will pose an even greater concern to the crew health and the integrity of the mechanical systems.

As NASA embarks on planetary surface missions to support its Exploration Vision, the effects of these extraterrestrial dusts must be well understood and systems must be designed to operate reliably and protect the crew in the dusty environments of the Moon and Mars.

The AIM Dust Assessment Team was tasked to identify systems that will be affected by the respective dust, how they will be affected, associated risks of dust exposure, requirements that will need to be developed, identified knowledge gaps, and recommended scientifice measurements to obtain information needed to develop requirements, and design and manufacture the surface systems that will support crew habitation in the lunar and Martian outposts.

Sandra Wagner

Jennifer Gessler	Jim Gaier
Elisa Sandvik	Joe Kosmo
Carlton Allen	Chiu-Wing Lam
Debra Chowning	Frances Mount
Bruce Duffield	David Treat
Julianna Fishman	Mike Gernhardt

A·I·M
ADVANCED INTEGRATION MATRIX

AN ASSESSMENT OF DUST EFFECTS ON PLANETARY SURFACE SYSTEMS TO SUPPORT EXPLORATION REQUIREMENTS

INTRODUCTION

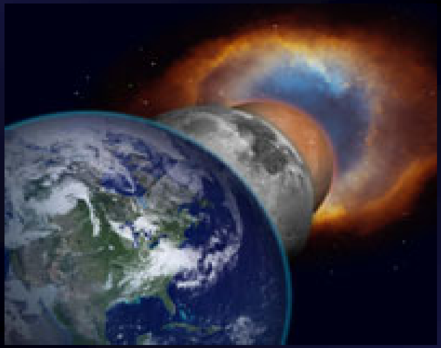
Planetary dust leads to major system and mission failure risks. In order to mitigate the risks associated with dust, Life Support and Habitation (LSH) initiated a study to determine direction to better understand lunar and Martian dusts.

Engineering requirements are required to bound measurable quantities within the functional limits of people or technologies. Good requirements are generated through a process that involves reviewing lessons learned, identifying systems impacted by dust and other contaminates. Once requirements are written, feasibility studies need to be performed to identify technologies to meet the requirements.

This scope of this assessment was to identify applicable documents relevant to lunar and Martian dust, identify lunar and Martian human support systems that will be affected by the dusts, determine the requirements that will need to be written, perform a gap analysis to determine what information is still needed to write the requirements, and recommend experiments and measurement on the Earth, Moon, and Mars to obtain needed information.

link to document goes here

AIM Dust Assessment



Define the Problem

- System Affected
- Subsystem Affected
- Effects on System

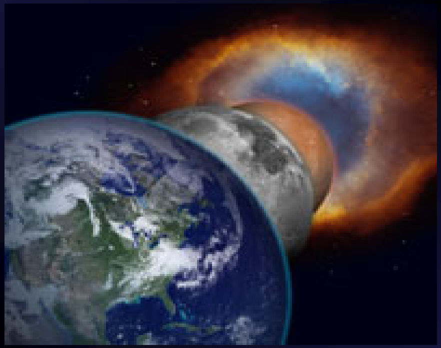
- Risks
  - ✓ Hazards
  - ✓ Habitability
  - ✓ Toxicity
- Requirements Needed
- Knowledge Gaps

Analyze the Problem

- Recommendation
  - ✓ Earth
  - ✓ Moon
  - ✓ Mars

Frame the Question

AIM Interdivisional Dust Study
Affected Systems



Advanced EVA Systems

- Airlock
- Suit Assembly
- Helmet
- PLSS Power and communications
- PLSS cooling
- PLSS O2
- PLSS Vent
- Ancillary equipment
- Structures
- Tools and hardware
- Rovers
- Displays
- Solar cells
- Windows
- Lights
- Sensors
- Cameras

Air Revitalization

- Water Recovery
- Solid Waste Processing
- Thermal Control
- Other ALS Systems

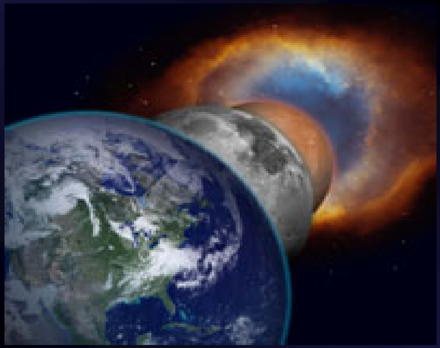
Advanced Food Systems

- Food Storage
- Food Processing
- Food Preparation.

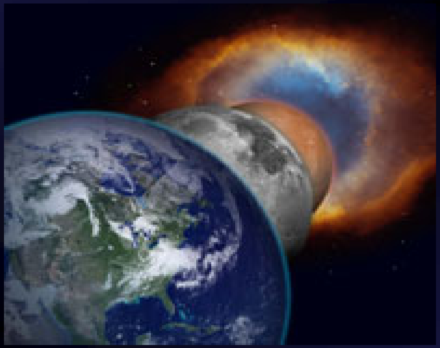
Other Associated Systems

- GN&C
- Structures
- IVA
- Fire Detection and Suppression
- Environmental Monitoring
- Power
- Electrical and Electronics
- Communications

AIM Dust Study
Effects on System
EVA Example



Subsystem/ Component	Effect due to Dust Exposure
Outer Garment	Dust accumulation/transfer to airlock-habitat; degradation of materials
Bearings	Seal degradation, leaks, higher spares/maintenance
Visor coatings	Scratches/severe abrasion; loss of coatings
Lighting	Reduced illumination due to dust coating illumination source



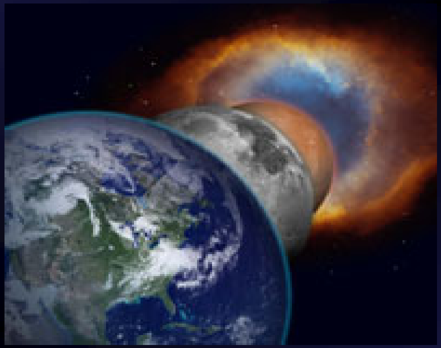
AIM Dust Study Recommendations

Measure the Things that Can Only be Measured on Mars

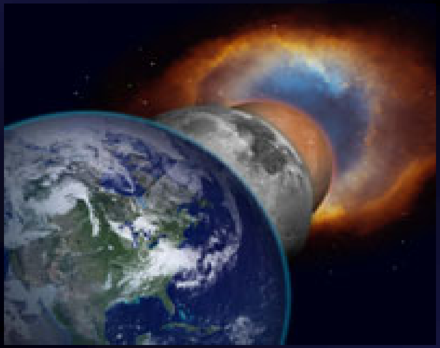
Measure the Things that Can Only be Measured on the Moon

Perform Simulations and Studies on Earth to Test the Effects on Human Support Systems

AIM Dust Study Recommendations - Earth



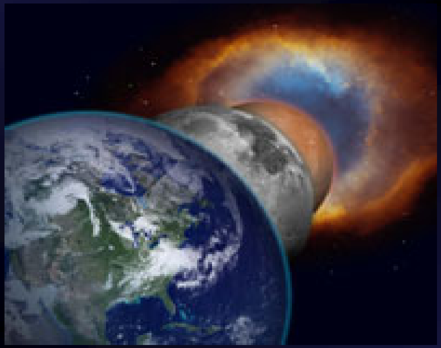
- Develop a standard set of Lunar and Martian dust properties for future designers.
- Develop and fully characterize new Lunar and Martian soil simulants.
- Develop Lunar and Martian test chamber that closely approximates environment.
- Develop Lunar and Martian dust test programs to demonstrate system reliability.
- Obtain small quantities of actual lunar dust for critical test programs (i.e., toxicology).
- Compile information on Apollo crew’s experience with the lunar dust.
- Implement medical monitoring for astronauts exposed to Lunar and Martian dust.
- Survey and mature innovative dust mitigation technologies.



ADVANCED EXTRAVEHICUAR ACTIVITY

Dust Focus Group
May 2005

ADVANCED EXTRAVEHICUAR ACTIVITY
AEVA Industry Dust Focus Group Objectives
Golden, Colorado – May 2005



Tolerate Dust Exposure

Minimize reliability/performance impacts on gas handling and processing systems from Lunar and Martian dust

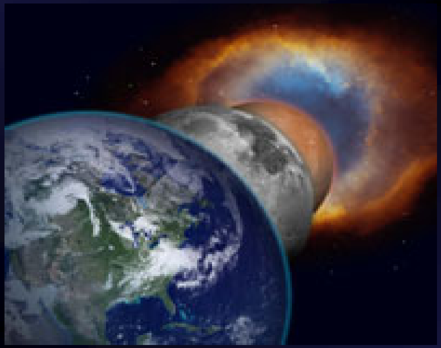
Minimize reliability/performance impacts on connectors and sealing surfaces from Lunar and Martian dust

Minimize reliability/performance impacts on exposed surface materials from Lunar and Martian dust

Minimize reliability/performance impacts on optical systems from Lunar and Martian dust

Minimize reliability/performance impacts on electrical and electronic systems from Lunar and Martian dust

Minimize reliability/performance impacts on Information and communication systems tolerate dust exposure



ADVANCED EXTRAVEHICUAR ACTIVITY
AEVA Industry Dust Focus Group Objectives
Golden, Colorado – May 2005

Detect and Monitor Dust

Maximize accuracy/ reliability of dust level monitoring devices

Control Entry of Dust

Minimize Lunar and Martian dust exposure to the astronaut during EVA operations

Minimize Lunar and Martian dust contamination in human habitable environments

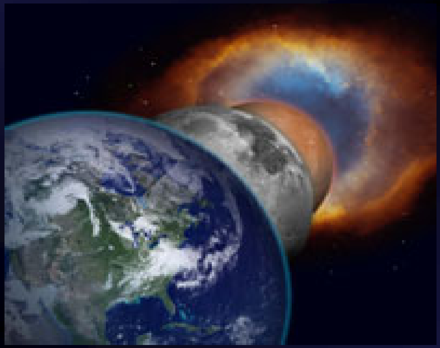
Remove Dust

Minimize dust deposition on critical surfaces

Minimize reliability/performance impacts on critical surfaces from Lunar and Martian dust

Minimize human effort required to conduct dust mitigation operations

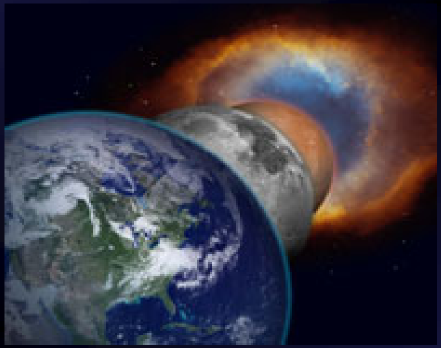
Potential Dust Mitigation Technologies



Identified by the AEVA Dust Focus Group Golden, Colorado - May 2005

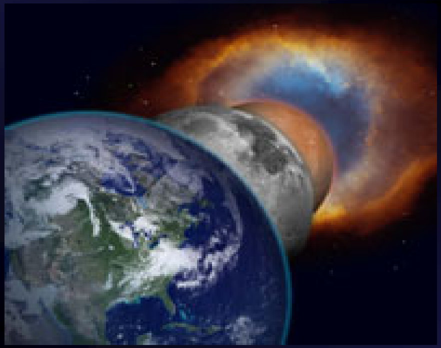
- Strippable Coatings
- CO2 Snow Cleaning
- Ice Blasting
- Laser Cleaning
- Dynamically Switchable Surfaces
- Airflow Cleaning of Surfaces
- Work Function Matching Thin Film Coatings
- Dense-phase CO2 Cleaning
- Compressed Waste Gas for Dust Removal
- Magnetic Self-Cleaning Connectors
- Electrodynamic Screen for Removal of Dust from EVA Suit and Visors
- Magnetic Brush
- Plasma Cleaning of Surfaces
- Fiber, Textiles and Non-wovens Technologies

Potential Dust Mitigation Technologies



Identified by the AEVA Dust Focus Group Golden, Colorado - May 2005

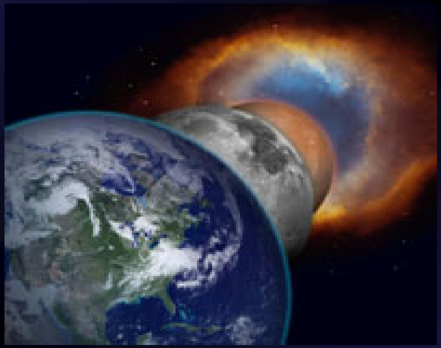
- Electrospinning
- Integrated Wear/Damage Monitoring
- Surface Modification of Space Suit Fabric (e.g. Nano-Tex Technology)
- Electronic Textiles to Facilitate Dust Removal by Dielectrophoresis
- Recycled Electrospun Protective Layers
- Thin Film Coatings
- Advanced Filters to Capture Planetary Dust 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



Apollo Lessons Learned

Mission Reports
Technical Debriefs

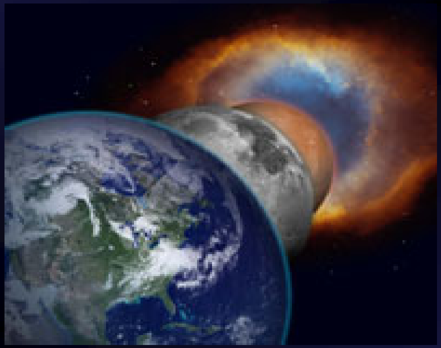
Apollo Lessons Learned



“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

Apollo Lessons Learned: Dust Was Pervasive



Lunar Module Descent - Surface Obscuration

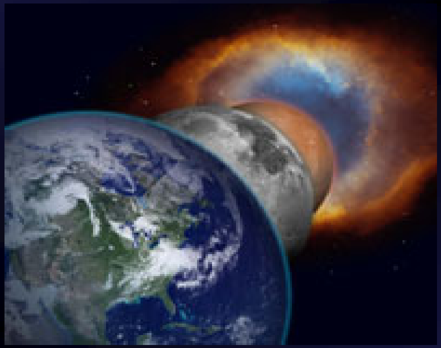
Lunar and Command Module Contamination Sources

- Space Suits
- Samples and Equipment
- Cables and Cords
- Translation Aids
- Lunar Rover Vehicle
- Pockets
- Tunnel Transfer

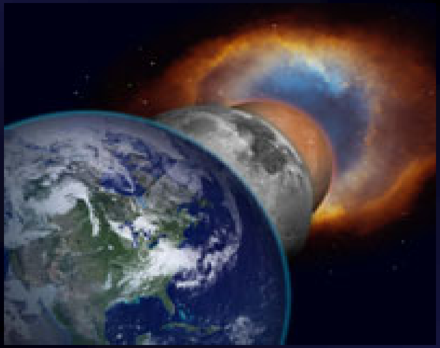
Equipment Affected – Not Just Space Suits

- Experiments
- Cameras
- Translation Aids
- Power and Thermal Systems
- Lunar Rover Vehicle
- Sampling Tools and Samples
- Space Suits
- Astronauts

Learning From Apollo: Manage Dust



- Start With the End in Mind
- Design For Reliability – ALL SYSTEMS
- Keep Dust Outside
- Develop Removal and Rejection Technologies



The Adventure Continues …

Thank You