



2007 Lunar Dust Workshop (NASA Ames) Outbrief

Daniel Winterhalter

Chief Scientist, NASA Engineering and Safety Center (NESC)

Also:

Lunar Program Scientist, Jet Propulsion Laboratory, California Institute of Technology



"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*



A common sense, layered, engineering design defense can solve any apparent problem with dust during long-term human activity and habitation in the lunar environment

*Jack Schmitt
Ames Research Center
February 2, 2004*



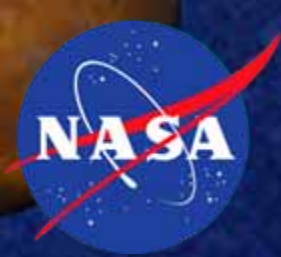
...The Real Dirt! (cont.)



Gene Cernan (17)

- **The Purpose of the Lunar Dust Workshop**
 - To bring together the diverse group of individuals currently studying Lunar Dust issues with the designers and operators of the hardware that will operate on the Moon.
 - To identify the major engineering, scientific, and medical issues relating to lunar dust and to brainstorm and identify potential solutions to these issues.

The final product will be a report that outlines these issues and potential solutions. It will represent an integrated Agency perspective on lunar dust. This will allow us to identify proactive testing and analysis that should be conducted in the near term.



The NESC's Role at Lunar Dust Workshop



- The NASA Engineering and Safety Center (NESC) sponsored the Lunar Dust Workshop January 30 through February 1, 2007, at the Ames Research Center.
- Lunar dust was identified by several NESC Technical Discipline Teams as an issue that should be proactively addressed.
- The NESC has an Agency-wide infrastructure that can facilitate an integrated review of the issues

The 3-day Lunar Dust Workshop was held at Ames Research Center with approximately 200 participants representing the major disciplines, centers, academia and industry.

A large number of relevant issues were raised and evaluated. To date, we have not brought those to a simple and straightforward set of conclusions. Hence, the evaluation and consensus reached is very broad in terms of number of issues. They are not yet focused down to a manageable number of findings.

We will accomplish this task in the continued extraction from the workshop and in a subsequent follow-up workshops planned for late summer.

- Lunar Architecture Team (LAT) - Mark Hyatt, GRC
- Constellation Program (CxP) Perspectives - Sandra Wagner, JSC
- Exploration Technology Development Program (ETDP) Perspective - David Beals, LaRC
- The Lunar Precursor Robotic Program (LPRP) -Ray French, MSFC
- Characteristics, Chemistry, Mineralogy and Charge Properties - Evolution of the Lunar Regolith - David McKay, JSC
- Medical Concerns - Jeff Jones, JSC
- Current Lunar samples – Possible Access and Conditions - Gary Lofgren, JSC
- Simulates - Utility & Limitations - David McKay, JSC



Splinter Group Discussions



- Each of the findings from the four main Splinter Groups represents the encapsulation of long and detailed discussions. The findings from the four groups are provided in the following slides.
 - ❑ Basic Research Group
 - ❑ Mechanical Systems Group
 - ❑ Medical/Health Group
 - ❑ Life Support Systems Group
- These discussions will be included in the full report. The lists from the different splinters have not yet been cross-checked with other splinter sessions, and thus there is probably considerable overlap among the session findings.

- The Basic Research Group understood the need for better characterization of the nature of the dust, especially below 20 microns, including charging properties. Specifically, this would require analyses of current fines and in-situ verification via robotic missions. The Basic Research community will be responsible to characterize sufficiently well current and future lunar simulants so that they are used appropriately for the tasks at hand. These simulants will be sufficiently standardized so that tests may be compared over time. Basic Research shared in the common theme of the importance of mining the existing data from previous missions, especially Apollo.
- Basic Research Group Findings
 - Develop a systematic understanding of the lunar plasma environment.
 - Mine existing data from Apollo, Lunar, and Prospector missions.
 - Characterize existing simulants to determine if they have the distribution and other properties found in real fines.
 - Develop mitigation and cleaning strategies from knowledge of the Apollo information available.
 - Perform in-situ verification on robotic missions.

- The Mechanical Systems Group recognizes risks associated with lunar dust. Lunar dust-like material for testing mechanical systems will be extensive and can only realistically be managed by the use of appropriate simulant materials.
- **Mechanical Systems Group Findings**
 - Compile a matrix of mechanical systems and sub-components in regard to the dust interactions.
 - Design a guide for the mechanical components operating in the lunar dust environment by functionality and lessons learned.
 - Develop the correct lunar simulant.
 - Evaluate existing Apollo components and distribute knowledge gained.
 - Ensure the consistency of the conops and the engineering solutions.
 - Design, develop, test, evaluate and select mitigation technologies.
 - Identify and obtain required physical, chemical, optical, mechanical, electrical dust properties for mechanical testing.

- **Mechanical Systems Group Findings (continued)**
 - Obtain additional ground-based measurements of lunar regolith required to understand basic properties, especially below the 20-micron fraction.
 - Simulants and derivatives need to be standardized based on formulation and processing functionality.
 - Obtain specific in-situ measurements needed to validate design analysis and ground-based verification testing.
 - Continue developing physics-based engineering tools for lunar environment simulation.
 - Employ standard test techniques and possibly modify techniques to understand sensitivity to lunar dust in operation and performance of mechanical systems.
 - Develop and implement robust qualification test program based on approved understanding, sensitivities and mitigation.



Medical/Health Group



- The Medical/Health Group requires the most pristine of current lunar samples (begin in vitro, then in vivo, and finally with physical and biological studies on the Moon to confirm biological impacts). From this outcome, the Medical/Health Group will be able to understand acute versus chronic exposures.
- **Medical/Health Group Findings**
 - Consider using impaction to remove small particles.
 - Perform studies on combined effects of radiation and dust.
 - Perform studies that aim to approximate the combination of factors in the lunar environment.
 - Do not bring suits in the HAB area for maintenance.
 - Find ways to predict individual responses to lunar dust.
 - Include a genomic strategy for studying dust reactivity in vitro.



Medical/Health Group (cont)



- **Medical/Health Group Findings (continued)**
 - Need acute versus chronic exposure studies.
 - Need dust level monitors in suit in the area (immediate and cumulative exposure).
 - Need physical and biologic studies in situ on the Moon to confirm biological activity.
 - Need monitoring of breathing patterns.
 - Need to use curated material for very early studies.
 - Pre-mixed dust with coatings before testing in vitro.
 - Vitro studies as cost-effective screen before in vivo studies.



Life Support Systems Group



- The Life Support Systems Group will rely on Apollo hardware and lessons learned as a starting point. Life Support, along with Mechanical Systems, desire an updated Lunar Environment Document (including lunar dust) that can focus on the design process. The Medical/Health Group will assist the Life Support Systems Group in establishing particulate size guidelines to clearly understand the appropriateness of current technologies, or whether advancement in filtration technologies may be necessary.



Life Support Systems Group (cont)

- **Life Support Group Findings**

- Assess need to develop new test facilities and capabilities. ECLSS and EVA need to convene with the medical community to discuss requirements and capabilities in both directions.
- Further inspection and analysis of the Apollo Crew Module equipment is desired to help determine dust penetration, filter impacts, material reaction and system degradation.
- Follow up workshop on lunar dust.
- Knowledge about dust relevant in environments needs to be captured and vetted.
- Need a rigorous testing program to meet the requirements of analog testing.
- Communicate dust barrier and lander system design considerations for dust exclusion to Program SE&I.
- Develop rigorous procedures for housekeeping.
- Have airlock or suitlock.
- Efficient plan for removing dust for suit, and any equipment prior to going into the airlock, mudroom or cleaning station, etc