The Impact of Lunar Dust and Mars Dust on Human Exploration:

Summary of the NASA Engineering and Safety Center (NESC) Workshops

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LSIC Dust Mitigation Focus Group

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NESC Workshops on Impact of Lunar and Planetary Dust on Human Exploration

<u>Dust in the Atmosphere of Mars and Its Impact on Human Exploration</u>, Lunar and Planetary Institute (LPI), Houston, TX, June 13-15, 2017 (100 participants).

<u>Lunar Dust and Its Impact on Human Exploration</u>, Lunar and Planetary Institute (LPI), Houston, TX, February 11-13, 2020 (125 participants).

Lunar Dust Workshop

Panel 1. Lunar Dust: Composition, Structure and Distribution (Panel Moderator: Joel S. Levine; Panel Recorder: Max Weinhold)

Panel 2. The Impact of Lunar Dust on Human Health (Panel Moderator: Russell Kerschmann; Panel Recorder: Peter Sim)

Panel 3. The Impact of Lunar Dust on Human Surface Systems and Operations and Techniques/Technologies to Reduce/Mitigate These Effects (Panel Moderators: Daniel Winterhalter and Michael Johansen; Panel Recorders: Michael Johansen and Daniel Winterhalter)

Lunar Dust and Its Impact on Human Exploration,
Lunar and Planetary Institute,
Feb. 11-13, 2020

Sponsors

NASA Engineering and Safety Center(NESC)
Lunar and Planetary Institute(LPI)
Universities Space Research Association(USRA)
Jet Propulsion Laboratory(JPL)
The College of William and Mary

Convener and Chair

Dr. Joel S. Levine: The College of William and Mary
and NASA Engineering and Safety Center(NESC)

Lunar Dust Workshop Online Information

General Information

https://www.hou.usra.edu/meetings/lunardust2020/

Program and Abstracts

https://www.hou.usra.edu/meetings/lunardust2020/pdf/lunardust2020_program.htm

Lunar Dust Workshop Products

NESC Workshop Report

Winterhalter, D., J. S. Levine, R. L. Kerschmann and T. K. Brady, Lunar Dust and Its Impact on Human Exploration NASA/TM-2020-5008219, NESC-RP-19-01469 September, 2020, 45 pages. https://ntrs.nasa.gov/citations/20205008219

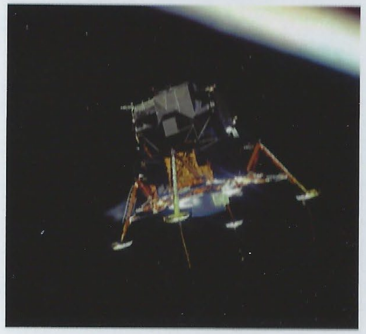
Workshop Proceedings

Levine, J. S. (Editor): The Impact of Lunar Dust on Human Exploration, Cambridge Scholars Publishing, UK, 2021, 285 pages(14 chapters, 48 contributors).

https://www.cambridgescholars.com/resources/pdfs/978-1-5275-6308-7-sample.pdf

The Impact of Lunar Dust on Human Exploration






Edited by

Joel S. Levine

Lunar Dust Recommendation 1

Characteristics of the finest fraction (<45 microns) of the lunar soil are not well understood. The knowledge gap increases with decreasing particle size. Further, there is insufficient knowledge of the variation in dust characteristics (e.g., chemical composition and mineralogy) and other characteristics of particles < 45 µm across lunar geological regions. It is recommended that future robotic and human lunar missions carry instrumentation to measure particle size and shape distribution from 45 to 0.1 micron on the lunar surface. Further, useful data on dust characteristics in this size range
(e.g., chemical composition, mineralogy, chemical reactivity, mobilization, migration and deposition, etc.) across the lunar geological regions should be obtained.

Lunar Dust Recommendation 2

There is uncertainty in the electrical charging properties of the lunar surface and individual particles. It is recommended that future robotic and human lunar missions carry instrumentation to measure electrical particle charging across dust grain sizes on the lunar surface.

Lunar Dust Recommendation 3

Little knowledge exists about the electrical charge characteristics of regolith particles on and above the lunar surface due to the interactions with the solar wind plasma, photoemission, and secondary electron emissions. It is recommended that measurements of the electrical charge characteristics are performed using Apollo samples to simulated interactions with solar wind plasma, photoemissions, and secondary electrons

Lunar Dust Recommendation 4

There has been little discussion of cabin and spacesuit (e.g., Lunar lander, Gateway) air cleaning systems. It is recommended that various routine technologies (e.g., filtration, external stowage platform (ESPs,) etc.) and innovative, integrated systems (e.g., photoionizers, enhanced ESPs, electret filters, etc.) are discussed, developed and selected for deployment. Selection should be based on important metrics to be identified (high removal efficiency, operability in environment under consideration, low-pressure drop, operating simplicity, etc.) by the responsible NASA technical teams.

Lunar Dust Recommendation 5

There is insufficient information with regard to the effect of lunar dust deposition on optical or thermal surface performance. It is recommended that the appropriate NASA Mission Directorate (MD) initiates/supports laboratory tests.

Lunar Dust Recommendation 6

While gaps exist, NASA’s Lunar Airborne Dust Toxicity Assessment Group (LADTAG) provided significant toxicological data to guide setting a crew permissible exposure limit (PEL) for dust exposure on short-term lunar missions. It is recommended that studies are supported, including those using return materials from Artemis 1, to better inform potential risks for exposure on the longer-duration Artemis 2 missions.

Lunar Dust Recommendation 7

There appears to be little coordinated discussions across the agency to identify the impact of lunar dust on mechanisms, seals, connectors, and solar panels, nor are there cleaning systems identified. It is recommended that NASA organizes an Agency-wide, coordinated effort (working groups, technical discipline teams, etc.) to discuss, develop, and select for deployment, device cleaning technologies. Selection should be based on important metrics to be identified (high removal efficiency, operability in environment under consideration, low-pressure drop, operating simplicity, etc.).

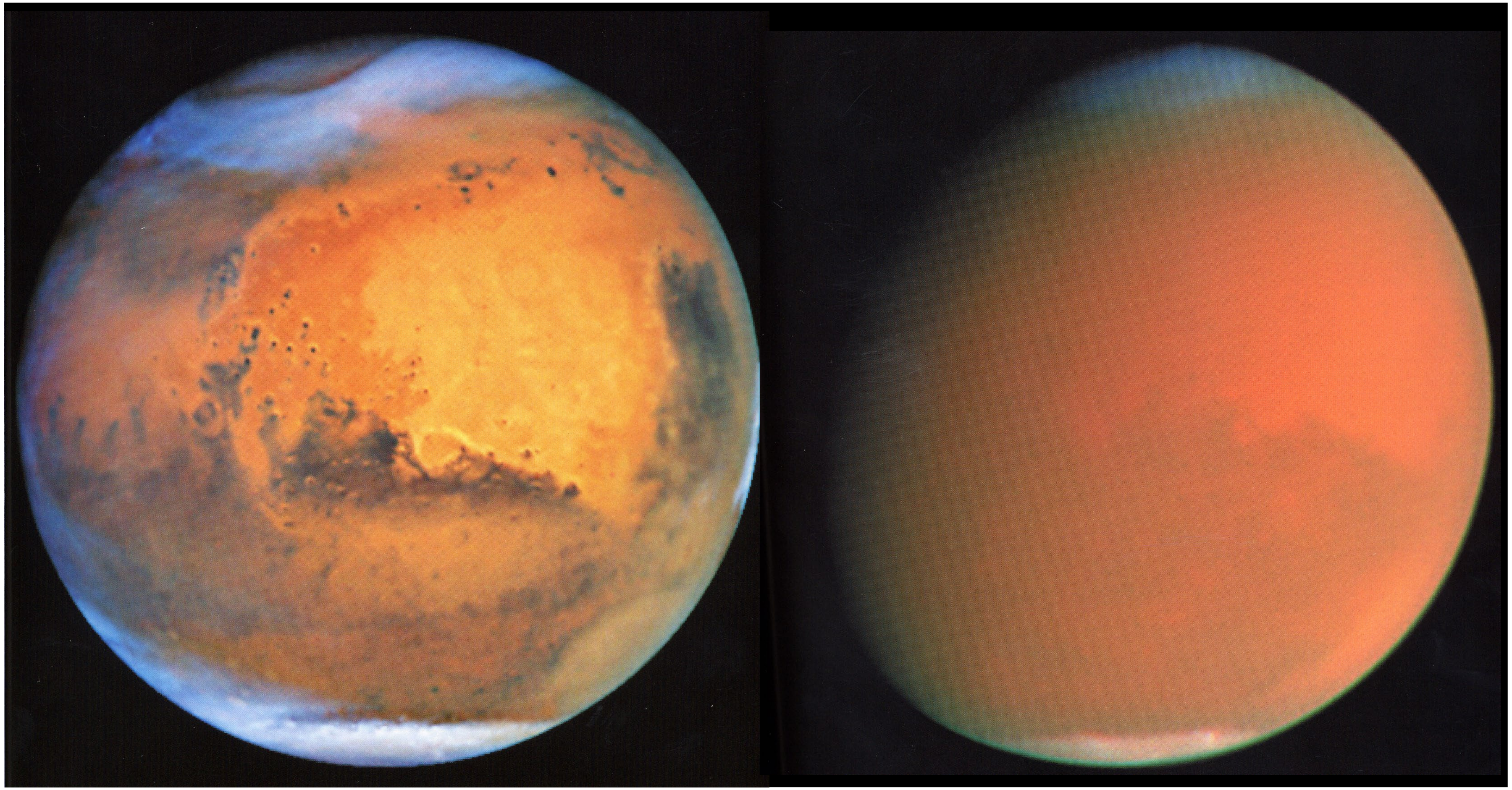
Lunar Dust Recommendation 8

No industry-standard set of NASA requirements and oversight mechanisms exist for the manufacturing, quality control, and validation of lunar dust simulants. It is recommended that NASA identify the most qualified group within the agency and/or other agencies to address this issue. This group should oversee quality and manufacture of a consistent simulant product for toxicologic and engineering applications.

Lunar Dust Summary Recommendation

In summary, the assembled experts concluded the dust problem is an agency and industry concern affecting most mission subsystems, and it must be addressed. In particular, measurements and experiments need to be taken and conducted on the lunar surface by precursor landers to ascertain dust characteristics that will influence hardware design, and provide toxicology data to safeguard crew health.

Mars: A Dusty Planet



Lifting of Mars Dust During Dust Storms Based on Viking Orbiter Photographs in 1977

Mass of atmospheric dust lofted into atmosphere associated with localized dust storm near Solis Planum: 13 million metric tons.

Mass of atmospheric dust lofted into atmosphere associated with regional dust storm: 430 million metric tons.

Reference: Martin, Journal Geophysical Research, 1995.

Mars Dust Workshop Products

NESC Report

Winterhalter, D., J. S. Levine and R. L. Kerschmann, The Dust in the Atmosphere of Mars and Its Impact on the Human Exploration of Mars, NASA/TM-2018-220084, NESC-RP-17-01263: August 2018, 30 pages.

https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180006321.pdf

Workshop Proceedings

Levine, J. S., D. Winterhalter and R. L. Kerschmann (Editors),Dust in the Atmosphere of Mars and its Impact on Human Exploration, Cambridge Scholars Publishing, UK, 2018, 293 pages (17 chapters, 41 contributors).

https://www.cambridgescholars.com/product/978-1-5275-1172-9

Dust in the Atmosphere of Mars and its Impact on Human Exploration

Edited by

Joel S. Levine, Daniel Winterhalter and Russell L. Kerschmann

Mars Dust Questions 1

Highest priority finding from Panel 1 (addressing dust structure, composition, and chemistry): There is insufficient knowledge on the possibility of extant life on Mars. It is especially important to know if there are microbes present in the globally circulating dust for the purposes of planetary protection for a returned human mission. It is inevitable that this material will interact with humans and systems on Mars and some will be returned to Earth by the return mission.

Recommendation: The question of life in the atmospheric dust can and should be addressed via Mars Sample Return. Because the atmospheric dust is globally mixed, the return and analysis of a single dust sample would be sufficient for this purpose. Life detection measurements (e.g., the lab on a chip, etc.) should also be included on a future Mars rover to search for extant life in near-surface materials that would be disturbed by human activities causing potential contamination.

Mars Dust Questions 2

Highest priority finding from Panel 2 (addressing dust impact on human health): There is currently insufficient information on the toxicological features of Mars dust to set standards for any duration of crew exposure. The prioritization of these investigations should be: 1. complete chemical speciation, 2. particle size distribution, 3. charge state, 4. component solubility, 5. porosity/surface to volume ratio, 6. hygroscopic properties, 7. bioavailability of grain components.

Recommendation: Future Mars missions should include instrumentation to obtain missing toxicologically relevant in-situ measurements, preferably at multiple locations, and especially for respirable dust <10 microns for both regolith-based and wind-borne dust if possible. Similarly, any Mars sample return materials should be examined to provide this information, either by direct studies on the native material or indirectly through use of validated, authentic simulants.

Mars Dust Questions 3

Highest priority finding from Panel 3 (addressing dust impact to systems): There is insufficient knowledge of the dust particle size and frequency distribution and flux below 10µm down to a few nm, especially in the lower atmosphere and on the surface. Should the flux be appreciable, the small particles will enter the astronauts' environments (suit, habitat, etc.) in significant quantity, unless the habitats are engineered with impractical and expensive constraints. Also, other mechanical and electrical/electronic systems, as well as Concepts of Operations (CONOPS) and In-situ Resource Utilization (ISRU), will be affected. All environments and systems will experience the potentially detrimental effects of the dust. Knowledge of the dust distribution would help the program on many levels. The knowledge gap can be closed by appropriate instrument(s) on the Martian surface. Laboratory tests (e.g., with simulants) will be necessary, but are not sufficient.

Recommendation: Conduct measurements on the Martian surface for an extended period of time (multiple seasons), preferably on multiple platforms if possible, and targeting the size range of 5nm□10µm. The measurements could be taken with a filtration system designed to capture the particles from the ambient air (preferred), in conjunction with a measurement technique (e.g., a micro-imager) to determine the desired dust characteristics. Mars exploration infrastructure designers could make conservative assumptions and engineer against them, but this adds to the cost of a human mission. These measurements should be collected early (well before cutting metal). For system designs, consider Mars 2020 mission environmental requirements. See Committee on Space Research (COSPAR) guidelines for planetary protection, especially for ≈10 nm (https://cosparhq.cnes.fr/).

Mars Dust Questions Summary

In summary, the assembled experts concluded that dust in the atmosphere of Mars is an issue to be addressed well before spacecraft are built to carry humans to the red planet. In particular, measurements and experiments need to be taken and conducted on the surface of Mars by precursor landers to ascertain dust characteristics that will influence hardware design as well as provide toxicology data to safeguard crew health. In addition, dust samples need to be collected and examined for possible extant life, perhaps via a Mars Sample Return mission. Recent findings by the Curiosity rover team regarding the presence of complex organics and seasonal methane are important steps in this direction.