

Introduction: As we return to the Moon, the lunar regolith (i.e. lunar dust) covering the surface will be an obstacle to nominal operations. Accounts from Apollo astronauts and analysis of hardware returned from the surface illustrate just how deleterious the dust can be [1]. During Apollo missions, the lunar dust adhered to hardware mechanically and electrostatically [2].

Surviving the Night: Mitigating the lunar dust will be critical to surviving the night. Going hand-in-hand with other extreme environment considerations, dust mitigation is critical to mission success.

Dust Impacts on Other Systems: The lunar dust can have negative implications for power, thermal, mechanisms, and several other systems or sub-systems. For example, Apollo encountered marked degradation of performance in heat rejection systems for the lunar roving vehicle, science packages, and other components because of the lunar dust [1]. For power alone, dust can cause internal clogging for power connectors, heat rejection issues, excessive dust on reflective surfaces, reduced power output for solar arrays, and so on.

Dust Mitigation Strategy: In addition to considering technology solutions, it is important for hardware, systems, and or components to have a dust mitigation strategy. At a high level, hardware that will encounter the lunar dust should consider these things when defining a dust mitigation strategy:

- Understand Natural Environment
- Understand Induced Environment
- Understand Tolerance to Dust
- Write Dust Requirements
- Select Dust Mitigation Solutions
- Test Hardware in Dusty Environment

More information on each of these can be provided to hardware owners.

Dust Mitigation Technology Development: NASA has a series of technologies that may be available for hardware that needs to survive the lunar night. Many of these solutions are leveraging dust mitigation technology development efforts from NASA's Space Technology Mission Directorate

(STMD), as well as efforts from ESDMD programs, industry, and academia.

Through a series of STMD programs (both internal to NASA and through partnerships), there are several technologies in development as considerations as dust mitigation solutions for hardware.

Within STMD, the Game Changing Development Program (GCD) has funded several internal dust mitigation projects including low to mid TRL development, demonstrations on CLPS landers of high TRL solutions, and creating standards and best practices for dust mitigation.

STMD dust mitigation efforts also include a series of partnerships for developing technologies and advancing the state of dust mitigation at NASA. This includes the Lunar Surface Innovation Consortium (LSIC), Small Business Innovation Research, Early Stage Innovations (ESI), Space Technology Research Grants (STRG), Announcement of Collaboration Opportunities (ACOs) and Tipping Points (TPs), and Challenges and Crowdsourcing, among others.

There are also a series of dust mitigation solutions that have been widely used terrestrially, or during Apollo. In recent years, several studies have produced more data on the efficacy of these potential solutions in the lunar environment.

Dust Mitigation Solutions: Dust mitigation solutions generally fall into four categories:

- Dust Tolerant Mechanisms
- Passive Dust Mitigation Capabilities
- Active Dust Mitigation Capabilities
- Dust Measurement Capabilities

There are a series of solutions that may prove beneficial for hardware that needs to survive the lunar night, including new technology development as well as proven, terrestrial solutions. This presentation will discuss in more detail what some of these solutions are for payloads going to the surface.

References: [1] J. R. Gaier, NASA/TM—2005-213610, The Effects of Lunar Dust on EVA Systems During the Apollo Missions [2] T. J. Stubbs, et al. Impact of Dust on Lunar Exploration, 2005