Lunar Dust and Its Impact on Human Exploration

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Lunar Dust: The Apollo Experience

As NASA is preparing to send humans back to the Moon under the Artemis Program, a major concern is the impact of lunar dust on the human exploration of the Moon. In their flights to Moon from 1969-1972, the Apollo astronauts experienced numerous problems with lunar dust (Gaier, 2005, Levine, 2020). Lunar dust blown up into the thin lunar atmosphere during the landing of the Lunar Module significantly impacted astronaut visibility. On the lunar surface, lunar dust kicked up by the astronauts walking and driving their lunar rover had deleterious effects on their space suits and helmets and surface equipment and instrumentation. The tiny, very sharp, glassy lunar dust particles eroded and deteriorated their space suits and their seals. On the flight back to Earth, free-floating lunar dust in the Command Module caused additional problems.

Apollo 17 astronaut Gene Cernan, one of the last two people to walk on the Moon summarized the lunar dust problem during his post-flight briefing as: *I think dust is probably one of the greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust…One of the most aggravating, restricting facets of lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and its restrictive friction-like action to everything it gets on.*

Apollo 12 astronaut Alan Bean reported: *After lunar liftoff…a great quantity of dust floated free within the cabin. This dust made breathing without the helmet difficult, and enough particles were present in the cabin atmosphere to affect our vision… The use of a whiskbroom prior to ingress would probably not be satisfactory in solving the dust problem, because the dust tends to rub deeper into the garment rather than to brush off.*

Gaier (2005) writes that one of the surprises of the Apollo experience was how troublesome the lunar dust turned out to be. It obscured their vision on landing, clogged mechanisms, abraded the Extravehicular Mobility Suits (EMS), scratched the instrument covers, degraded the performance of radiators, compromised seals, irritated their eyes and lungs, and generally coated everything with surprising tenacity. Some of the EMS components were deteriorating at the end of the missions, which ranged from 21 to 75 hours on the lunar surface.

The Formation of Lunar Dust Particles

Over billions of years, the lunar regolith has been constantly bombarded by micrometeoroids. The Moon is continually bombarded by on the order of 10^6 kg/y of interplanetary dust particles (IDP) of cometary and asteroidal origin. Most of these projectiles range from 10 nm to about 1 mm in size and impact the Moon with

speeds in the range of 10 to 72 km/s. On Earth, the entry and traverse of these projectiles are referred to as "shooting stars." When the micrometeoroids hit the lunar surface regolith, they create a miniature shockwave in the soil, which causes some of the soil to melt and form secondary ejecta particles and some to vaporize to a gas (Heiken, Vaniman and French, 1991). The molten soil immediately freezes again forming tiny pieces of glass—glass shards. These tiny glass shards are jagged and very sharp. Most of the ejecta particles have initial speeds below the escape velocity of the Moon (2.4 km/s) and they return to the lunar surface, blanketing the lunar crust with a highly pulverized and impact gardened regolith. Micron and sub-micron size secondary particles that are ejected at speeds up to the escape velocity form a highly variable, but permanently present, dust cloud around the Moon (Horanyi et al., 2020). Due to the absence of wind or rain on the Moon, the glass shards remain jagged and very sharp over time. As a result of the constant "hammering" by micrometeoroids over billions of years, the lunar surface dust is extraordinary fine, similar to flour, which makes it very sticky and causes it to cling to everything, e.g., spacesuits, helmets, surface equipment and instruments, etc.

Lunar Dust: Key Measurements for Artemis Lunar Surface Missions

1. What are the particle size distribution, mineralogy/chemical composition and possible toxicity of lunar dust, especially for the particles less than 50 microns?

2. What processes/mechanisms control the transport/dynamics of lunar surface dust?

3. What are the electrical and magnetic properties of lunar dust?

References

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