Introduction

The lunar surface presents a unique laboratory to study the interactions of dust particles with plasma. In January 2020, JPL, with funding from the NASA's Division of Biological and Physical Sciences, formed a Lunar Dust Science Definition Team. The final report from the study team will be completed in September 2020. The team has identified key science objectives related to dust and plasma on the Moon, and a brief summary is presented here. The science return of instruments designed to address the identified science objectives could be enhanced by astronaut interaction (e.g. allowing deployment in multiple locations, or multiple instrument configurations).

Statement of Problem

In the absence of a shielding atmosphere or magnetic fields, the dusty regolith on the lunar surface interacts directly with the local plasma environment. This interaction results in electrical charging of the dust, and the resulting electrostatic forces can influence the behavior of dust particles. Charged dust may clump together, adhere to spacecraft and spacesuits, and/or obscure optical observations made from the lunar surface. Additionally, dust was seen as a major challenge during the Apollo surface operations [2]. Electrostatic dust motion has been hypothesized to occur at the Moon since the Surveyor era [3], and these phenomena have been observed in the lab [4]. However, there is no direct observational evidence of electrostatic dust motion, nor of the relevant physical properties that would produce these phenomena. Investigations of dust-plasma interactions and direct observation of electrostatic lofting or levitation would inform our understanding of the potentially active processes on airless bodies, as well as inform future efforts to assess and mitigate the threat of dust on future exploration missions.

Brief Physics Background

The solar wind plasma interacts directly with the lunar regolith, which contains particles down to nano-scale in size. Additionally, solar wind UV radiation causes photoemission of regolith. The net positive daytime lunar surface will attract electrons, causing a region of increased electron density near the surface called the plasma sheath. The non-uniform ion and electron density in the plasma sheath results in an electric field. If the electrostatic force is larger than the gravity and cohesive forces holding the particle on the surface, the particle will detach [1], a phenomenon termed electrostatic lofting. Electrostatic lofting may be a naturally occurring phenomenon and may also be enhanced by exploration activities: for example, rover-induced tribocharging or spacecraft shadows (causing stronger local electric fields) may induce electrostatic lofting.

Similar, but distinct from electrostatic lofting is the phenomenon of electrostatic levitation. While electrostatic lofting is the detachment of particles from the surface, electrostatically levitating particles hover above a surface. Levitating particles may be detached from the lunar surface due to electrostatic lofting, micrometeorite impacts or exploration activities. Because all regolith particles are charged, these detached particles will also experience an electrostatic force. In some cases, the electrostatic force is predicted to oppose gravity. Thus, particles launched with a specific range of initial conditions may hover above the surface. Electrostatic levitation may influence the transport of regolith across the lunar surface and may influence observations made from the lunar surface.

Science Objectives

Below is a brief description of the major science objectives related to dust-plasma interactions. **We recommend that the Artemis III mission make the following measurements at multiple local times, heights above the surface, and geographic locations. The ability of astronauts to facilitate successive deployments would greatly increase the science return of the instruments.**

- **Measure the plasma properties near the lunar surface.** While models of the near-surface plasma environment exist, measurements of the species densities, species energy distribution and electric field near the lunar surface are necessary to validate these models. The solar UV radiation causes photoemission, which is the dominant charging process on the lunar dayside. Measurements of the photoemissive properties of lunar regolith are necessary in order to quantify the charge state of regolith particles. The plasma environment influences electrostatic dust motion, spacecraft operations, and the design of remediation technologies.
- **Determine whether or not electrostatic lofting occurs naturally.** There is no undisputed, in situ evidence of electrostatic lofting on the undisturbed lunar surface. The occurrence of electrostatic lofting has implications both for the evolution of the surfaces of the Moon and other airless planetary bodies.
- **Determine whether or not electrostatic levitation occurs.** Computational models and laboratory experiments demonstrate that electrostatic levitation is possible, but there are no in situ observations of this phenomenon. The feasibility of electrostatic levitation may be strongly influenced by exploration operations, which may result in particle release or increased particle charging. Levitating particles or particles that are redistributed via levitation may present a hazard to landed spacecraft.

References

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