# QUANTIFYING THE PROCESSES THAT CONTROL THE DISTRIBUTION OF DUST IN THE MOON'S ATMOSPHERE.

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**Introduction:** Dust is a regular and omnipresent feature of the Moon's surface and atmosphere. Lunar dust has been recognized as a significant challenge to prolonged robotic and human presence on the Moon. Lunar dust negatively impacts human health and the operation and hence, lifetime of mechanical systems. Lunar surface dust lofted into the thin lunar atmosphere may carry electrostatic charge and generate electrical discharge. At the present time, very little is known about the chemical composition, toxicity to humans, impact on materials and the electrostatic discharge properties of lunar dust or the mechanisms that drive its abundance and variability in the lunar atmosphere.

**The Moon's Atmosphere:** Observations of dust in the lunar atmosphere are sparse and fairly diverse. They range from a few point measurements of the lunar horizon-glow as it is called from instruments on the early lunar-landers [1,2,3,4] to crude hand-drawn sketches made by the Apollo astronauts from lunar orbit [5] and instrumentation they left behind [6,7,8]. Some of the most recent and comprehensive measurements were made by the Clementine satellite [9,10]. The early measurements detected the low lying distribution of large dust particles having a very small scale height on the order of a meter. Increasingly more sensitive observations from later missions, primarily from lunar orbit have revealed the full extent of the dust to altitudes of 100km or more. Along with the growing body of observations is the development of lunar atmospheric dust models that can explain the observations. The current theory is that atmospheric dust is produced through the charging of surface dust grains by high energy photons and particles followed by electrostatic repulsion and levitation [11].

With the planned permanent return to the moon to establish a lunar outpost in the 2020 timeframe comes the need to improve our understanding of the tenuous lunar atmosphere and lunar dust in particular. Experience from the Apollo lunar landing missions is that lunar dust is attracted to surfaces such as equipment and spacesuits and supports the current electrostatic model for lunar dust production. This dust poses a significant risk to humans and their equipment by it toxicity, abrasiveness, and potential for destructive electrostatic discharge to sensitive equipment. An improved understanding of the nature of lunar dust and the mechanisms that control its production/distribution will be required if engineers are to develop new systems that are tolerant to or can actively inhibit dust's effects. A full understanding of the characteristics and variability of lunar dust could be used to schedule activities during times of minimal dust, design equipment to utilize any preferred flow of dust to its advantage, develop means to actively shield or repel dust from sensitive areas.

**Measurement Strategy:** The bulk of the extant evidence and current theories about the origin of dust in the lunar atmosphere point to surface charging of dust grains by high energy photons and particles and the primary mechanism. The sparse set of observations to date are insufficient to guide the development and validation of a detailed lunar dust model. The following are a brief set of questions that will need to be answered in the next 10 years if the behavior of lunar dust is to be understood prior to the development and deployment of a permanent lunar outpost:

- What is the distribution of dust in the lunar atmosphere?
- What are the mechanisms that cause dust grains loft and precipitate?
- Are the dust grains redistributed globally over the lunar surface?
- How does the dust distribution vary with (local solar) time?
- What is the resultant electrostatic field?
- Are the dust grain trajectories random or is there a preferred direction (dust wind)?
- Does the scale height of the dust layer depend upon the size of the dust grains?
- How does lunar topography influence the dust layer (does dust flow down hill)?
- How does this "dust plasma" interact with the Earth's Magnetic field and/or the solar wind?
- How does the dust distribution (height, abundance, & direction) vary with solar activity (flares, particle and x-ray fluxes in particular)? Decay of the dust layer from transient forcing events yields information on the particle lifetime (residence times).

A comprehensive suite of sensors to measure both the dust distribution and key forcing parameters will include both passive and active in-situ and remote sensors. In order to monitor the production of electrically charged dust grains, the sensor package must measure the in-situ flux of energetic photons and particles impinging onto the surface from the sun and the Earth's magnetosphere. The sensor suite will monitor the near surface response to this forcing through the deployment of an instrumented tower with a vertically distributed array of instruments to measure Electric and Magnetic fields and size-resolved particle flux (e.g. QCM or optical particle counter). This will measure the variations of dust scale height as a function of particle size along with the variations in the electrostatic field accelerating the particles. Separate measurements of the upward and downward fluxes will be used to determine local particle lofting and deposition rates as well as residence times. Characterization of the distribution and dynamics of the dust layer more than a few tens of meters above the lunar surface will rely on a scanning Doppler LiDAR. The Doppler LiDAR will be able to determine not only the abundance of dust several tens of kilometers above the surface, but also the velocity distribution of the dust grains. Scanning the LiDAR beam to view the dust from different directions is used to reconstruct the 3-D velocity field. Additionally, scanning the beam to the horizontal will enable the LiDAR system to characterize spatial inhomogeneity in the dust lofting mechanisms as well as observe how the dust interacts with the lunar topography (e.g., does the lofted dust flow down hill). The proposed suite of instruments could be deployed as a self contained, automated lunar lander.

The current plan for a lunar outpost calls for it to be located at the Moon's south pole. This region is very challenging to characterize since it is always very close to the terminator where there will be large gradients and spatial inhomogeneities in surface forcing. These same characteristics will provide lunar dust models with a difficult scenario to reproduce and will produce an excellent dataset for model validation. A simpler, complementary dataset from an equatorial mare location would provide a dataset where the individual processes could be isolated and explored. So, a minimum of two sensor suites on separate landers are needed. Development and deployment of this instrument suite will need to occur early enough for the resultant new knowledge to have an influence on the design and technology development leading to the lunar outpost (planned for ~2020). The mission timing should take advantage of the peak of the next solar cycle expected to occur in the 2014 timeframe.

**References**:

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