

Lunar Dust Transport Package. T. Munsat,^{1,2} Z. Sternovsky^{1,3}, S. Robertson,^{1,2} E. Grün,¹ M. Horanyi,^{1,2,3}

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Introduction: The electrostatic levitation and transport of lunar dust remains an interesting and controversial science issue from the Apollo era. This issue is also of great engineering importance in designing human habitats and protecting optical and mechanical devices. As a function of time and location, the lunar surface is exposed to solar wind plasma, UV radiation, and/or the plasma environment of our magnetosphere. Dust grains on the lunar surface collect an electrostatic charge and contribute to the large-scale surface charge density distribution. They emit and absorb plasma particles and solar UV photons, and provide an electromagnetic interface to the lunar interior. There are several in-situ and remote sensing observations that indicate that dusty plasma processes are responsible for the mobilization and transport of lunar soil. These processes are relevant to: (a) understand the lunar surface environment; (b) develop dust mitigation strategies; (c) understand the basic physical processes involved in the repeated build-up and collapse of dust-loaded plasma sheaths. This talk describes the concepts of the Lunar Dust Transport Package (LDTP) to investigate dusty plasma processes on the lunar surface. LDTP would be deployed autonomously, or during short missions to the Moon. We are designing a combination of in-situ and remote sensing observations to address the temporal variation of the spatial and size distributions of the levitated/transported dust grains, as well as to characterize the surface plasma environment. This package includes cameras, plasma and electric field booms, and instrumentation to measure the size, speed and the charge of the mobilized dust grains. This suite of instruments could also contribute to fundamental astrophysical observations by measuring the size, speed, and composition of interplanetary and interstellar grains bombarding the Moon. The goals of this ongoing effort at the newly established NLSI Colorado Center for Lunar Dust and Atmospheric Studies are:

- To define what is needed to understand the physics of surface charging and the individual dust grains in the near-surface plasma and photoelectron sheaths of the Moon, the possible mobilization and lift-off of dust particles, and the subsequent dynamics of dust as it is controlled by the local plasma environment.
- To define the necessary observations and derive the measurement requirements.
- Develop the concepts for an appropriate instrumentation package to be deployed on the lunar surface with minimal human assistance, that could stay there and

autonomously continue operations for an extended period of time.

- Use, as much as possible, existing instrumentation to gauge the resource requirements (cost, weight, power, volume, ease of deployment) and to identify the possible needs for further developments.
- To identify additional basic physical or astrophysical science issues to be addressed with the proposed suite of instruments.

Open questions to be addressed by LDTP:

- What is the spatial configuration (location, horizontal and vertical extent) of the horizon glow clouds? Is there a gap between the lunar surface and these clouds that could indicate stably levitated grains?
- What is the size distribution of the levitated/transported grains in these clouds? Is there a size-sorting with height above the lunar surface?
- How does the cloud change during day/night transitions, and along the lunar orbit?
- What is the charge density distribution on the surface as a function of local time and how does it change along the orbit as the Moon enters the various regions of our magnetosphere?
- What is the plasma density distribution above the surface, and how does it change with height and time?
- What is the configuration of the local small-scale electric fields? How do the vertical and horizontal components evolve during the passage of the lit/dark boundary, and along the lunar orbit?
- What are the size, charge, and velocity of the mobilized lunar dust grains?
- What is the temporal and spatial variability of the properties of the lofted/transported grains? Is their transport triggered by lit/dark transition or, alternatively, is there continuous dust transport?

Proposed Instrument Package:

Camera: Based on the Surveyor observations of the horizon glow (HG), the LDTP camera should image the horizon with a 10° field of view (FOV) centered on local sunset. Its resolution should be adequate to resolve a cloud of near-surface dust that is ≈ 0.3 m high on the horizon which could be as far as 1 km away and its dynamic range large enough to distinguish between the levitated dust and the background zodiacal light which will also be present in the image. A pair of identical imagers, or a single camera with a two-position flip mirror, can view both sunrise and sunset. Frame rates and data storage requirements are modest because the Moon's rotation is slow and the Surveyor cameras detected HG for only 2-3 hours after

sunset.

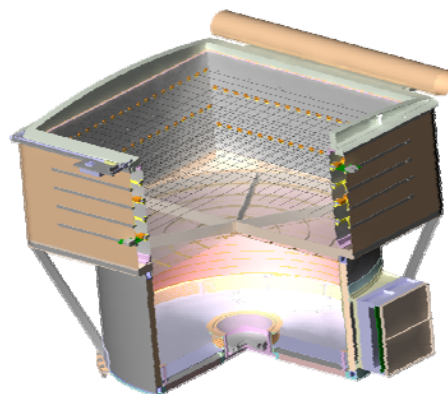
Fields and Particles Detectors: The standard technique to measure the electron energy distribution at low (few eV) temperatures is a Langmuir probe. The current-voltage (I-V) characteristic of the Langmuir probe is determined by sweeping the potential of the probe from ion (and photoelectron) saturation to electron saturation. The I-V characteristic contains information about the density and energy distribution of the electrons collected by the probe. A set of three probes, deployed at different heights above the surface, could measure the distribution of the potential and electric field in the near surface environment.



Dust Telescope: The Dust Telescope instrument would monitor the incoming micrometeoroid bombardment of the lunar surface and the generation of fast secondary ejecta particles. DT has two parts: The top part is the Dust Trajectory Sensor (DTS) that measures velocity vector and allows determination of the source of incoming dust (cometary vs. asteroidal). The bottom part is the Large Area Mass Analyzer (LAMA) that can detect submicron sized micrometeoroids and analyze their elemental composition. The Lunar surface also provides a unique platform to analyze the near-earth dust environment.

Electrostatic Lunar Dust Analyzer

Dust particles mobilized above the surface will have a velocity range of approximately 1-100 m/s. The momentum or kinetic energy of micron sized particles at these velocities is simply too low to apply momentum transfer or impact ionization processes for the detection. The Dust Trajectory Sensor (DTS) utilizes the charge on the particles for detection (thousands of particles). The trajectory is measured as the particles pass through an array of wire electrodes, each connected to a separate charge sensitive amplifier.



Summary of LDTP Objectives:

Lunar Science and Engineering: Determine the charge state, the size and velocity distribution of levitated/transported lunar fines as a function of local time, and position along the lunar orbit. Measure the variations of the charge density distribution on the surface, and the plasma properties of the near-surface environment. Map the variable structure of the near-surface electric field. Identify an optimal time of day for astronaut activity, and height above the lunar surface where dust contamination could be minimized.

Basic Plasma Science: Understand the buildup and the collapse of a plasma and photoelectric sheath, and its changing properties with dust loading. Understand the charging processes of a surface, and of the individual grains resting on it, as a function of the variable properties of the near-surface electric fields and plasma environment.

Planetary and Astrophysical Sciences: Understand the mechanism leading to dust transport on airless bodies. Reliably distinguish between interplanetary and interstellar grains, measure their fluxes, size and velocity distributions, and composition.

References: <http://lasp.colorado.edu/celdas>