CHARACTERIZING AND UNDERSTANDING THE INTERACTION OF DUST AND PLASMA ON THE SURFACE OF THE MOON AND IN THE EXOSPHERE. T. J. Stubbs, University of Maryland, Baltimore County, Goddard Earth Science and Technology Center, and NASA Goddard Space Flight Center, Mail Code 674, Greenbelt, MD 20771, (Timothy.J.Stubbs.1@gsfc.nasa.gov).

Summary of Science Topic: The ambient plasma environment and solar UV at the Moon cause the regolith on the lunar surface to become electrically charged [1–3]. This can result in the electrostatic transport of charged dust (< 10 µm) in the lunar exosphere, which has been observed to reach altitudes >100 km [4–6] and speeds of up to 1 km/s [7].

Value of Science Topic: From the Apollo era it is known that dust will have an immediate impact on surface exploration activities and must be addressed to ensure mission success [8–10]. Electrostatic processes almost certainly enhanced problems with dust, such as adhesion, during Apollo, see Fig. 1. Characterizing the surface electric field and the electrostatically transported dust grain size, charge and spatial distribution, as well as the perturbation of man-made structures to these measurements, is required to provide an understanding of the lunar dust-plasma environment and its impact. Cross-disciplinary impacts: Astronomy and Astrophysics, Geology, Environmental Characterization, Operational Environmental Monitoring.

Figure 1. Substantial amounts of lunar dust were clearly adhering to Jack Schmitt's spacesuit during Apollo 17.

Description of Science Topic: During the Apollo era it was discovered that sunlight was scattered at the lunar terminator giving rise to "horizon glow" and "streamers" above the surface [e.g., 4], as shown in Fig. 2. This was most likely caused by sunlight scattered by electrically charged dust grains originating from the surface [6,11]. The lunar surface is electrically charged by the local plasma environment and the photoemission of electrons by solar UV [1–3].

Under certain conditions, the like-charged surface and dust grains act to repel each other, thus transporting the dust grains away from the surface. The limited observations of this phenomenon, together with laboratory and theoretical work, suggests that there are two modes of charged dust transport: "levitation" [e.g., 12] and "lofting" [13], both of which are driven by the surface electric field. Micron-scale dust is levitated at ~ 10 cm, while ~0.1 µm dust is lofted to altitudes >100 km. The Apollo 17 Lunar Ejecta and Meteorites (LEAM) surface experiment directly detected the transport of highly-charged lunar dust traveling at up to 1 km/s [7]. The dust impacts were observed to peak around the terminator regions, as shown in Fig. 3, thus suggesting a relationship with horizon glow.

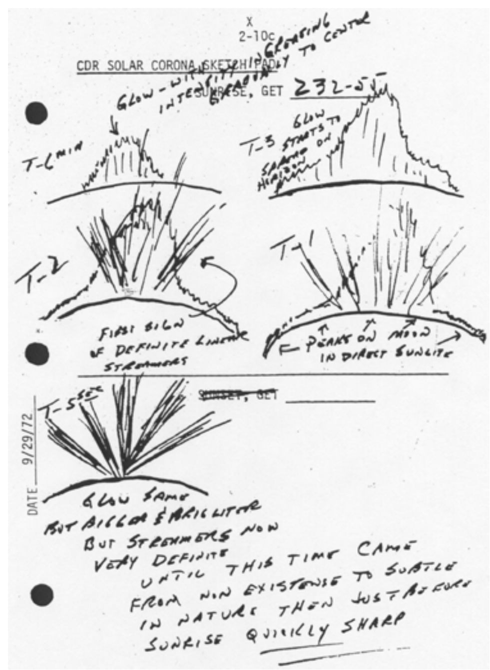

Figure 2. Sketches of sunrise with "horizon glow" and "streamers" viewed from lunar orbit by astronaut Gene Cernan during Apollo 17 [4]. Note: phenomenon also observed by coronal photography during Apollo 15 and 17 [5].

In addition, this work will further our understanding of the environments of other airless bodies, such as Mercury and the asteroids.

Description of Methodology and Implementation: All the existing observations of the transport of charged dust were acquired by instruments designed to measure something else (e.g., LEAM was set-up to detect hypervelocity impacts). Therefore, it is necessary to make targeted in-situ measurements of dust-plasma-surface interactions on the Moon in order to fully understand this alien environment.

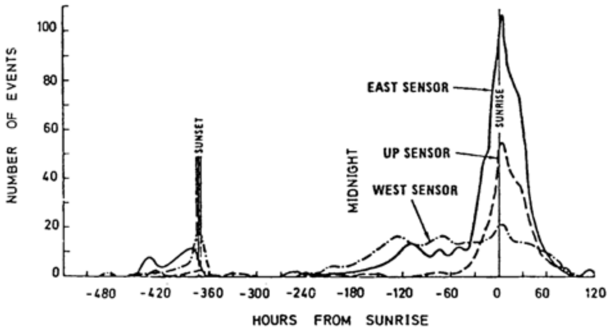

Figure 3. Number of highly-charged dust impacts registered by the 3 sensors of the Lunar Eject and Meteorite (LEAM) experiment per 3-hour period (integrated over 22 lunations) as a function of time from sunrise [7].

The necessary in situ measurements for characterizing the lunar dust-plasma environment are summarized in Table 1. They can be achieved from orbit to give a global-scale view, or from the surface for a local perspective. To optimize the characterization of this environment, it is recommended that measurements from orbit and the surface are coordinated, such that we may understand the connection between processes at these scales. Several landers would be advantageous, since not every point on the lunar surface experiences the same conditions, e.g., locations near the poles will be quite different from those nearer the equator.

Measurement	**Instrument**
Exospheric Dust Concentrations	Photometer (passive) LIDAR (active)
Dust Strikes (Distribution of dust mass, velocity and charge).	Impact Sensor (Must be more sensitive and discriminating than Apollo 17 LEAM experiment)
Plasma characteristics (e.g., moments)	Electron and Ion spectrometers
Electric fields	E-field Probes
Magnetic fields	Magnetometer
Solar Ultraviolet	UV Spectrometer

Table 1: Required measurements and instrumentation.

The instruments described above have a high TRL, with many of them being standard on many heliophysics missions. Requirements for mass and power are a few kg and a few Watts, and the size can be kept relatively small. Telemetry rates are relatively low, but this depends on time resolution of measurements.

Benefit of Astronaut Involvement: Astronauts could be used to distribute a network of sensors on the lunar surface. In addition to measuring the natural environment, the instrumentation described above will also detect the charge on the astronauts and the dust transport caused by their moving around on the surface. This will reveal how astronauts and equipment are coupled to the dust-plasma environment.

Rationale of Timing with Respect to Lunar Exploration: From the experiences of the Apollo astronauts it is known that dust will be a significant impediment to surface operations; therefore, it is crucial that we have a much better understanding of this environment as early as possible.

Early Robotic Phase (<2018). Acquire vital early measurements of natural environment from orbit and strategic locations on the surface.

Early Human Phase (2018 – 2025). Continue monitoring of natural background, as well as study impact of surface operations on this environment.

Beyond (>2025). Deploy large-scale surface network to monitor this environment in order to make predictions (analogous to weather forecasting on Earth).

Future Wider Benefits: The characterization of this environment, and the resulting development of dust mitigation technology, will permit a sustainable exploration program requiring surface operations, (particularly astronaut EVAs). This will pave the way for future missions, In Situ Resource Utilization (ISRU) activities and the commercialization of the Moon.

Horizon glow, and other mysterious phenomena caused by the electrostatic transport of lunar dust discovered during the Apollo era, hold a great fascination for the general public [e.g., 14]; therefore this work will also be of great benefit to NASA's Education and Public Outreach program.

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