SLOW DUST DETECTOR FOR LUNAR POLAR SURFACE OPERATION. W. M. Farrell, D. C. Bradley, L. R. Miles, and R. J .MacDowall, NASA Goddard Space Flight Center, Greenbelt, MD (William.M.Farrell@nasa.gov).

Introduction: In terminator regions, the lunar surface electrostatic potential becomes very complex due to the near-horizontally flowing solar wind interaction with topographic features. In sunlight, the surface charges positive due to photoelectron emission. However, in adjacent shadowed regions behind larger obstacles, the surface charges strongly negative due to the difficulty in solar wind plasma to fill in behind the obstacle (i.e., the formation of an obstacle plasma void or wake) [1].

Possible evidence of this terminator differential surface charging is found in Surveyor photos of a twilight glow that develops after local sunset. This glow has been interpreted as lofted or levitated dust grains of a few microns in size that are forward scattering light to Surveyor. The region of lofted dust was considered to be a few hundred meters from the lander. The dust has been theorized to be lifted by the complex E-fields located just nightside of the terminator [2]

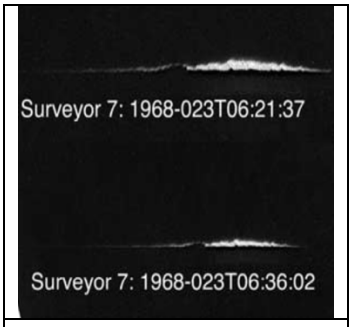

Figure 1. Surveyor images of a horizon glow, possibly associated with levitated/lofted dust (from [2]).

In order to test this possibility, we propose to send a slow dust detector - a detector that can measure the presence of charged dust moving at speeds as low as 1-2 meters per second. The detector is small and can be installed by the astronauts on a lunar lander leg (or pre-placed on the leg in a CLPS application).

There are two possible sources for the dust lifting/lofting at the terminator - including the polar terminator.

Source #1: Dust Lofting via the Complex Polar Terminator Surface Potentials. At the lunar terminator regions, the solar wind is flowing primarily horizontal over the lunar surface. Local topography then acts to block or obstruct the plasma as it flows – creating voids in the solar wind fluid immediately downstream of the obstacle.

Since the plasma is collisionless, there is not a gas pressure to 'push' the plasma into the voids. Instead, due to their intrinsically higher thermal velocity, the low-mass electrons will move into the void ahead of the ions.

In regions immediately downstream of the topographic obstacle, the high mass solar wind ions flowing at 400 km/s cannot immediately change direction to fill in behind the obstacle, leaving only the low mass electrons to form an 'electron cloud'- an electron-rich region that charges the surface strongly negative [1,3,4]. As described in Z, there is a debate as to how high these surface potentials can become since they have to come into equilibrium with secondary negative particles emitted from the surface. This electron cloud region has thus been hypothesized to give rise to lofted negatively-charged dust [f] which acts to partially-remedy the large negative charge build-up on surfaces below the electron cloud region. This plasma expansion process and electron cloud region could possibly then give rise to the dust lofting at twilight at the terminator.

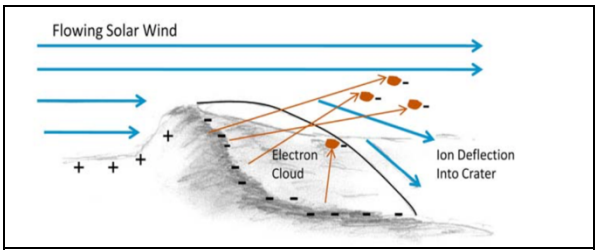

Figure 2. An illustration of the dust response to the electron cloud that forms in the plasma expansion process (from [1]).

Source #2: Dust Lofted via Meteoric Ejection. LADEE's LDEX instrument discovered surface-ejected submicron-sized and micron-sized particulates many 100's of kilometers in altitude [5]. The particulates are in association with sporadic [6] and stream [7] meteor populations.

In this scenario, hyper-velocity interplanetary dust particles are directly incident on the lunar surface. These energetic impact events incident on the surface at 10's of kilometers per second send a shower of small particulates back into the exosphere with speeds on average near 700 m/sec [8]. A population of grains of a few microns ejected from the quasi-continuous bombardment of hyper-velocity dust particles might then be the source of the forward scattered horizon glow.

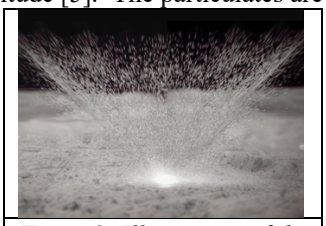

Figure3 -Illustration of the ejecta cloud from a meteor impact on the lunar surface.

We note that LADEE LDEX did not find evidence of electrostatically-lofted dust between 3-250 km

altitude [9]. Thus, if the electrostatic dust lofting process occurs, it must be of substantially lower energy than the impact ejection process.

Slow Dust Detector (SDD). In order to determine the origin of the terminator dust lofting process, we propose to place a slow dust detector capable of sensing lofted grains having speeds of 1 to > 1000 m/s. A simply tube system was developed under a GSFC IRAD in 2012.

SDD Objective: To determine the source of horizon glow dust populations. The proposed south pole landing sites are chosen specifically to be in sunlight for long periods. However, there are predictable times when these sites go into darkness – and during these times we could expect electron cloud regions to form during the passage of the terminator. Thus, if Source #1 is operational, we would anticipate slow-moving lofted dust to be detected during these predicted terminator passage times. However, if the glow is due to impact ejecta process, Source #2, then moderately fast dust should be detected for the entire observation period in association with the sporadic meteor population – independent of terminator location. If both processes are operating, faster dust would be quasi-continually detected while slow dust is detected in association with terminator crossings.

SDD Concept of Operation. The SDD operates on the capacitive coupling between a moving dust grain and a metal electrode. This concepts differs from the impact ionization concept applied for hyper-velocity grains. Specifically, the SDD has two metal rings connected to extra-low frequency (ELF) preamps, as illustrated in Figure 4. When a charged dust grains passes into the detector, each preamp will measure a bipolar pulse with the pulse width a function of speed and pulse height a function of both grain speed and charge state. There are actually three different velocity measurements: one derived from the pulse structure at each electrode, and one pulse time difference between electrodes. In the 2012 IRAD, we applied the three velocity measurements to uniquely identify grain time-of-flight paths when multiple grains were in the tube.

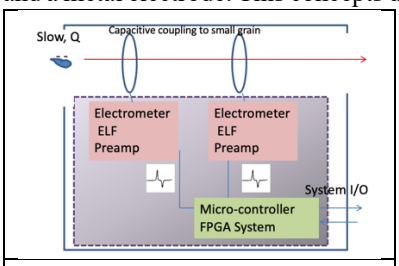

Figure 4 – SDD Block Diagram

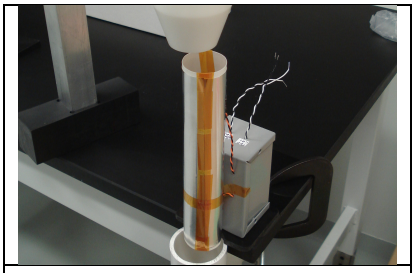

Figure 5 – Prototype SDD

SDD Testing. A set of prototype SDD sensor heads were built (Figure 5) and grains of various sizes were dropped into the tube. Figure 6 shows the bipolar pulse associated with a Talc grain of ~ 10 microns in size passing through the dual ring system at 1-2 m/s. Both signal channels are shown with the bipolar pulse appearing in each channel. This grain size and speed are similar to those expected to be lofted at the terminator.

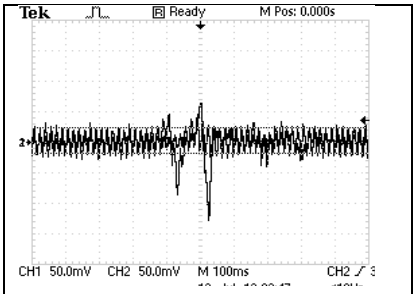

Figure 6 – Pulses from a small charged talc grain (~10 microns) passing through the detector.

SDD Resources. The SDD sensor head is lightweight and most of the mass is associated with the supporting electronics, including a command and data handling system and power board. Very rough estimate of resources include: Mass 5 kg, Power 15W, Volume 3000 cm^3, Cost to develop $6M, Cost to operate: $1M per year. Landing site requirements: The terminator passes near and over the SDD deployment site.

Crew Interaction. The SDD can be placed near the bottom of a lander leg (< 0.5-m from the surface) and turned on upon landing. Hence the system could fly as part of a CLPS lander. However, astronauts can interact with the SDD by collecting and dropping lunar dust into the tube. By collecting dust grains, they inherently tribocharge the grains that then then drop into the tube. In essence, the astronauts are part of an active experiment. The crew can also take an SDD to locations distant from the lander to deploy as part of an ALSEP-like package. The system could be set alongside a plasma spectrometer to examine the plasma-dust connection

References. [1] Farrell, W. M., et al (2010), J. Geophys. Res., 115, E03004. [2] Colwell, J. E, et al. (2007), Rev. of Geophys, 45, RG2006. [3] Zimmerman, M. I., et al. (2011), Geophys. Res. Lett., 38, L19202. [4] Rhodes, D. J. and W. M. Farrell, (2019), J. Geophys. Res., 124, 4983. [5] Horanyi, M. et al. (2015) , Nature, 522, 324. [6] Szalay, J. R. et al. (2019), J. Geophys. Res., 124, 10.1029/2018JE005756. [7] Szalay, J. R. and M. Horanyi (2016), Icarus, 275, 221. [8] Szalay, J. R. and M. Horanyi (2016), Geophys. Res. Lett., 43, 4893. [9] Szalay, J. R. and M. Horanyi (2015), Geophys. Res. Lett., 42, 10.1002/2015GL064324.