ELECTROSTATIC DUST ANALYZER (EDA) FOR CHARACTERIZING DUST TRANSPORT ON THE LUNAR SURFACE.

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Introduction: Electrostatic transport of regolith dust on airless planetary bodies due to exposure to solar wind plasma and solar radiation has been suggested to explain a number of unusual observations [1]. The first set of evidence was from several Apollo observations, including the lunar horizon glow, the high-altitude ray-pattern streamers, and the low-speed dust detection. Since then, observations on other airless bodies, such as the radial spokes in Saturn's rings and the "dust ponds" on asteroid Eros and comet 67P, have also been related to the electrostatic dust transport process. It has remained as an open question for decades to understand mechanisms behind this process and its role in shaping the surfaces of the Moon and other airless bodies.

Recent laboratory studies [1] have revolutionized our understanding of the fundamental charging process, showing that electrostatic dust transport may indeed occur on the surfaces of airless bodies including the Moon. Here we introduce an Electrostatic Dust Analyzer (EDA) for in situ measurements to find ground truth about electrostatic dust transport and to advance our understanding of its effects on regolith physical properties and near-surface dust environments on the Moon. As a universal phenomenon, these measurements will provide implications to surface processes on other airless bodies. In addition, these measurements will help understand potential dust hazards in order to develop mitigation strategies for future robotic and human exploration on the lunar surface.

Several key characteristics of dust lofting and transport have been measured in simulated space conditions in the laboratory [1-3], providing critical parameter constraints for designing the EDA instrument and experiment on the lunar surface.

Experiment at the lunar south pole: Based on the recent laboratory experiments, it is expected that charging and subsequent lofting of lunar dust varies with solar UV radiation and/or solar wind plasma conditions. It is therefore interesting to know how electrostatic dust transport varies across the lunar surface. The south polar region exploration provides a great opportunity to understand such physical process at the lunar poles. As shown in the laboratory results, a large population of lunar dust is expected to be lofted within 1 m height. This requires the EDA instrument to be placed on the surface in order to maximize the dust collection. Astronauts can greatly help the instrument deployment if no robotic mechanism is available for a lander. The instrument will be tethered with the lander that provides power and data/commands communication.

Design of the EDA sensor: The EDA sensor is designed based on a prototype of the Electrostatic Lunar Dust Analyzer (ELDA) [4]. The sensor consists of two identical Dust Trajectory Sensors (DTS) on both ends of the sensor, which sandwich a Deflection Field Electrodes (DFE) unit, as shown in Fig. 1. When a charged dust particle enters the sensor from either end, its charge and velocity are measured with two arrays of wire electrodes in the DTS on which the image charge of the dust particle is induced. The charged particle will be then deflected by the DFE and exit through the second DTS on the other end. The mass of the dust particle is derived from its deflected trajectory. Charge signals are measured through Charge Sensitive Amplifiers (CSA).

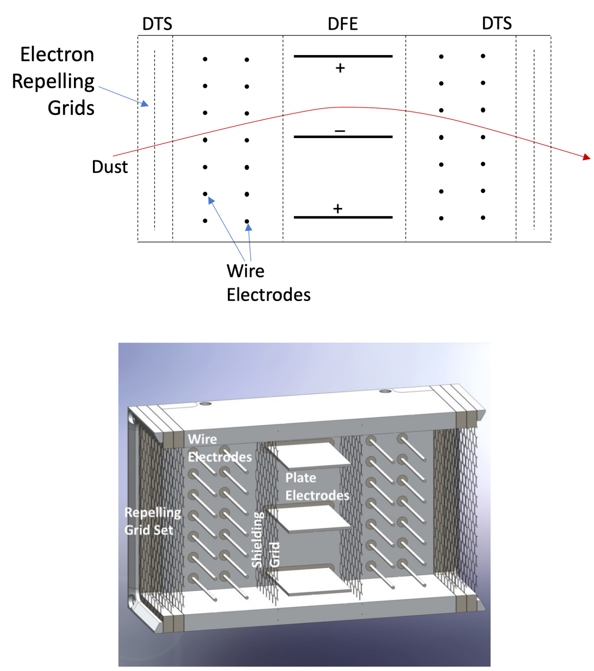

Figure 1. Top: Schematic of the EDA sensor; Bottom: Cut-view of a CAD model.

Design of the EDA system: The dust sensor is housed in a metal box with two doors (Fig. 2). During measurements, one of the doors will be opened to allow dust particles to come through the sensor, depending on the instrument pointing direction relative to the Sun. The instrument will be tilted to an optimized angle with a tilting mechanism.

Summary: The EDA instrument is under development for future lunar lander missions to characterize the charge, mass, velocity and flux of electrostatically lofted dust particles on the lunar surface. The future south polar region exploration provides a great opportunity for such experiment. In situ measurements enabled by EDA will answer a five-decade-long question about electrostatic dust transport and its effects on regolith physical properties and near-surface dust environments on the Moon as well as implications to surface processes on other airless bodies. In addition, these measurements will help understand the impact of potential dust hazards for future robotic and human exploration on the lunar surface.

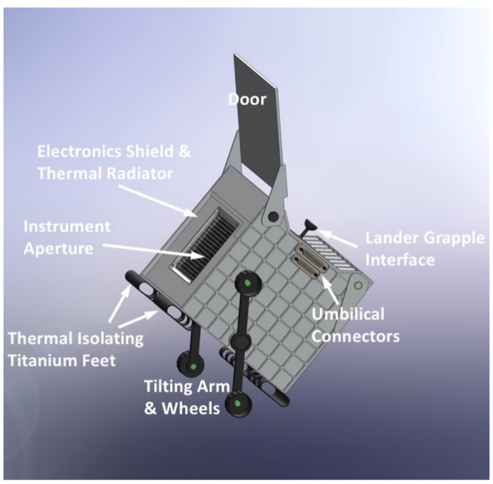

Figure 2. A CAD model of the EDA housing system.

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References: [1] Wang, X., Schwan, J., Hsu, H.-W., Grün, E., and Horányi, M. (2016) GRL, 43, 6103–6110. [2] Schwan, J., Wang, X., Hsu, H.-W., Grün, E., and Horányi, M. (2017) GRL, 44, 3059–3065. [3] Hood, N., Carroll, A., Mike, R., Wang, X., Schwan, J., Hsu, H.-W., and Horányi, M. (2018) GRL, 45, 13,206–13,212. [4] Duncan, N., Sternovsky, Z., Grün, E., Auer, S., Horányi, M., Drake, K., Xie, J., Lawrence, G., Hansen, D., and Le, H. (2011) Planet. Space Sci., 59, 1446-1454.