THE LUNAR DUST EXPERIMENT (*LDEX*) FOR THE LUNAR ATMOSPHERE AND DUST ENVIRONMENT EXPLORER (LADEE) MISSION Mihály . Horányi[1,2] (horanyi@colorado.edu), Zoltán Sternovsky[1] (Zoltan.Sternovsky@colorado.edu), Eberhard Grün[1,3] (eberhard.gruen@mpi-hd.mpg.de), Ralf Srama[3,4] (ralf.srama@mpi-hd.mpg.de), Mark .Lankton[1] (Mark.Lankton@lasp.colorado.edu) and David Gathright[1] (David.Gathright@lasp.colorado.edu) [1]Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309-0392, USA; [2]Department of Physics, Physics, University of Colorado, Boulder, CO 80309-0392, USA; [3]Max Planck Institute for Nuclear Physics, Heidelberg, D-69117, Germany; [4]Institute of Space Systems, U. of Stuttgart, D-70569 Stuttgart, Germany

Introduction: The lunar dust environment is expected to be dominated by submicron-sized dust particles released from the Moon due to the continual bombardment by micrometeoroids, and due to plasma-induced near-surface intense electric fields. The Lunar Dust EXperiment (***LDEX***) is designed to map the spatial and temporal variability of the dust size and density distributions in the lunar environment. ***LDEX*** is an impact detector, capable of measuring the mass of dust grains with m ≥ 1.7×10^{-16} kg (radius $r_g \geq 0.3$ μm), in a ~50 km altitude circular orbit about the Moon. ***LDEX*** will also measure the collective current of the dust grains that are below the detection threshold for single dust impacts; hence it can search for the putative population of grains with $r_g \sim 0.1$ μm lofted over the terminator regions by plasma effects. ***LDEX*** has been developed at LASP and has a high degree of heritage based on similar instruments on the HEOS 2, Ulysses, Galileo, and Cassini missions. The ***LDEX*** engineering model has been successfully tested and calibrated at the Heidelberg dust accelerator facility.

Scientific Objectives: The ***LDEX*** instrument will address the dust science objective of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission, as stated in the NASA Science Definition Team (SDT) Study Report (May 21, 2008): **LADEE science objective 2: "Characterize the lunar exospheric dust environment and measure any spatial and temporal variability and impacts on the lunar atmosphere."**

This science objective is addressed by measuring the temporal and spatial variability of the density and size distributions of dust in orbit around the Moon. The SDT report identified the measurement requirement to detect submicron sized particles, in order to gauge the relative importance of the two expected sources of dust: a) ejecta production due to continual bombardment by interplanetary meteoroids, and b) lofting due to plasma effects.

LDEX* instrument:** ***LDEX is an impact ionization dust detector with a sensor area of ~ 0.01 m^2, derived from the heritage of the dust instruments operating on HEOS 2, Galileo, Ulysses, and Cassini. ***LDEX*** is a low risk, compact instrument with no deployable or moving parts, and uses no flight software (**Figure 1**). In addition to individual dust impacts of grains with radii $r_g > 0.3$ μm, ***LDEX*** can identify a large population of smaller grains ($0.1 < r_g < 0.3$ μm) by measuring their collective signal.

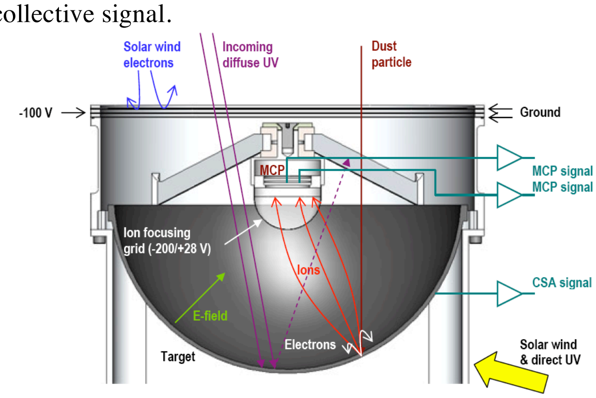

Figure 1. ***LDEX*** schematics.

A dust particle impacts the hemispherical target and generates a plasma cloud. The -200 V bias applied on the ion focusing grid creates a radial electric field and separates the electrons and ions. The electrons are collected on the target and measured by a charge sensitive amplifier (CSA). The ions are detected by the microchannel plate (MCP) placed behind the focusing grid. The MCP anode is divided into two sections with equal area each collecting about half of the signal. Both MCP outputs are connected to current-to-voltage (I/V) amplifiers to measure the current pulse of the impact. The two MCP signals are used for coincident detection ensuring the identification of dust impacts. Single particle events, such as cosmic rays or high-energy solar particles, will generate a signal only on one MCP channel. The impact charge is obtained independently from the CSA and the MCP signals. The mass and size of the dust particle is calculated from the impact charge using laboratory calibration.

Besides individual impact detection, ***LDEX*** can identify a large population of small ($r_g < 0.3$ μm) dust grains. Dust grains in the size range of 0.1 μm < r_g < 0.3 μm generate 100 $e^- < Q_I <$ 3,000 e^-. If these particles impact ***LDEX*** at the predicted rate of 10^3 s^{-1}, their cumulative impact charge, > 10^5 $e^- s^{-1}$, is comparable to or larger than the charge from individual impacts with $r_g \geq 0.3$ μm. ***LDEX*** integrates the MCP signal for 0.1 s to measure the cumulative charge from small dust impacts. The cumulative charge signal is expected to rise over the terminator region if small particles are present. This signal also includes contributions from all noise sources (e.g. UV, energetic particles, etc.). The noise background is measured every 10 s and will be used to correct the measurements during data analysis. With 0.1 Hz frequency, the bias on the ions focusing grid is switched from -200 V to +28 V for a duration of 1 sec. The positive bias stops all dust impact generated ions and the MCP signal is solely due to background noise.

Table 1. ***LDEX*** Resource Estimates

Resource	CBE + M	Margin (M)
Volume	15×15×25 cm^3	N/A
Mass	3 kg	50%
Power	5 W	25%
Telemetry Rate	1000 bits / sec	50%

Investigation Requirements: LADEE is expected to follow an approximately circular, retrograde orbit at an altitude of 50 km. The dust density ***LDE*** will observe is dominated by grains on bound ballistic orbits which reach their maximum height at the spacecraft (S/C) altitude. Hence, the impact speed between the grains and a detector will remain close to the speed of the S/C $V_{S/C} \approx 1.7$ km/s.

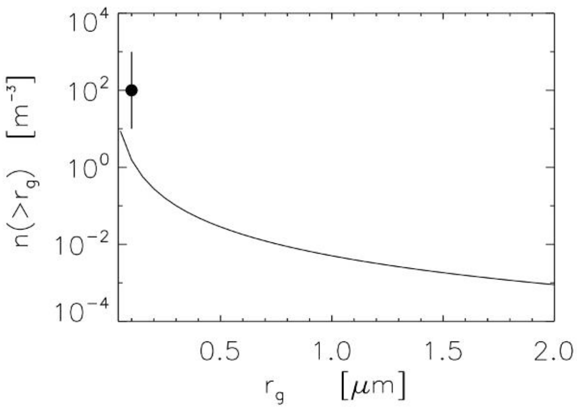

Figure 2. The expected cumulative density of dust grains as function of particle radii at an altitude of 50 km. The continuous line is a model prediction of the dust exosphere maintained by the continual bombardment of the lunar surface by interplanetary dust. The dot shows the suggested dust density lofted over the terminators [1].

In order to resolve the dust density distribution over the terminator ***LDEX*** will have a temporal resolution of < 3 s to make at least 100 measurements in 6 minutes over an approximately 20° region approaching the terminator. To obtain the size distribution, ***LDEX*** will differentiate dust into at least five bins over the measured size range of <1 to 5 μm. The expected ***LDEX*** signals have been simulated using a model (**Figure 2**) of the predicted spatial and size distributions. The simulation proceeds by calculating the collision mean time $dt=NAV_{S/C}$ (N is the total dust density) and randomly selecting an impactor from the size distribution. **Figure 3** shows the predicted impact rate for ejecta particles.. The individually detected particles are accompanied by a large number of smaller grains that can collectively generate a measurable signal. **Figure** 4 shows the cumulative charge for an integration period of dt = 0.1 s. To enable the search for a population of dust below single detection threshold, ***LDEX*** is capable of measuring their cumulative impact charge.

The engineering prototype of ***LDEX*** is shown **in Figure 5.** ***LDEX*** observations will bring closure to questions about the lunar dust environment, and the processes responsible for maintaining it.

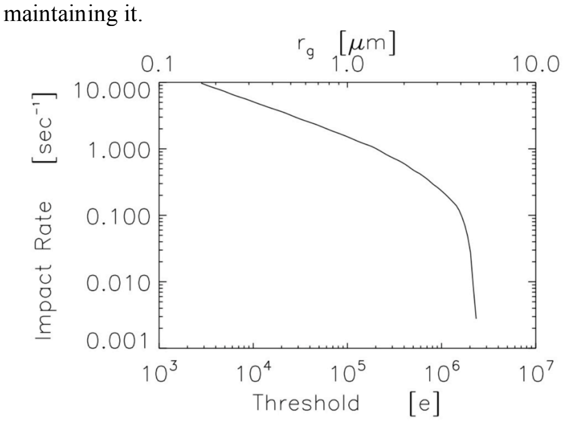

Figure 3. The predicted impact rate for ***LDEX***, using the putative spatial and size distributions of dust at an altitude of 50 km (**Figure. 2**), for a sensor area of A = 0.01 m^2. Only the ejecta particles are expected to be large enough for individual detection, hence this rate is likely to remain approximately constant along the orbit, except during periods of meteor showers.

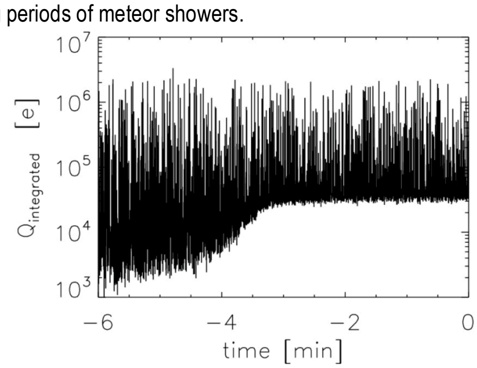

Figure 4. The total charge ***LDEX*** is expected to collect for an integration period of dt = 0.1 s. Large particle impacts can be easily identified. The collective signal of small particles causes a step-function like change of the background current over the terminator region.

Figure 5. The engineering prototype of ***LDEX.***