***LDEX*⁺: LUNAR DUST EXPERIMENT WITH CHEMICAL ANALYSIS CAPABILITY TO SEARCH FOR WATER.**

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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 onboard the upcoming Lunar Atmosphere and Dust Environment Explorer (LADEE) mission [1, 2]. LDEX is an impact detector, capable of measuring the mass of dust grains with $m \geq 1.7\times10^{-16}$ kg (radius $r \geq 0.3$ 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 $r \sim 0.1$ 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 [3]. The LDEX engineering model has been successfully tested and calibrated at the Heidelberg dust accelerator facility. The LDEX⁺ instrument is being developed for a possible LADEE follow-up mission to add the capability for the in-situ chemical analysis of the impacting dust particles in order to verify the existence of water ice on the lunar surface.

The lunar dust environment: The two expected sources of dust in the lunar environment are (**Figure 1**): a) ejecta production due to continual bombardment by interplanetary meteoroids, and b) lofting due to plasma effects.

The *LDEX instrument* is an impact ionization dust detector with a sensor area of ~ 0.01 m^2. LDEX is a low risk, compact instrument with no deployable or moving parts, and uses no flight software (**Figure 2**). In addition to individual dust impacts of grains with radii r > 0.3 μm, LDEX can identify a large population of smaller grains (0.1 < r < 0.3 μm) by measuring their collective signal. LDEX resource requirements are summarized in **Table 1.** The expected impact rates, and the signature of lofted small grains expected over the terminators are shown in **Figure 3**.

The *LDEX*⁺ *instrument* extends the *LDEX* capabilities to also measure the chemical composition of the impacting particles with a mass resolution of M/ΔM > 30. Traditional methods to analyze surfaces of airless planetary objects from an orbiter are IR and gamma-

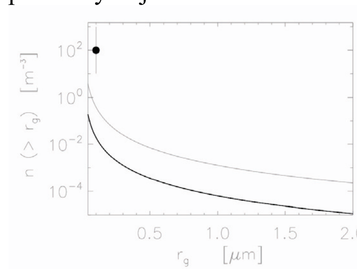

Figure 1. The expected number density of the ejecta cloud as function of particle radii at an altitude of 50 km, based on dust measurements near the Galilean moons of Jupiter [4]. Moderate ejectta production yield (Y~500, thick black line) and high yield (Y ~ 10⁴, grey line) cases are plotted. The dot shows the dust density of the lunar dust exosphere, derived from Apollo observations of the solar corona above the lunar terminator [5,6].

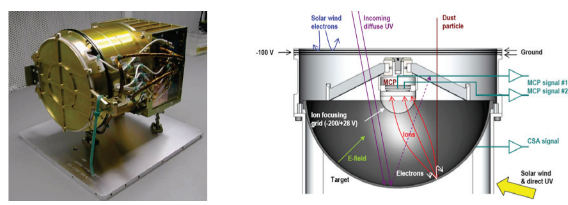

Figure 2. Engineering model and schematics of LDEX

RESOURCE		
Mass	3.6	Kg
Power	3.8	W
Downlink	64	Mbits/day
Dimensions	15x15x20	cm^3

Table 1. LDEX Resources

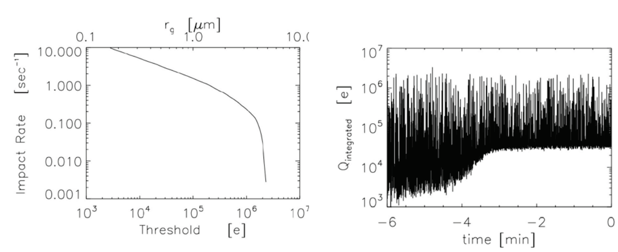

Figure 3. The expected impact rate on ***LDEX*** from meteoroid impact generated ejecta particles with radii r > 0.3 μm (*left*). The expected 'collective' signal from lofted grains during LADEE's approach of the terminator generated by impact of dust grains with radii 0.1 < rg < 0.3 μm (*right*).

-ray spectroscopy, and neutron backscatter measurements. A complementary method to analyze dust particles as samples of planetary objects from which they were released. The source region of each analyzed

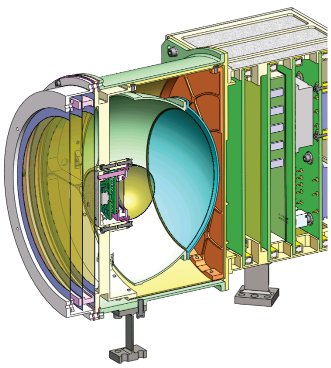

Figure 4. ***LDEX+*** schematics. The target hemisphere is segmented to accommodate impact detection to determine the mass and speed of dust grains (top segment) and a time-of-flight setup for chemical analysis (bottom segment).

grain can be determined with accuracy at the surface that is approximately the altitude of the orbit. This 'dust spectrometer' approach provides key chemical constraints for varying provinces on the lunar surfaces**.** ***LDEX+*** **is of particular interest to verify from orbit the presence of water ice in the permanently shadowed lunar craters.**

LDEX+ combines the impact detection capabilities of LDEX with a linear time-of-flight system, similar to the Cassini Cosmic Dust Analyzer (CDA) instrument. **Figure 4** shows the schematics of ***LDEX+*** . **Figure 5** shows an example time-of-flight mass spectrum of an ice-bearing dust grain.

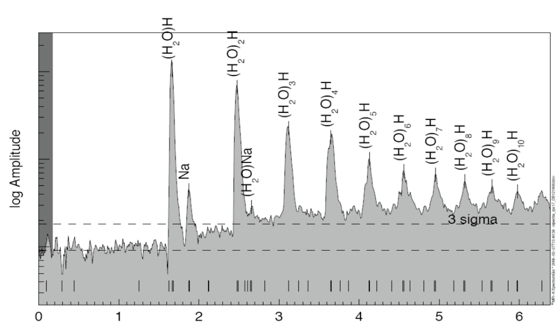

Figure 5. Spectrum of a water ice particle obtained at ~ 4 km/s impact speed by the Cassini CDA instrument in Saturn's E ring The dominant peaks are mass lines of water cluster ions $(H_2O)_nH^+$, generated upon impact of an ice-bearing particle [6].

Conclusions. ***LDEX+*** onboard a spacecraft orbiting the Moon can collect a large number of samples from a greater part of the entire surface for analysis. It thus combines the advantages of a remote sensing instrument and a lander. The instrument is especially sensitive to the metallic compounds of minerals and any species which easily form ions (e.g. water).

The accuracy of the trajectory back tracing to the surface is comparable to the altitude of the satellite (**Figure 6**). Therefore, this in situ method allows compositional surface mapping of the Moon. Since the dust spectrometer is particularly sensitive to refractory compounds which are difficult to access by other methods it is also complementary to remote sensing spectroscopy and an ion or neutral mass spectrometer.

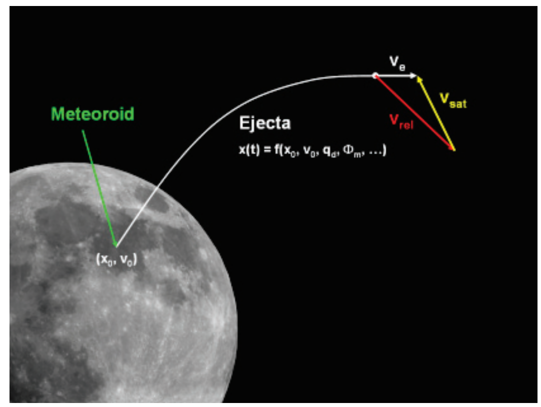

Figure 6. Schematics of dust spectrometry of the lunar surface. Ejecta particles lifted by micrometeoroid impacts from the satellites' surface are analyzed by a dust composition mass spectrometer. By tracing the trajectory to the surface, compositional maps of Moon can be generated.

A ram pointing ***LDEX+*** and the nadir pointing remote sensing instruments collect data from approximately the same general spot on the surface of the Moon, hence the combination of these measurements greatly enhances our ability to map the chemical composition of its surface and identify water-bearing regions. An ***LDEX+*** type instrument could also address many of the science goals of a Europa Jupiter System Mission (EJSM) about the surface chemistry of icy satellites.

References: [1] Delory *et al., Proc. Lunar. Sci. Conf.* 40*th*, 2025 (2009). [2] Delory *et al., Proc. Lunar. Sci. Conf.* 41*th*, 2459 (2010). [3] Horanyi *et al*., *Proc. Lunar. Sci. Conf.* 40*th*, 1741 (2009). [4] Krüger *et al*., *Icarus 164*, 170, (2003). [5] McCoy, *Proc. Lunar. Sci. Conf.* 7*th*, (1976). [6] Postberg *et al., Planetary and Space Sci*., in press, (2010).