THE LUNAR METEOROID MONITOR (LMM)
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Introduction: We report on the development of the Lunar Meteoroid Monitor (LMM) instrument to measure the flux, size, speed distributions, and directions of the meteoroids bombarding the lunar surface. These measurements have both scientific and technical importance supporting lunar explorations, including contributions to the development of dust impact hazard mitigation strategies for crewed and robotic missions to the Moon.

Science background: The flux, size, and speed distributions of interplanetary meteoroids have remained of scientific and engineering interest since the beginning of the space age. Interplanetary dust or meteoroids, with typical size range from the sub-micron to the mm scale, have been recognized to deliver cosmic material into planetary atmospheres, generate impact ejecta and contribute to space weathering of the surfaces of airless planetary bodies, while posing hazard to instrumentation, crew, and missions to the Moon. However, “It might be surprising to many, but the meteoroid population appears to be one of the most uncertain space environment components”. Water is thought to be continually delivered to the Moon through geological timescales by water-bearing comets and asteroids and produced continuously in-situ by the impacts of solar wind protons of oxygen-rich minerals exposed on the surface. Interplanetary dust particles are an unlikely source of water due to their long UV exposure in the inner solar system, but their high-speed impacts can mobilize secondary ejecta dust particles, atoms, and molecules, some with high-enough speed to escape the Moon. Other surface processes that can lead to mobilization, transport, and loss of water molecules and other volatiles include solar heating, photochemical processes, and solar wind sputtering. Since none of these are at work in Permanently Shadowed Regions (PSR), dust impacts remain the dominant process to dictate the evolution of volatiles in PSRs. The mobilized atoms and molecules can get trapped in PSRs, and the accumulation of water in these regions has been suggested since the early days of the space age. While there are several processes leading to the accumulation of volatiles in PSRs, the only recognized and possibly significant loss mechanism is due to IDP impacts. The competing effects of dust impacts are: a) ejecta production leading to loss out of a PSR; b) gardening and overturning the regolith; and c) the possible accumulation of impact ejecta, leading to the burial of the volatiles. The competition between the volatile influx and these dust impact induced processes determines the ability of a PSR to accumulate volatiles, as well as their accessibility for In-Situ Resource Utilization (ISRU) (Arnold, 1979). Hence, the measurement of the temporal and spatial variability of the interplanetary meteoroid influx is critical to assess the availability of water in PSRs.

Figure 1. LMM in stowed (top) and deployed (bottom) configurations.

Methodology: LMM is a large surface area dust impact detector utilizing thin Polyvinylidene Fluoride (PVDF) films. PVDF-based dust detectors have an excellent record in space applications, including instruments onboard VEGA 1 and 2, the Giotto mission to comet Halley, Cassini to Saturn, New Horizons to Pluto, and the AIM Earth-orbiting satellite. The development effort is for the development of a) a deployable structure to enable a large detector area while providing a compact configuration for stowing through launch; b) a low-power electronics for signal processing that will enable the use of LMM through the lunar night; and c) a thermal design to enable the safe operations of LMM during the lunar day (when temperatures can reach above 120 C) and night (when temperatures drop below -170 C). Principle of operations: LMM (Figure 1.) is an impact dust detector that measures the impact speed and mass of individual particles. The
LMM instrument employs two thin, permanently polarized polyvinylidene fluoride (PVDF) plastic sensor films that generate an electrical signal when dust particles penetrate their surface. PVDF sensors require no bias voltage, they are simple, inexpensive, reliable, electrically, and thermally stable, mechanically rugged, radiation resistant, and do not respond to energetic ions or electrons. The PVDF based Student Dust Counter (SDC) has been successfully operating since 2006 onboard the New Horizons spacecraft. The LASP-built SDC and the ARGOS Space Dust (SPADUS) instruments from the University of Chicago provide the design and development approach.