Optical Monitoring of the Dust Environment at Lunar Surface Exploration Sites.

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Abstract: The lunar dust environment and its impact on surface operations during the Artemis era are critical areas of study at this time. Lessons from the Apollo program showed that dust perturbed by human activities on the lunar surface can interfere with the operation of mechanical, thermal and optical systems, in particular the integrity of moving mechanisms and pressure seals.

Monitoring the local dust environment during surface activities by measuring the overlying dust loading will be a priority. This could be accomplished at individual locations using elevated in situ dust detectors, but a more comprehensive approach would be to measure the intensity of scattered sunlight from dust in the local environment. These measurements, made locally or by remote sensing, can be accomplished using modest multi-wavelength cameras or dispersive optics and will yield the abundance of dust along an observer line-of-sight. Observations along several look-directions can reveal the dust spatial distribution and can also constrain the average grain size by measuring the angular width of the forward scattering lobe. Optical measurements of this type can be very sensitive, as demonstrated by the recent detection of faint FUV sunlight scattering by dust in the permanent impact-generated ejecta cloud surrounding the Moon.

The largest uncertainties in such measurements will lie in the grain scattering properties, namely scattering coefficient, phase function shape and polarization. All of these become more important at larger scattering angles, where diffraction no longer dominates. Typically, the dust size distribution cannot be measured uniquely, and must be constrained by a set of forward simulations at multiple wavelengths and scattering angles.

Using a precomputed grid of grain scattering properties, we simulate spectral intensities for a set of plausible dust distributions around an exploration site. Our present scattering grid spans UV to near-IR wavelengths and is computed for multiple grain shapes and sizes. Scattering from smaller grains is computed using the Discrete Dipole (DDA) method, and that from larger grains is estimated using the Hapke equivalent slab method, with diffraction superimposed. The large grain portion of the grid will soon be replaced with the results of ray-tracing computations. Simulations of this type will reveal the capabilities (as well as limitations) of optical dust measurements on the lunar surface.