MARAUDERS: Using instrumented nano-impactors to probe the icy properties of Lunar permanently shadowed regions

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The Mini lAndeRs And boUncers Deployed for Exploration and Regolith Science (MARAUDERS) is a small satellite concept that aims to characterize the surface and volatile properties of regolith in permanently shadowed regions (PSRs) around the Moon’s poles. Large PSRs are cold enough to trap scientifically and economically valuable volatiles such as water ice. However, despite ongoing studies, the distribution, abundance, and physical phase of volatiles at the Moon’s poles remains elusive [1]. *In-situ* measurements are required to conclusively determine the geotechnical and physical properties of lunar polar volatiles. To address these needs, the MARAUDERS team is currently developing a technique using instrumented nano-impactors to determine the mechanical properties of regolith at the impact point.

Small spacecraft equipped with penetrators or inertial measurement units (IMU) can characterize the strength and structure of the planetary surface that they impact. Early space exploration used penetrometers to determine the surface properties of the Moon and Mars before the arrival of astronauts and rovers. In recent decades, spacecraft equipped with IMUs characterized the surface of Titan [1], and determined the sub-surface stratification of ice and rock on the comet 67P/C-G [2]. While this technique is unable to relay the detailed mineralogical and elemental composition at the impact point, it obtains a first-order structural knowledge of potentially hazardous surfaces and sub-surfaces that cannot be obtained through remote sensing. This is highly relevant for PSRs due to extreme environmental conditions such as the lack of solar illumination, cold temperatures, and challenging communications.

Here, we present preliminary analysis on the instrument capabilities based on the potential deployment scenarios to PSRs, and the possible mechanical properties of the regolith found within these regions (Fig. 1). We present a computational study of the varying response of an instrumented impactor impacting regolith with variable i) water ice content (0-10%), ii) impactor speeds (50-250 m/s], and iii) impact angles (45-90°), using a discrete element method code [4]. Furthermore, we analyse the ejecta properties and resulting crater morphology in order to gain a better understanding of impact processes on icy bodies. Our next steps will be to conduct laboratory impact experiments using prototypes of our instrumented impactors to calibrate the impact response on lunar simulant with variable water-ice content.

References:

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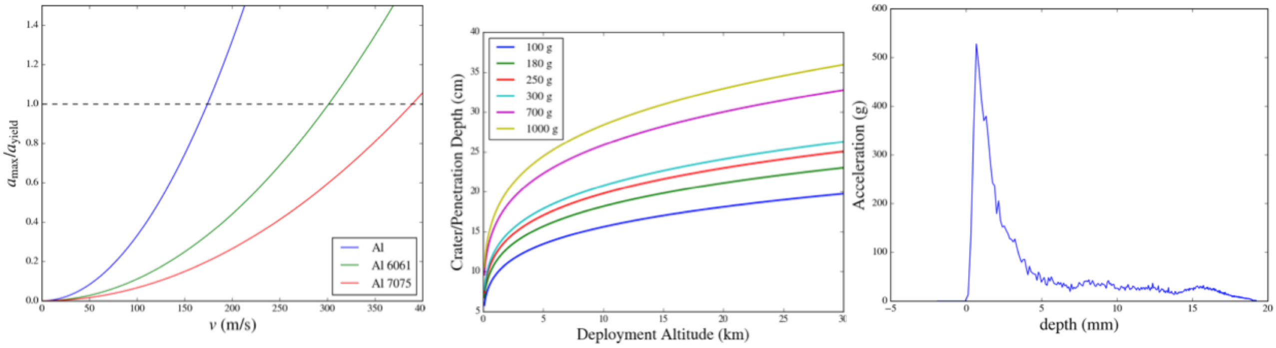

Fig. 1. Preliminary analysis showing shock tolerance, penetration depth, and instrument response for different instrument designs and impact speeds. Left: Maximum shock tolerance before material failure for three different aluminum alloy instrument housings. An Al-7075 housing can withstand impact speeds greater than 350 m/s. Middle: Penetrations depths for a 250 m/s impact for different impactor masses (100 - 1000 grams). For a nominal impactor mass of 180 g, a deployment from 15 km from the lunar surface results in a penetration depth of < 20 cm (based on [3]). Right: Simulated response of a 180 g impactor using a particle dynamics simulation.

