IAF SPACE EXPLORATION SYMPOSIUM (A3)
Small Bodies Missions and Technologies (Part 2) (4B)

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IN SITU MEASUREMENTS OF REGOLITH PROPERTIES ON SMALL SOLAR SYSTEM BODIES USING SPACECRAFT/ROVER HYBRIDS

Abstract

This work considers in situ techniques to measure regolith properties from small landers on the surface of small Solar System bodies, such as comets, asteroids and small moons. Motivated by the need to improve spacecraft safety in sample return missions, while potentially increasing science return with surface mobility, our work focuses on techniques that enable a small (1-100 kg) class of untethered landers, called spacecraft/rover hybrids (SRHs), to directly measure mechanical regolith properties. In situ measurements, such as regolith hardness to a depth of 10-15 centimeters, are particularly challenging on small bodies due to the minimal gravitational forces.

In this work, we describe and evaluate two methods that could enable SRHs to measure regolith properties. The first uses a hammering mechanism (similar to the MUPUS instrument flown on the Rosetta mission), while the second takes advantage of a SRH's flywheels dynamics to penetrate and scoop surface regolith.

For the MUPUS-type hammering method, we show that it is possible to drive a penetrating rod into regolith simulant in reduced gravity (e.g. 1% of Earth's gravity), while using the SRH to provide the countermass to significantly limit the recoil forces. A reset procedure is demonstrated that manages the SRH's travel in the opposite direction to the penetrator. Sensors on the SRH monitor the dynamic interactions between the penetrator and the surface, allowing the mechanical properties of the subsurface regolith to be characterized, e.g. by providing cone penetration index versus depth. It was also shown that spatially varying mechanical properties can be observed for layered regolith, e.g. dusty and fluffy layers on top of harder layers, that may be analogs of comet surfaces.

The second method, referred as a Brake-type, uses the SRH's internal flywheels and a braking mechanism to rotate the SRH's chassis to interact with the surface regolith. This allows measurements to be made either by penetration with a dedicated probe, or by measuring the drag forces and torques acting on the SRH. These can include, but are not limited to, transportation of thermal probes, permittivity probes, buzzers, mechanical vanes or sampling systems. Experimental results and observations are presented and discussed in the context of a proposed science package and mission scenario.