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Instrumented Moles for Planetary Subsurface Regolith Studies

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Soil-like materials, or regolith, on solar system objects provide a record of physical and/or chemical weathering processes on the object in question and as such possess significant scientific relevance for study by landed planetary missions. In the case of Mars, a complex interplay has been at work between impact gardening, aeolian as well as possibly fluvial processes. This resulted in regolith that is texturally as well as compositionally layered as hinted at by results from the Mars Exploration Rover (MER) missions which are capable of accessing shallow subsurface soils by wheel trenching with subsequent geochemical investigations through the Athena payload.

Significant subsurface soil access on Mars, i.e. to depths of a meter or more, remains to be accomplished on future missions. This has been one of the objectives of the unsuccessful Beagle 2 landed element of the ESA Mars Express mission having been equipped with the Planetary Underground Tool (PLUTO) subsurface soil sampling Mole system capable of self-penetration into regolith due to an internal electromechanical hammering mechanism. This lightweight device of less than 900 g mass was designed to repeatedly obtain and deliver to the lander regolith samples from depths down to 2 m which would have been analysed for organic matter and, specifically, organic carbon from potential extinct microbial activity with diagenesis products of Martian biota possibly having been preserved at depth because of protection from surface UV flux and putative oxidants.

With funding from the ESA technology programme, an evolved Mole system is presently being developed which is to serve as the carrier for in situ instruments for measurements in planetary subsurface soils. This could complement or even eliminate the need to recover samples to the surface, where - in case of Mars - organic material could be modified or destroyed by UV radiation prior to an analysis. The prototype hardware being developed within this Instrumented Mole System (IMS) effort is geared towards accommodating a geophysical instrument package (Heat Flow and Physical Properties Package, HP3) that would be capable of measuring planetary heat flow, regolith mechanical and thermal properties. The chosen design encompasses a two-body Mole consisting of a ’tractor’ element containing the hammering mechanism and a trailed compartment housing the instruments. Modularity ensures that a different instrument suite may be carried instead of the geophysical one, such as a miniaturized X-ray fluorescence spectrometer for elemental analyses, a VIS/NIR Attenuated Total Reflection spectrometer (ATR) for mineralogical studies or the optical head of a Raman spectrometer (likewise, for mineralogy).