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SUBSURFACE LUNAR ICY SAMPLES COLLECTION: THE TOOL-SOIL ENERGY EXCHANGE MODEL TO DRIVE PENETRATORS DESIGN

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Abstract

In the frame of the current exploration mission studies which include in situ science, scientists are greatly interested in icy and volatiles specimen retrieval and analysis, from the Moon first, but from icy planets like Europa and Enceladus as well.
Such a scientific target translates in a very challenging set of design and operational constraints on tools devoted to soil sample collection and delivery to either the scientific instrument or the preservation box to be returned to Earth. Moreover, a set of beneath surface samples are requested, to get material unmistakably representing the local chemical\physical history and not affected by exogenous factors acting on the surface. The combination of the beneath surface sampling and volatile\ice preservation translates into the development of soil penetrating tools with low energy exchange with the surrounding soil during perforation, coring, collection, delivery, to ensure the sample to keep its few tenths of Kelvin temperature to preserve its volatiles and icy structure.
Several exploration missions would benefit from icy sample collection capabilities, some of those may be part of a Moon focused space program. Volatiles search and analysis in the Moon Polar Regions is already a matter of scientific research and the technology is mature to seriously discuss on low temperature sample retrieval feasibility.
Politecnico di Milano developed an experimentally validated Energy Exchange Model (EEM) tool to support for the design and operation definitions of the icy soil penetrators. In particular, the penetrator mechanical energy transferred to the soil and the sample during the whole tool operations is modelled, taking into account the detailed drill geometry and the thermo\physical soil characteristics; radiation, conduction and convection mechanisms occurring among the tool, the free space and the soil are modelled. The penetration velocity and power, the drill geometry and materials are kept as parameters to run the sensitivity analyses and drive the design; the soil thermo-physical properties and its stratification are treated as parameters as well and tuned through the experimental campaign run at Finmeccanica premise, which is responsible for the penetrator development. The EEM offers - as output - the 3D temperature profile - along the whole penetrator operational window - the cored specimen inside the tool, the tool, the surrounding soil and. The EEM is presented in details highlighting its beneficial exploitation to support the design of tools for current and future icy Moons sampling missions in which the specimen thermal control is mandatory.