Z5.05-6062 - Modeling Rover Interactions with Lunar Regolith in Permanently Shadowed Regions

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NON-PROPRIETARY DATA

IDENTIFICATION AND SIGNIFICANCE OF INNOVATION

Outward Technologies proposes to develop a Discrete Element Method (DEM) modeling framework using open-source software to simulate the combined thermal and mechanical interactions between rovers and regolith in Permanently Shadowed Regions at the lunar poles. This proposed set of numerical tools innovates on the current state of the art by explicitly solving for thermal and mechanical interactions between rover components and regolith, and by the inclusion of volatiles such as water ice of various forms (e.g. vapor deposited "frost", blocky deposits, and icy regolith mixtures) in a grain-based DEM model. A coupled thermo-hydro-mechanical model in DEM will further be explored for its suitability in simulating volatile phase change and gas transport through cryogenic regolith. These combined numerical tools will enable NASA and its partners to inexpensively evaluate hardware designs for lunar ISRU missions aimed at exploration and prospecting, leading to more rugged and capable rovers for lunar polar missions while reducing their costs of development and testing.

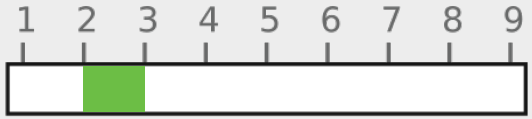
TECHNICAL OBJECTIVES AND PROPOSED DELIVERABLES

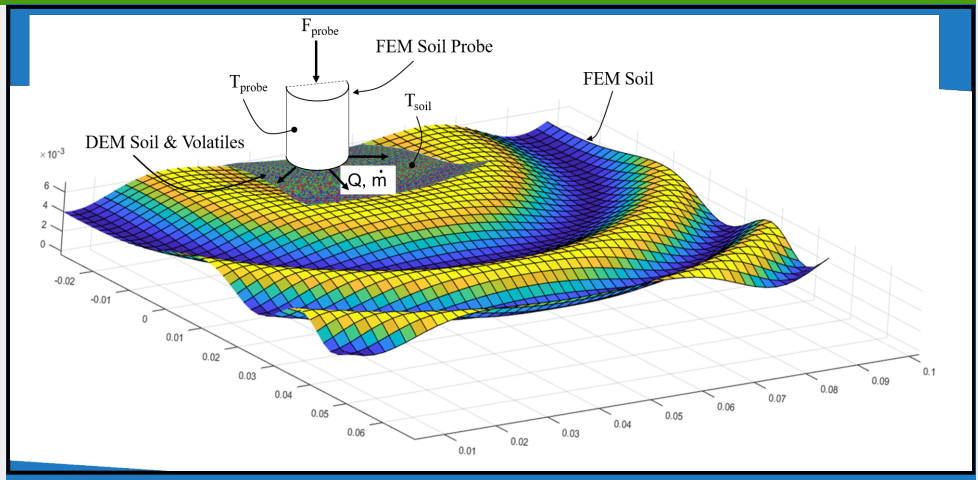
The technical objectives are to:
1) Using open-source software, develop a grain-based soil model capable of simulating thermo-hydro-mechanical behavior of regolith, icy-regolith mixtures, ice, and rock
2) Determine phase change of water in situ or within a retrieved soil sample by calculating both transient and steady-state heat flow through a soil matrix
3) Evaluate capabilities for approximating mass transport of water vapor through lunar regolith
4) Combine these capabilities into an easy-to-use, coupled thermo-hydro-mechanical model of lunar regolith defined by a) stochastic inputs for regolith size and shape distributions; b) expected forms of water ice and their spatial distributions within the regolith; and c) coupling with existing FEM software to simulate rovers and sampling equipment

The proposed deliverables are:
-(DEM) Model heat transfer through soil matrix with realistic grain shapes, as defined through clusters of bonded particles
-(DEM) Automate the generation of a lunar soil model from stochastic inputs for regolith containing volatiles
-(DEM) Identify phase change of ice in regolith if melting/vaporization temperatures are met
-(DEM-FEM) Demonstrate mechanical and thermal coupling between DEM and FEM
-(DEM) Evaluate suitability of modeling mass flow of volatiles and advective heat transfer through regolith using a coupled thermo-hydro-mechanical model

TRL

Estimated





NASA APPLICATIONS

This project leads to many potential NASA applications including the design and evaluation of rovers and sampling equipment for use in lunar polar regions for ISRU prospecting and exploration missions. The proposed DEM-FEM coupled software and its associated advancements will bring additional knowledge to the challenges faced in lunar polar missions while presenting a low-cost evaluation tool for hardware design, rover control strategies, and volatile sampling. These improvements will lead to lower cost lunar ISRU missions with reduced risk.

NON-NASA APPLICATIONS

By increasing the sampling of the high-dimensional design space of DEM microscale input selection, Outward Technologies will be able to gain a competitive advantage in thermo-mechanical DEM models related to granular mechanics and will be able to incrementally increase our customer base, tailoring services to companies in the field of powder handling, pharmaceuticals, oil and gas, and mining.

FIRM CONTACTS

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