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 has developed 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 set of numerical tools innovates on the current state of the art by simulating both thermal and mechanical interactions between rover components and regolith, and by the inclusion of volatiles in a grain-based DEM model capable of simulating volatile phase change and gas transport through cryogenic regolith. In Phase II, the DEM model will be calibrated to fit experimental tests on ice-regolith mixtures in cryogenic vacuum conditions and will be coupled open-source FEM software to simulate rover hardware and far-field soil. These comprehensive, calibrated numerical tools will enable NASA and its partners to inexpensively evaluate hardware designs for lunar ISRU missions aimed at exploration and prospecting across a range of conditions which may be encountered, leading to more rugged and capable rovers for lunar polar missions.

TECHNICAL OBJECTIVES AND PROPOSED DELIVERABLES

The primary Phase II technical objectives are to:

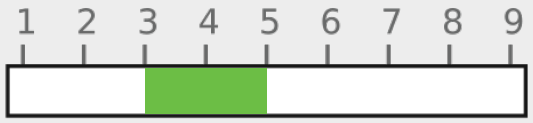
1. Calibrate the DEM thermo-hydro-mechanical models developed in Phase I to match heat transfer and soil mechanics data from laboratory experiments on dry and ice-regolith mixtures in cryogenic vacuum conditions
2. Improve computational performance of modeling gas flow and advective heat transfer through a regolith matrix containing volatiles in YADE
3. Explore the changes to soil mechanics and thermal properties of ice-regolith mixtures following sublimation and deposition of volatiles with a focus on potential hazards posed to rover mobility
4. Evaluate heat loss and mobility performance of a rover wheel (or soil probe) interacting with ice-regolith mixtures of varying forms
5. Model a rover component (e.g. wheel, probe, scoop) interacting with a lunar soil containing volatiles to analyze transient and steady-state heat transfer and the potential changes to thermal and mechanical properties of the soil through continued interactions

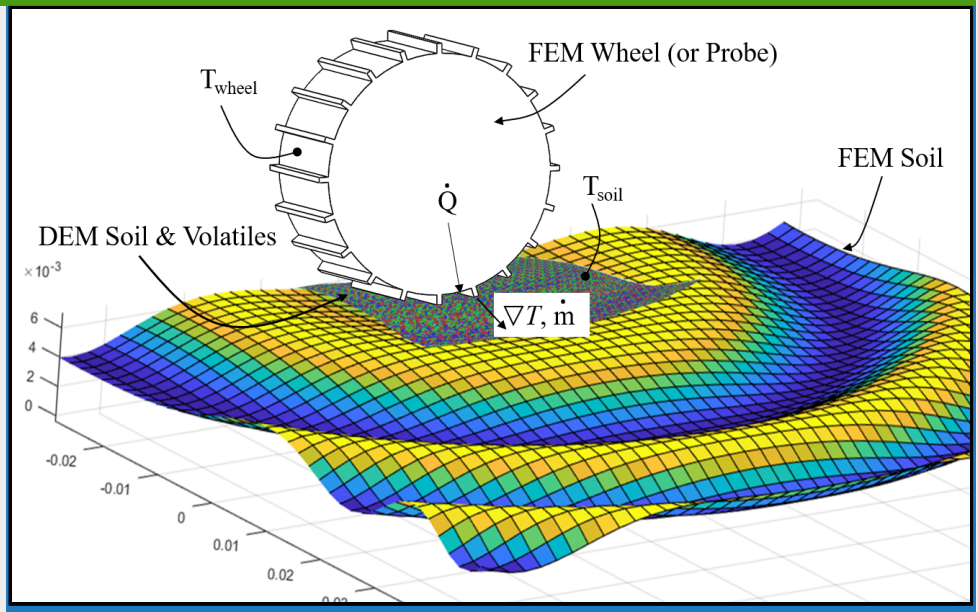
Proposed Deliverables:

1. Calibrated inputs to grain-based DEM model for simulating thermal and mechanical properties of ice-regolith mixtures in cryogenic vacuum conditions
2. Easy-to-use numerical modeling framework implemented in open-source software for simulating thermo-mechanical interactions between rover hardware and regolith to evaluate a range of possible conditions which may be encountered at the lunar poles

TRL

Estimated





NASA APPLICATIONS

The Phase II leads to several 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 provide automated calibration services for companies and users of thermo-mechanical DEM models and provide improved numerical models to companies in the fields of powder handling, pharmaceuticals, oil and gas, and mining.

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