robotic Mars sample return missions – will be to acquire samples of lunar soil some distance away from the actual lander, and to bring them back to the spacecraft for analysis by on-board instruments. This will enable access to soils that are less contaminated by lander descent propulsion system plumes to increase the chances of detection of any indigenous lunar volatiles contained within the samples. Starting from the requirements imposed on the rover, this paper describes the trade-off's performed on the mobility and overall system design with a focus on the mobility and power subsystems, followed by a description of the conceptual design, the predicted mobility performance under lunar conditions, and plans for brassboarding and associated testing in the 2012/2013 timeframe.

Report from the 2011 Summer Series of Workshops on "xTerramechanics"

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A series of workshops were held in the summer of 2011 at Caltech in Pasadena, CA on the topic of "xTerramechanics". These workshops were sponsored by the Keck Institute for Space Studies (KISS) with co-leads from JPL, Caltech, and MIT (listed here as authors of this paper). This paper will present a brief synopsis of the workshop, including motivations, content, insights, and future prospects for research and space missions.

xTerramechanics (XTM) is a discipline that broadly entails the study and modeling of interactions between spacecraft (e.g., rovers) and extraterrestrial geomaterials (e.g., Martian soils). By bringing together key technical experts from across, the workshops aimed to initiate a transformative advancement in the capabilities available to NASA missions. We introduced our study by focusing on the canonical case of surface interactions stemming from mobility issues related to Martian rovers to deepen our understanding of key mission life-cycle processes: formulation trades, design, mission operations, and in-situ science context and integration. The collaborations that resulted in these workshops were born from experiences of the Spirit rover's embedding incident on Mars, with concern for future operations of the MSL Opportunity rover when it lands on Mars in August 2012.

The events began with a half-day short course on the fundamentals of planetary terramechanics, as presented by NASA project scientists and academic partners in the fields of robotics and computational soil mechanics. To facilitate a positive, synergistic group dynamic, our roster was capped at thirty participants, including planetary scientists, engineers, roboticists, soil mechanicians, modelers, and analysts. Attendees came from JPL and other NASA centers, Caltech and several other universities, and industrial partners including Caterpillar. Much of the first workshop was spent defining the limitations and horizons of the field. A core theme was parameter identification, correlation, extraction, and reduction, with a goal of converting mechanical mobility systems into "N+1" science instruments.

A working study period was held to further delineate possible modes of collaboration and work toward a possible overall community research architecture. We focused on a multi-pronged modeling strategy supported by experimentalists, scientists, and engineering practitioners. Such a framework supports movement toward two goals: (1) long-term goals of full physics-based modeling as a means for enabling new, radical mission concepts, and (2) short-term goals of providing the best possible tools to assist in rover mission driving operations. These second set of goals will be supported by an active reducedorder modeling effort alongside the full-model development. The final consensus of the group was that a strong modeling and simulation community will be required by NASA to remain competitive and innovative as new mobility, sample acquisition, and sample return challenges are presented in environments of unknown characteristics and no ability to be represented in terrestrial physical testbeds.

Soil Motion Analysis System for Examining Wheel-Soil Shearing

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Though much research has been conducted regarding traction of tires in soft granular terrain, little empirical data ex-ist on the motion of soil particles beneath a tire. A novel experimentation and analysis technique has been developed to enable investigation of terramechanics fundamentals in great detail. This technique, the Shear Interface Imaging Anal-ysis Tool, provides visualization and analysis capability of soil motion at and below the wheel-soil interface. The me-thod places a wheel (or other traction device) in granular soil up against a transparent sidewall. While driving or towing the tire, images are taken of the sub-surface soil, and are processed with optical flow software. Analysis of the resulting displacement field identifies clusters of soil motion and shear interfaces. Complexities in soil flow patterns greatly affect soil structure below the wheel and the resulting tractive capability. The Shear Interface Imaging Analysis Tool visualizes and helps analyze these complexities in richer detail than possible before, and allows for a deeper understand-ing of the physics behind wheel-terrain interaction. Results are presented for rigid wheels at various slip conditions, and various wheel configurations such as diameter, grouser spacing and compliance.

Keywords: terramechanics, rover, robotics, regolith, wheel