Mars Exploration Rover Opportunity Terramechanics Across Ripple-covered Bedrock in Meridiani Planum

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Objectives and Approach

• Develop ARTEMIS, a multi-element dynamic model of Opportunity rover interacting with realistic terrain elements
• Include digital elevation models from orbital and rover-based data
• Include spatially variable deformable soils and bedrock
• Test with single wheel model and experiments
• Test with “Mars Yard” engineering rover drives
• Reproduce selected Opportunity drives
• Use validated model for path planning when Opportunity has to cross soil-covered slopes to get to Endeavour’s rim

Model Wheel-Soil Interactions

Opportunity Mobility Issues

• Opportunity has successfully driven over 26 km across the plains of Meridiani
• Mobility issues have been associated with increased soil sinkage, compaction resistance, and slippage when:
  - Driving over large ripples when all six wheels were climbing ripple flanks
  - Driving up or down steep, soil-covered slopes (interiors of Endurance and Victorian craters)
• Significant slip encountered on uphill drives on bedrock (Santa Maria rim)
• Skidding has been observed on downhill drives

Model Wheel Soils Parameter Diagram

Summary and Future Work

• Artemis has been developed and is being tested with lab and flight data
• Able to model ripple-crossing slippage and sinkage, along with downhill skid on soil covered slope, and uphill slippage on bedrock thinly covered by soil
• Conducting detailed testing and stream-lining code to be ready to model risky drives (high slippage and sinkage expected) associated with traversing soil-covered slopes (10 to 20° tilts) to get to Noachian outcrops on Endeavour’s rim (Cape York, Solander Point, and Cape Tribulation)

Example Model and Analysis

Opportunity Visual Odometry-Based Wheel Slip Data Since Leaving Victoria Crater

How to get to Noachian crust on Endeavour’s rim?

Left: Wheel soil laboratory rig at MIT to be used to test single wheel model. Middle: Navcam view of tracks associated with the Sol 2143 ripple crossing drive frames. Right: Tracks from the sol 2451 ascent to the rim of Santa Maria crater. Visual odometry indicates up to 58% slippage for the ripple crossing, and modest downhill skid and uphill slippage for the ascent to the Santa Maria rim.

HiRISE draped over DEM from stereo pairs