Simulating Mars Exploration Rover Opportunity Drives Using Artemis

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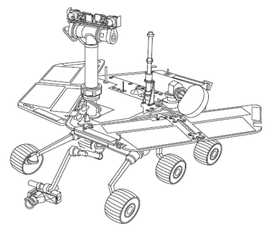
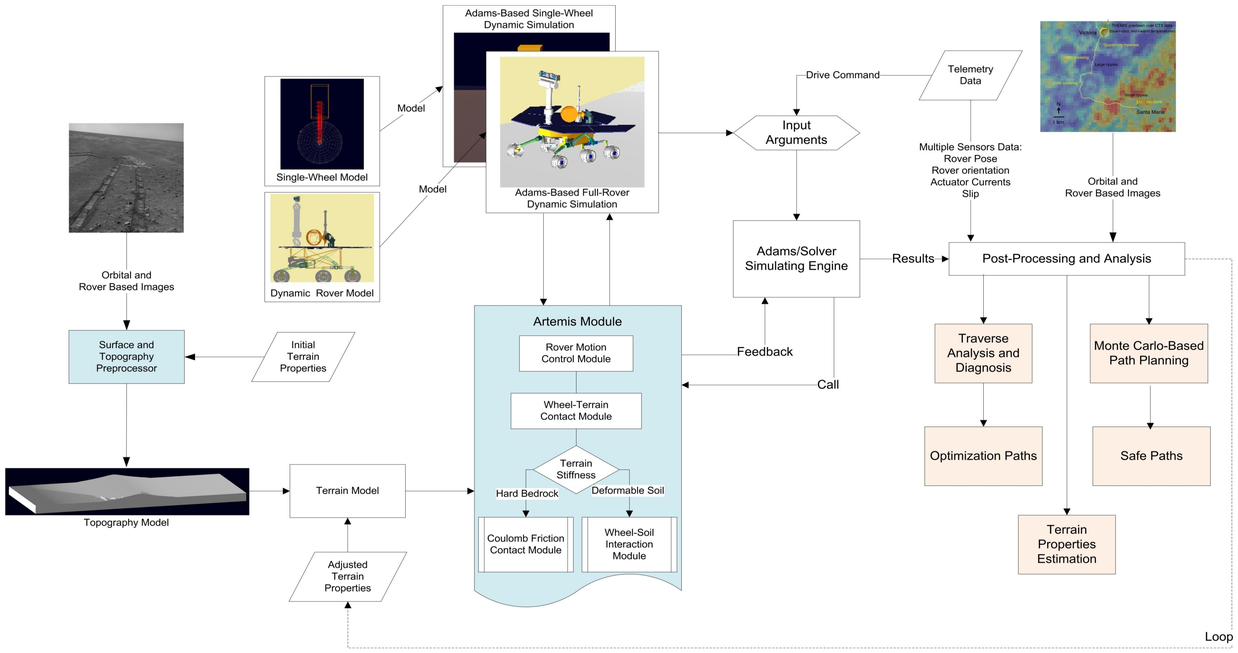


Introduction

- Artemis is a software tool developed to simulate rigid-wheel planetary rover traverses across realistic planetary terrain models, including topography, deformable soils, and bedrock outcrops.
- Based on classical terramechanics equations
- Includes both soil and bedrock properties and topography from orbital and surface stereo data
- Compares flight data (wheel sinkage, slip, motor currents, rover orientation) along traverse to model data to retrieve terrain properties
- Validated using MIT soil lab single wheel tests and field deployment at Dumont Dunes, CA, with MER engineering test bed (SSTB-Lite)

Modeling and Analysis Overview



Summary and Future Work

- Artemis is able to simulate Opportunity's traverses in high fidelity ways.
- Artemis is used on a continuing basis in a predictive manner to evaluate mobility issues over candidate drives.
- Artemis is being used to retrieve terrain properties through comparison of model and actual drive results.

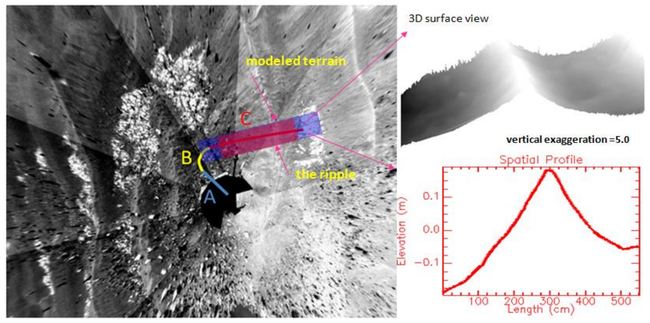
Reference

- [1] Zhou, F. et al. (2012), J. Field Robotics, submitted, under revision.
- [2] Arvidson, R. et al. (2011), J. Geophysical Research.

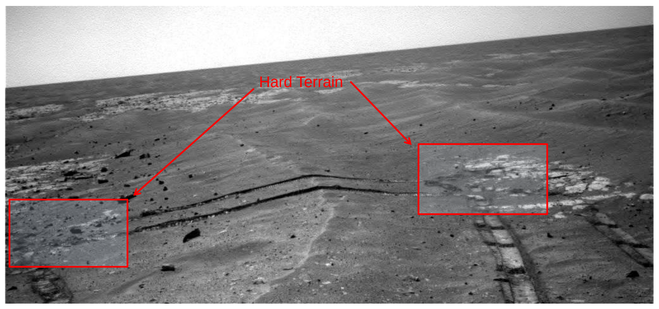
Modeling High Slip Event on Sol 2143

On Sol 2143 Opportunity was commanded to traverse a ~5 m wide, ~0.4 m high wind-blown sand ripple. A 59% 3D slip was recorded in the telemetry during the traverse.

Sol 2143 overview mosaic and ripple profile

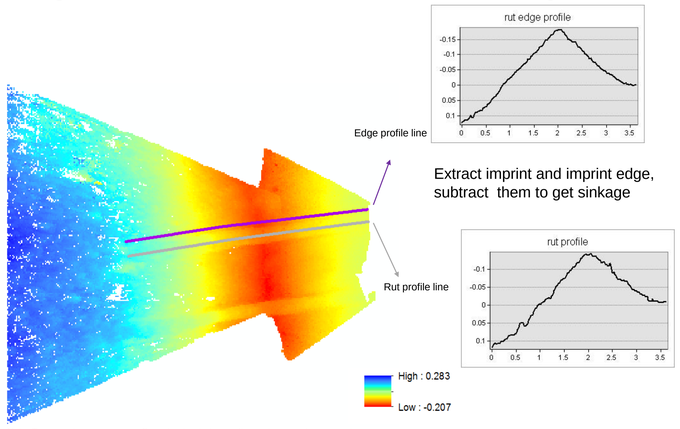


Navcam images acquired after the ripple crossing on Sol 2143.



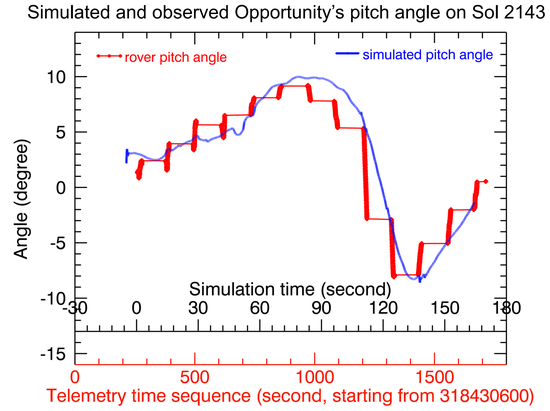
Note: Based on this image, we modeled the terrain in three properties: the beginning and end of the ripple crossing consist of a mix of bedrock and a thin soil cover, whereas most of the ripple is dominated by deformable soil.

Sinkage extraction from DEM derived from Navcam images

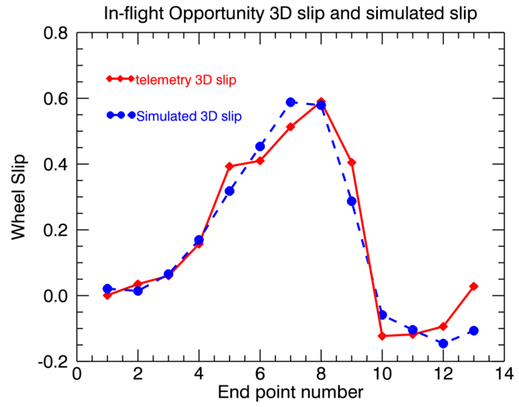


Note: The elevation is based on Opportunity site frame. Its positive direction is pointing down.

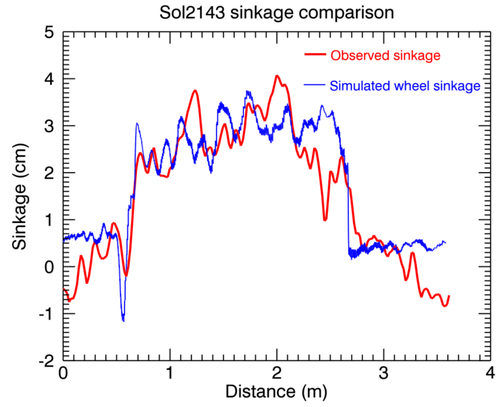
Simulated and observed Opportunity's pitch angle on Sol 2143



In-flight Opportunity 3D slip and simulated slip

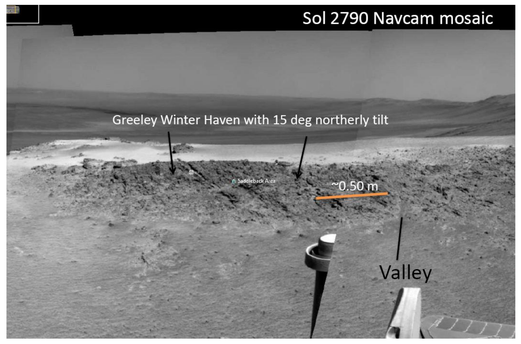


Sol2143 sinkage comparison

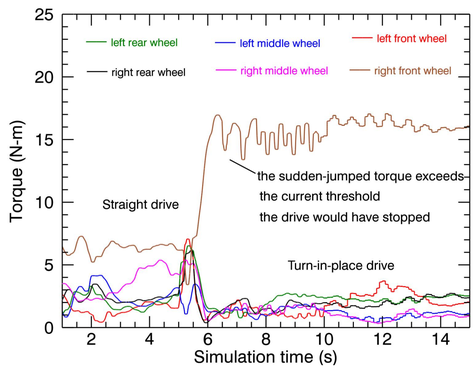


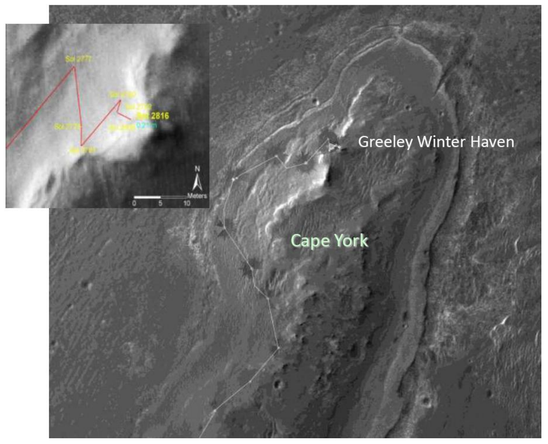
Modeling Stick-Slip Bedrock Drive on Sol 2808

Greeley Winter Haven is an impact breccia outcrop with an irregular surface and a tilt ~15°. On Sol 2808, Opportunity was commanded to drive forward and then turn-in-place using visodom on this tilted outcrop. The drive stopped during a turn-in-place. The increase in the right front wheel actuator current caused the drive to automatically stop because a current threshold was reached.

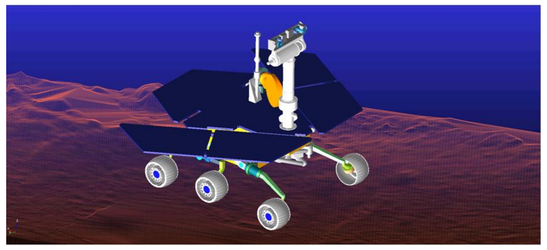


Simulated torque for each wheel on Sol 2808 diagnosis simulation (wheel-drive-actuator current anomaly)





Sol 2808 simulation



Note: From this view, Opportunity is tilted approximately 15 degrees on the slope within a 6m*8m modeled surface extracted from Navcam stereo images. The bumpy terrain mesh reflects the irregular bedrock surface.

To further understand driving on this irregular bedrock surface, the immediately next drive, Sol 2816 drive was also simulated. The simulated wheel driving torque has the same patterns as actuator current data on Sol 2816.

Simulated torque for each wheel on Sol 2816