Mars Exploration Rovers as Virtual Instruments for Determination of Terrain Roughness and Physical Properties.

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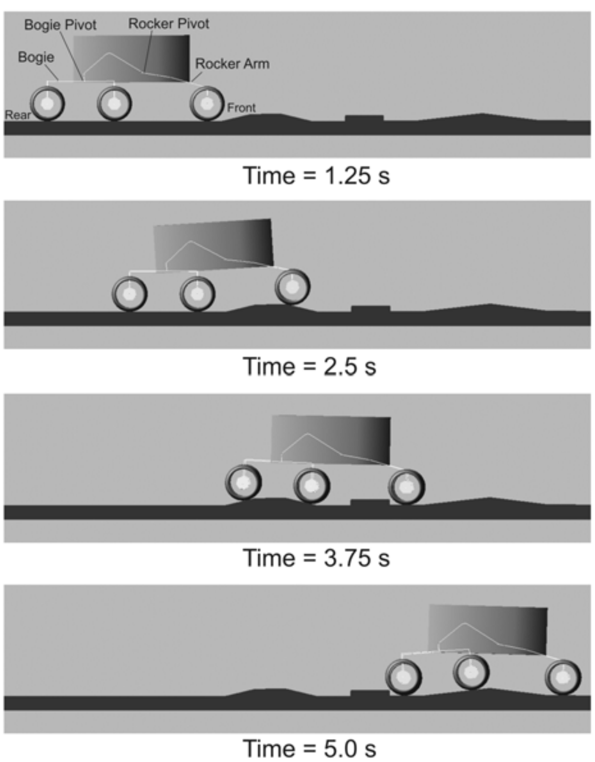
Introduction: The two 2003 Mars Exploration Rovers (MERs), in combination with the Athena Payload, will be used as virtual instrument systems to infer terrain properties during traverses, in addition to using the rover wheels to excavate trenches, exposing subsurface materials for remote and *in-situ* observations [1].

Rover Models. The MERs are being modeled using finite element-based rover system transfer functions that utilize the distribution of masses associated with the vehicle, together with suspension and wheel dynamics, to infer surface roughness and mechanical properties from traverse time series data containing vehicle yaw, pitch, roll, encoder counts, and motor currents (Figures 1 and 2). These analyses will be supplemented with imaging and other Athena Payload measurements. The approach is being validated using Sojourner data [2], the FIDO rover [3], and experiments with MER testbed vehicles.



Trenching. In addition to conducting traverse science and associated analyses, trenches will be excavated by the MERs to depths of approximately 10-20 cm by locking all but one of the front wheels and rotating that wheel backwards so that the excavated material is piled up on the side of the trench away from the vehicle. Soil cohesion and angle of internal friction will be determined from the trench telemetry data. Emission spectroscopy and *in-situ* observations will be made using the Athena payload before and after imaging. Trenching and observational protocols have been developed using Sojourner results [2]; data from the FIDO rover [3], including trenches dug into sand, mud cracks, and weakly indurated bedrock (Figures 3 and 4); and experiments with MER testbed rovers. Particular attention will be focused on Mini-TES measurements designed to determine the abundance and state of subsurface water (e.g. hydrated, in zeolites, residual pore ice?) predicted to be present from Odyssey GRS/NS/HEND data [4].

[1] Arvidson, R.E. et al. (2002) Science & Technology Experiments Associated with the 2003 Mars Exploration Rovers, *JGR*, in press. [2] Moore, H.J. et al. (1999) *JGR, 104,* E4, 8729-8746. [3] Arvidson, R.E. et al. (2002) *JGR, 107*, E9, 10.1029/2000JE001464. [4] Boynton, W.V. et al. (2002) *Science, 297*, 5578, 81-85.

Figure 1. Numerical simulation of rover with MER-like mass distribution, suspension, and wheels rolling down an 8 degree slope and over topographic obstacles. View is tilted by 8 degrees so that surface appears to be horizontal.

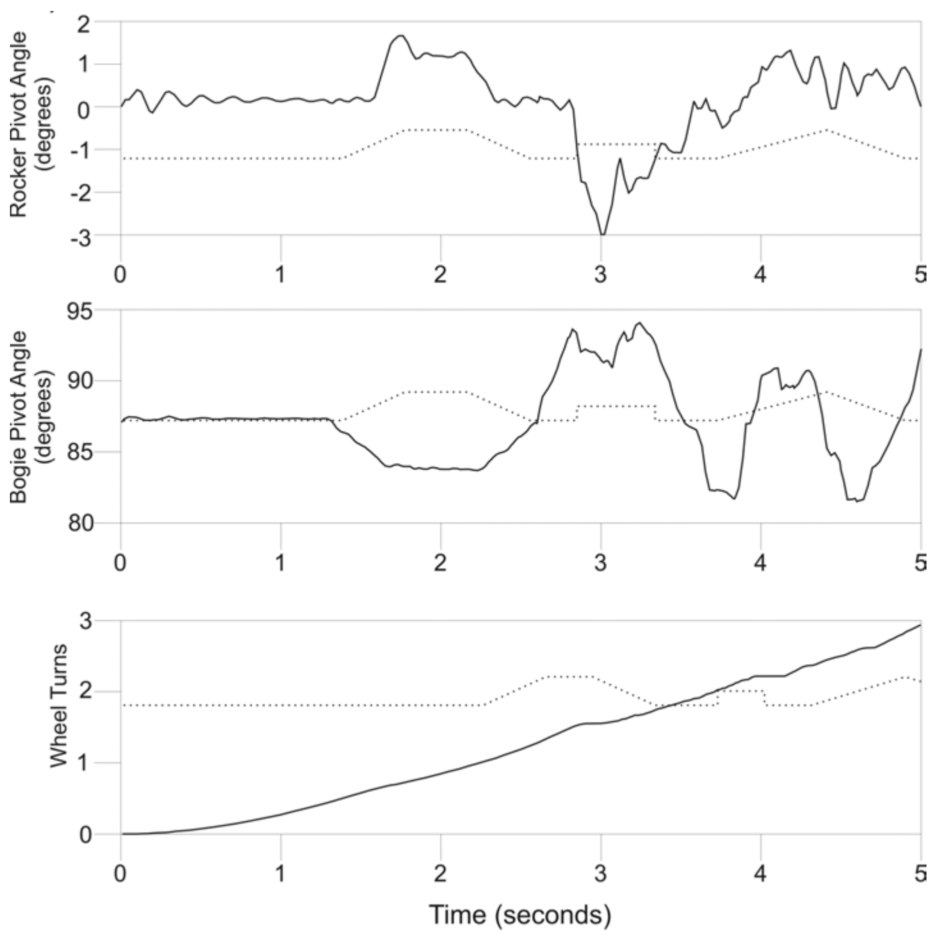


Figure 2. Simulated telemetry showing rocker and bogie pivot angles as function of time during the rolling experiment with MER-like vehicle. The number of wheel turns for the rear wheel is shown on the bottom panel. The topography encountered beneath the center of the rover is shown as a dotted line for the top two panels. For the bottom panel, the topography is shown beneath the center of the rear wheel. The compressed topographic profile with the increasing time is due to rover acceleration. Note that this simulation is the first step toward making a fully MER-like model with powered and steerable wheels. For the simulation shown, the wheel resisting torques were lowered relative to MER conditions to allow rolling on an 8 degree slope.

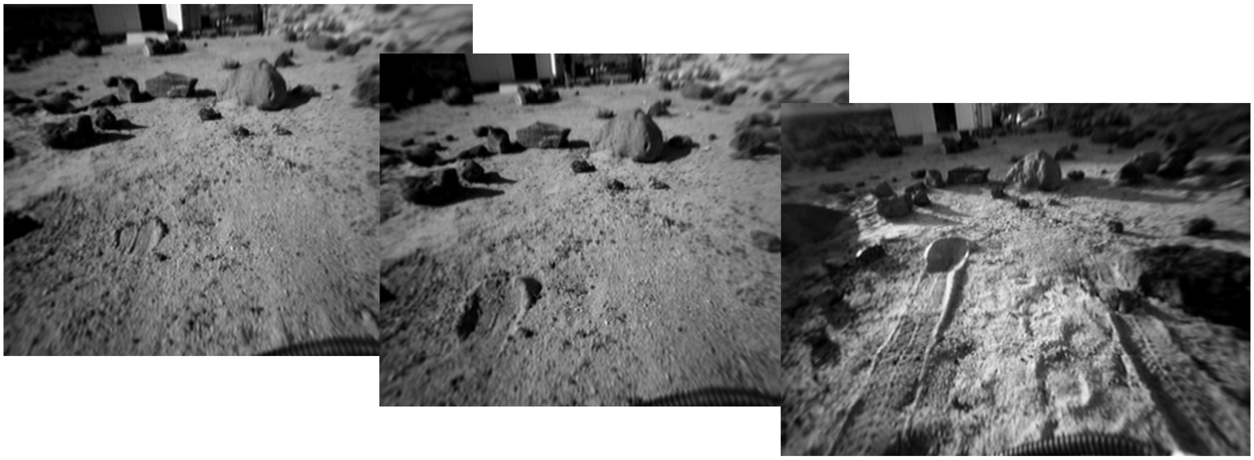


Figure 3. FIDO created a trench in loose sand with front left drive wheel by holding 5 wheels fixed and rotating the front wheel in reverse by ~6 wheel revs. Rover approached site and trenched, backed off and imaged trench, approached site again and trenched, backed off and imaged trench, approached site again and trenched twice (motor stalled on second trench attempt), backed off and imaged trench. Final trench was 7-8 cm deep.

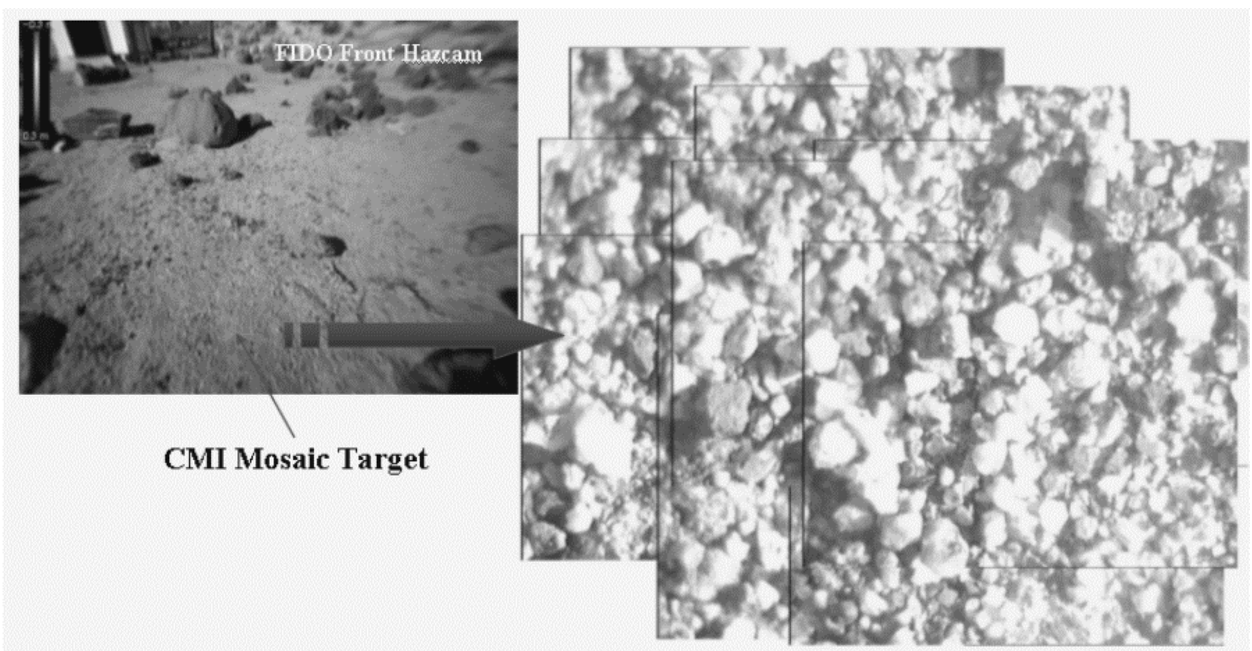


Figure 4. Microscopic Imager on FIDO instrument used to acquire stereo images with 5 mm horizontal and lateral spacing between images