MARS EXPLORATION ROVERS: LABORATORY SIMULATIONS OF AEOLIAN INTERACTIONS

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Introduction: Aeolian activity is an important pervasive surface modifiers on Mars. Therefore it is important to study the interactions between the wind and landed mission components, specifically the Mars Exploration Rovers (MERs). The goals of this study are subdivided into two main groups: (1) Hazard assessment, and (2) Science analysis of the aeolian environment around the rover. Within these categories, simple boundary layer wind shear and vortical, "dust devil" action were both studied in the context of a 1/6 scale model of the MER in the laboratory.

Background: Wind streaks, ripples and/or micro-dunes were observed at all previous landing sites [1]. *Mars Pathfinder* showed the greatest variation in aeolian morphologies including wind streaks, ripples, ventifacts, and dust devils [2,3,4]. Therefore, wind processes are pervasive on the surface of Mars and wind action is a concern for any landed mission. The stereo imagers are the best instruments on the MERs for studying the effects of the wind. In the absence of other meteorological instruments it is necessary to study the affect of rover geometry on depositional/erosional wind patterns as from visual clues.

All experiments were conducted at the Arizona State University Wind Tunnel Facility, using both the boundary layer wind tunnel and the Arizona State University Vortex Generator (ASUVG). The wind tunnel allowed testing of simple boundary layer wind interactions with the shape of the rover, whereas the ASUVG allowed simulation of "dust devils."

Methods: All experiments were conducted using well-sorted silica sand with a mean particle size ~150 _m. The experiments are divided between wind tunnel and vortex generator experiments. In the wind tunnel, free stream wind speeds, rover orientation, instrument orientations, and simulated rover target orientations were all varied to test the effect of each with sand deposition. Wind speeds included both ~1.5 m/s (just above threshold) and ~3.0 m/s (well above threshold). Rover orientations included cardinal positions of 0˚, 90˚, 180˚, and 270˚, in which 0˚ coincides with the rover facing into the flow. Instruments that had the most effect on deposition such as the Pancam Mast Assembly (PMA), the High Gain Antenna (HGA), and the Instrument Deployment Device (IDD) [5] were also tested in various positions. A small wedge-shaped rock was used to simulate a sample target rock for the MER. Deposition due to the position of this rock with respect to the rover was tested as a function of azimuth and distance. High-speed photos were taken to examine the sand movement between the target rock and the forward Hazcams to assess the potential for damage to the cameras from blowing sand. The IDD and the PMA have protective measures for the lenses [5].

Dust devil simulations used the vortex generator with vortex sizes roughly scaled to the rover. Vortex radii averaged 2-3 cm with tangential velocities of 1-3 m/s. Dry ice (CO_2) was crushed and placed on the test surface beneath the rover model to visualize the vortical flow, and sand was sieved onto the rover to simulate sand deposition on the solar panels during the mission. The rover model was moved horizontally through a running vortex to simulate the interaction of a dust devil with the rover.

Results: Results from the boundary layer wind tests show that for specific configurations of the instruments, rock, and rover there are different amounts of sand deposition on the solar panels. This is important to know from a hazard perspective as well as a science viewpoint. Without meteorological instruments, the deposition patterns on the rover can be used to determine the direction of wind. Because of the asymmetric geometry of the rover, deposition patterns on the ground around the rover are distinct. Again, the patterns can be used as indicators of wind orientation relative to the rover. Assessment of the forward region between the target and Hazcams could be an area of high sand activity (potentially dangerous) based on the high-speed images.

Vortex interactions show interesting changes in vortex structure as the column makes contact with the rover. To conserve angular momentum, the column expands, rotation slows, and the rover is enveloped in the vortex. Sand and ice pieces from the experiment circulated around the base of the rover, which potentially could be another source of material threatening the Hazcams. Another result shows dust devils efficiently removing the sand/dust covering deposited on the solar array.

Conclusions: Deposition of sand on the rover is limited to a few locations where "shadow zones" are formed by specific instruments. The most deposition occurred when the HGA was stowed directly behind the PMA. Because of the highly asymmetric rover geometry, the resulting wind streak patterns, should the lander be in one location for an extended period of time, can show wind direction no matter the orientation of the rover. Sand grains or rock chips could be potential threats as shown by high-speed photography. Dust devils have the ability to clear sand/dust off the solar array, potentially increasing the duration of the mission.

References: [1] *reviewed by* Greeley et al., 1992; [2] Schofield et al., *Science*, 1997; [3] Bridges et al., *JGR*, 1998; [4] Metzger et al., *GRL*, 1998; [5] Squyres et al., *JGR*, 2003.

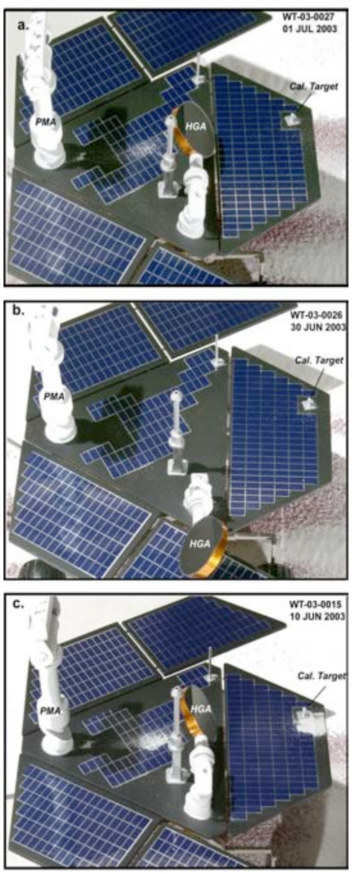

Figure 1. Images showing deposition of sand dependent on HGA position. (a) stowed, rock directly in front of rover; (b) deployed, rock directly in front of rover; (c) stowed, rock at 315°.

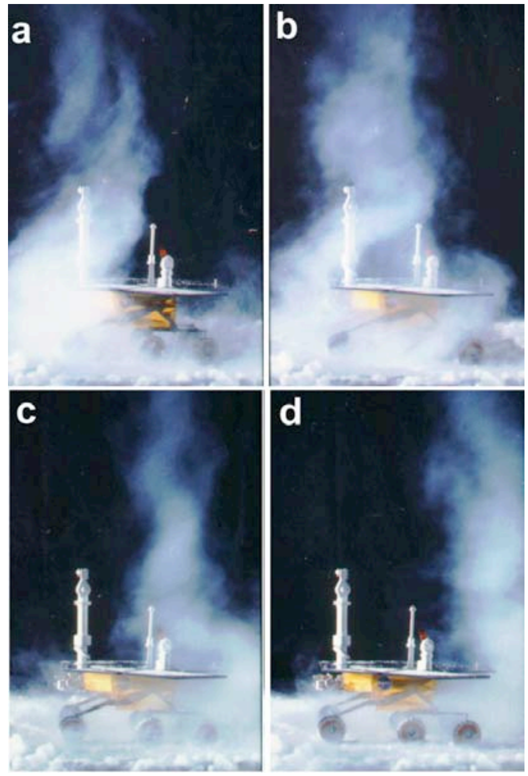

Figure 2. *Experiments showing interaction of simulated dust devil with 1/6 scale model of the MER. a.) Initial contact of dust devil with rover; b.) widening of the vortex base when dust devil is in full contact with the rover; c.) dust devil column moving off back of rover; d.) last contact of the dust devil with the rover.*