AEOLIAN PARTICLE TRANSPORT AS A FUNCTION OF SPACECRAFT DESIGN: AN EXPERIMENTAL STUDY OF POTENTIAL FORWARD CONTAMINATION

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Introduction: Spacecraft deployed to other planetary bodies have the potential for *forward contamination,* in which terrestrial materials are implanted on the object of exploration. Such contamination has the potential to introduce errors into measurements made from the spacecraft, thus jeopardizing mission goals. To mitigate this potential problem, an investigation is underway at JPL to develop computational models of particle transport by wind from spacecraft on Mars. The model would predict contamination zones around the lander where measurements should be avoided. Laboratory experiments at Arizona State University (ASU) and NASA Ames were used to validate and supplement computational models simulating forward contamination. By assessing particle flow, deposition zones, and transport thresholds.

Approach: Wind tunnel facilities at ASU and NASA Ames were used. A stylized spacecraft model (s/c) 15x10x6 cm (length, width, height) was mounted on four cylinders 1.5 cm in diameter by 3 cm high, inset 1 cm. The s/c was placed in the wind tunnel test section, 5.6 m downwind from the bellmouth intake. The model was oriented at two angles from the wind flow, 0° orientation and 30° clockwise rotation from flow (Figures 1 & 2).

Testing variables included s/c orientation, particle dynamics, and free stream velocity (U). Silica sand 20 (SS ~500 μm) and Oklahoma 90 sand (OK90 ~127 μm) were sieved onto the s/c and subjected to the wind. To determine deposition zones, OK90 was sieved onto the surface of the model and blown off into leeward collection trays. The trays were aligned into an array 30x45 cm, with 216 individual cells (Figure 3). Mass collection in the cells was then measured with a digital balance.

Static particle transport threshold properties were observed for Carbondale Red Clay (CRC <~4 μm) and crushed walnut shells (CWS ~45 μm), which exhibit reduced density, compensating for martian gravity. A small amount of dust was emplaced on the s/c to determine threshold of movement.

Results: Flow patterns for OK90 and SS exhibit similar patterns on the deck with respective orientations. The 0° forms a progressive gap caused by a flow reversing boundary layer separation over the top of the model. Therefore separating stoss and lee flow patterns ~2.5 cm stoss side, as indicated from erosion (Figure 1). The 30° forms two stoss side channels stemming from the impact on the stoss s/c corner in the direction of flow (Figure 2). The flow around the model (Figure 4) reveals the wind flow impacting the stoss side, reversing, and redirecting into the streamlines around the model.

Both the 0° and 30° s/c orientations exhibit similar mass distribution zones leeward (Figure 5). Most transported particles concentrated ~15 cm leeward, aligned in the wake of the s/c (Figure 5 & 6). Deposition of the sand varies with velocity. Leeward deposition from wind-entrained particles also occurs (Figure 6).

Threshold of static particles vary with static forces. The average threshold out of five trials for CRC transport was U = ~5.6 m/s. The threshold of transport for CWS was U < ~3.0 m/s.

Summary and Conclusion: From the dust-clearing event of the Mars Exploration Rover (2), it is known that aeolian processes transport particles from spacecraft. With future spacecraft to be implemented, such as Mars Science Laboratory, understanding the potential transport of material from the spacecraft will be crucial for optimum scientific return. As a result of this study, a method for predicting particle flow patterns, transported distribution zones, and static thresholds have been devised.

Future Work: Impact saltation and strong wind gusts can transport fine static particles. The easiest particle size for saltation transport on Mars is ~100-200 μm (1). Earth based bacterial spores with the potential for forward contamination are in the micron particle range, exhibiting static properties. Therefore using similar size particles (OK90, CRC, and CWS) will be necessary for continued study of saltating impact deposition and threshold of movement for future spacecraft designs.

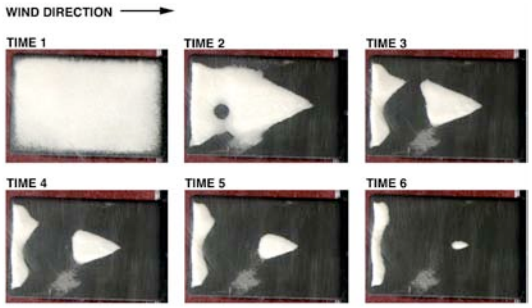

Figure 1. Wind flow patterns from sand erosion on s/c at 0° orientation. U = ~7.0 m/s

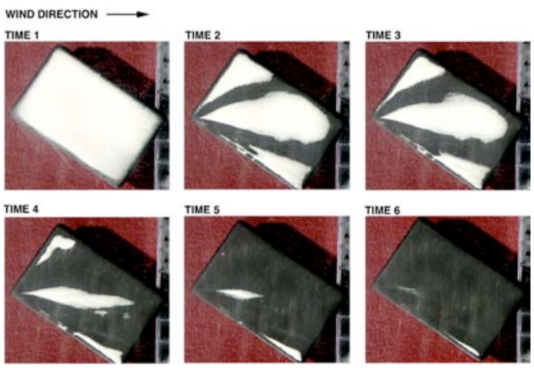

Figure 2. Wind flow patterns from sand erosion on s/c at 30°orientation. U = ~7.0 m/s

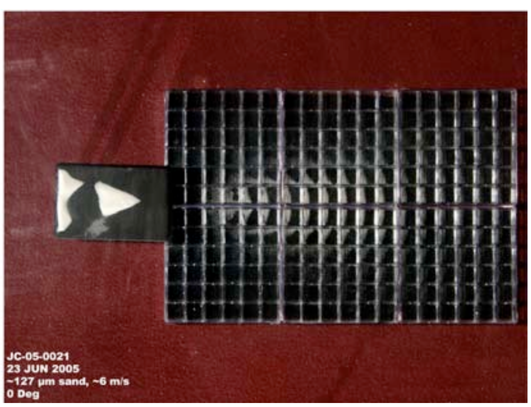

Figure 3. Collection trays for plotting mass distribution zones of particles in Aeolian transport.

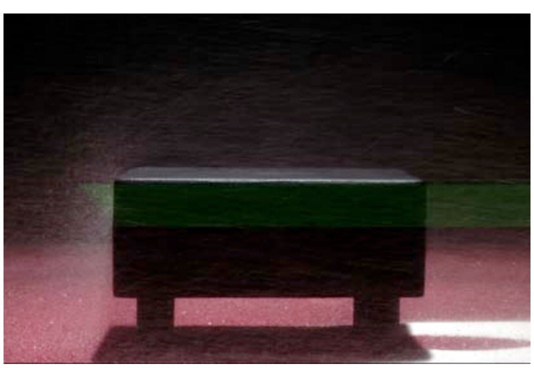

Figure 4. Flow pattern around model from impacting and saltating particles in aeolian transport.

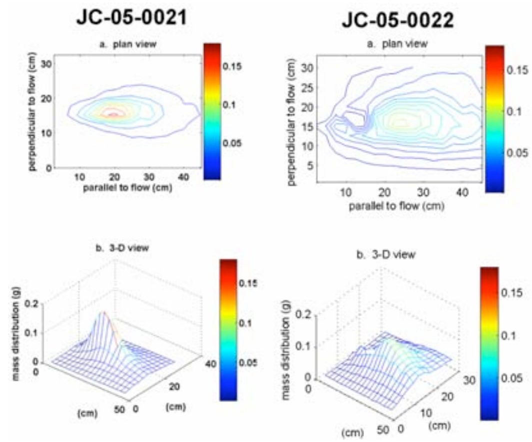

Figure 5. Mass distribution zones, comparison plots of 0° and 30° orientations. Three-dimensional graphs were created with Matlab utilizing surface area and mass measurements in 3D mesh.

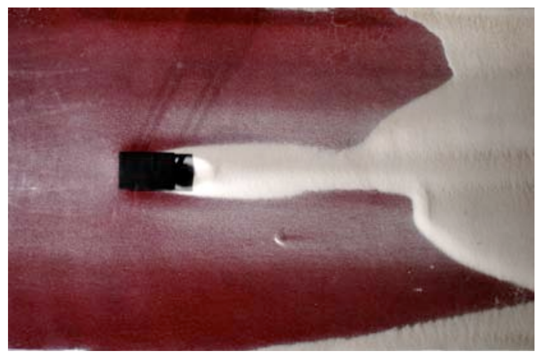

Figure 6. Deposition zone leeward of s/c from particles entrained in wind flow.

References: 1] Greeley and Iverson (1985), 2] Greeley et al., (2005), JGR in press.