AEOLIAN BIODISPERSAL OF TERRESTRIAL MICROORGANISMS THROUGH SALTATION BOMBARDMENT. L. K. Fenton[1], J. R. Marshall[1], A S. Schuerger[2], J. K. Smith[3], K. L. Kelley[2], [1]SETI Institute, 339 Bernardo Ave., Mountain View, CA, 94043, USA (lfenton@seti.org), [2]Univ. Florida, Merritt Island, FL, USA, [3]Arizona St. Univ., Tempe, AZ, USA.

Introduction: Contamination of Mars by terrestrial microbiota (i.e., forward contamination) is a major concern for planetary protection efforts. Despite extensive decontamination of spacecraft before launch and the extreme environment of interplanetary space, viable terrestrial microorganisms likely have already arrived on Mars as stowaways on landed spacecraft [e.g., 1,2]. On the Martian surface, these stowaways experience harsh environmental conditions, most notably ultraviolet irradiance and extreme desiccation [e.g., 3,4]. However, a growing body of research indicates that some hardy organisms can survive limited exposures in martian soils [e.g., 5,6]. A key knowledge gap is an understanding of environmental removal and transport of terrestrial microbes from landed spacecraft on Mars [7], which may determine the potential for survival and propagation of these microorganisms.

The abrasive nature of saltating sand can disrupt spores [8], removing them from surfaces through aeolian abrasion [9]. If microbial removal rates are known, numerical models can simulate their dispersal in the Martian environment, assessing the likelihood of forward contamination. Saltating grains on Mars impact with a wide range of kinetic energies (and thus grain speeds) [e.g., 10, 11], but it is not yet known what minimum impact speeds are sufficient to dislodge or crush microbes.

Here we describe experiments to measure the spore removal rate through impact by sand grains as a function of grain speed and impact angle.

Method: Microbe-laden targets were sandblasted by sand moving at one of four speeds, impacting at one of three angles (**Tab. 1**). Targets were then inspected with a scanning electron microscope (SEM) to quantify spore removal and damage.

Samples: Six microbial sample holders, each containing four ~2x3 cm 6061-Aluminum coupons, were applied with killed spores of *Bacillus subtilis* HA101 (**Fig. 1**). Each sample holder represents one set of tests replicated three times, plus a control that was left untouched.

Impacting sand: Rounded quartz sand was sieved to a diameter range of 106-151 µm. At saltation speeds, rounded grains produce Hertzian contacts on impact, with a predictable diameter related to grain size and speed, as well as elastic properties of the impacting grain and target surface [12]. It is within this contact area that impacting grains may remove or crush spores. To produce a uniform and complete degree of impact coverage from one set of tests to the next, we determined the probability that 99% of the target area would be hit by successive, overlapping impacts, accounting for both the size of the Hertzian contact and impact angle (**Fig. 2, Tab. 1**).

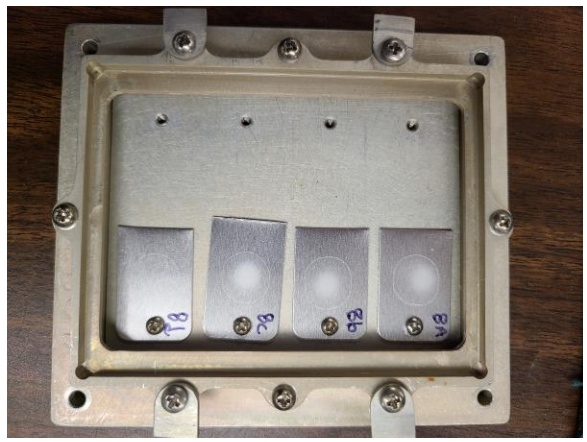

Figure 1. Sample holder containing four coupons applied with killed spores. Coupons 8a, 8b, and 8c have been subjected to saltation bombardment by grains moving at 2.4±0.2 m/s; 8d is a control.

Table 1. Set of tests run on each set of samples.

Set #	Grain speed	Impact angle	Grain mass
008	2.4±0.2 m/s	90°	3.61 g
004	5.3±0.7 m/s	90°	2.00 g
003	9.3±1.0 m/s	90°	1.25 g
007	12.4±1.3 m/s	90°	1.00 g
006	9.8±1.4 m/s	45°	2.34 g
011	9.8±1.4 m/s	30°	4.07 g

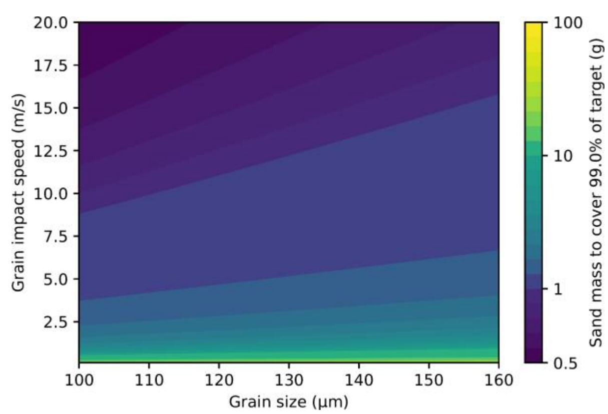

Figure 2. The amount of sand required to impact 99% of the target area, for quartz grains impacting on an aluminum surface at an impact angle of 90°.

Sand gun: A "sand gun" was developed as an alternative to wind tunnel tests, as it performs sand impacts against targets with a high degree of control of speed (~2-20 m/s to within ±~1 m/s) and impact angle (0-180° to within ~3°). Test targets (**Fig. 3**) were mounted on an adjustable stage that enables control of the impact site and angle.

The gun itself fires sand grains from a 5 mm bore tube using a jet of high-speed air generated by a small pump. Sand is drawn into the air jet by a 'gas-ejector (Venturi) effect'. The sand feed rate to the gun is controlled by impinging a gentle air jet onto a sand chamber, creating a small sand cloud that continuously falls into an open hopper that feeds into the sand gun barrel. Grain speeds were determined using high speed video obtained during each test (see example videos).

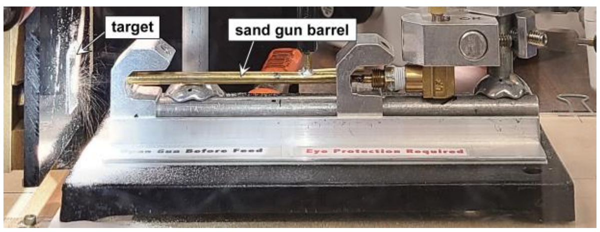

Figure 3. The lower portion of the sand gun, showing sand bombardment of coupon 008c. Sand was blown from right to left, exiting the brass bore tube and impacting on the target coupon.

Results: Initial results indicate that higher grain speed impacts either remove or crush all spores save for those that remain protected by the texture of the aluminum surface (**Fig. 4b**). At slower grain speeds, the aluminum surface is less damaged, and ~70% of the spores remain (**Fig. 4c**). However, many of the spores are crushed even by slow impacts.

Conclusions: This abstract represents a work in progress. Early results suggest that even slow grains in saltation can dislodge or crush *B. subtilis* HA101 endospores. Further work will more fully quantify spore removal rates for 99% impact coverage as a function of grain speed and impact angle.

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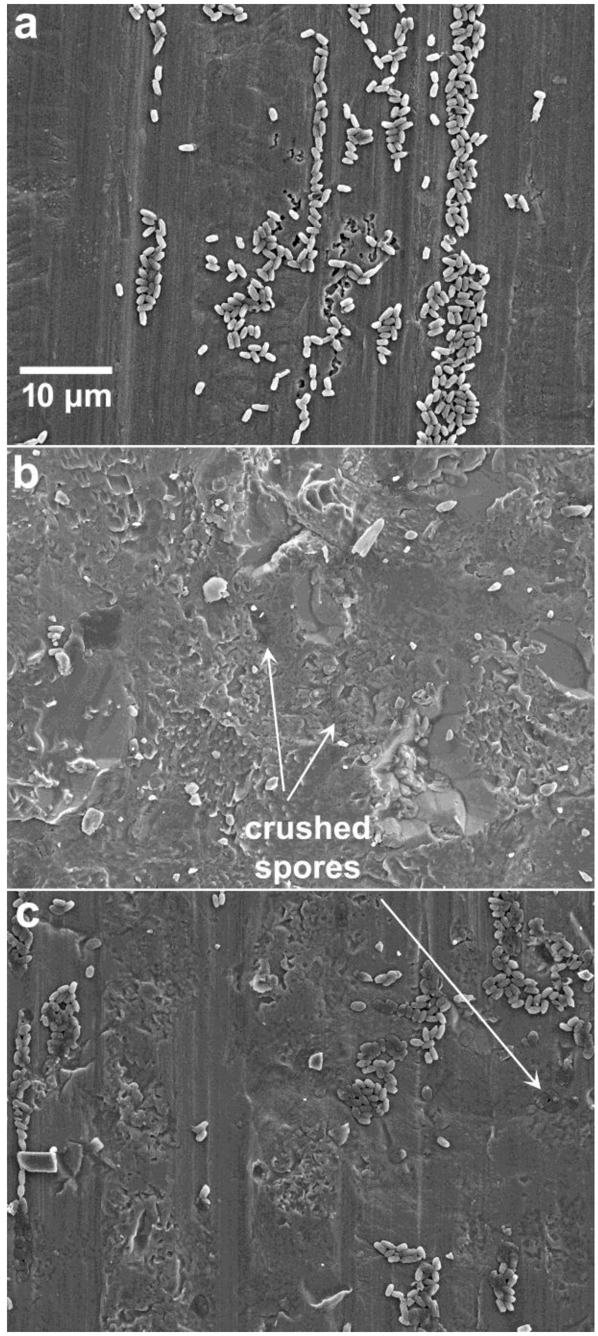

Figure 4. SEM images from 3 coupons: (a) killed* B. subtilis *spores (control), (b) ~100% spore removal by 12.4±1.3 m/s impacts (set 007), and (c) ~30% spore removal by 2.4±0.2 m/s impacts (set 008).