EXAMINING THE UPPERMOST SURFACE OF THE LUNAR REGOLITH. S. K. Noble[1], [1]University of Alabama Huntsville / MSFC, Mail Code VP62, 320 Sparkman Dr., Huntsville AL 35805 Sarah.K.Noble@nasa.gov

Introduction: Understanding the properties of the uppermost surface of the lunar regolith is critical as it is the optical surface that is probed by remotely-sensed data, such as those acquired on recent and current missions (e.g. M^3, LRO). Lunar exploration crews and their systems will also have direct contact with this surface, therefore understanding its properties will be important for dust mitigation and toxicology issues. Furthermore, exploring the properties of this uppermost surface may provide insight into conditions at this crucial interface, such as grain charging and levitation [1].

Background: The Apollo16 Clam Shell Sampling Devices (CSSDs) were designed to sample the uppermost surface of lunar soil [2]. The two devices used Beta cloth (69003), similar to the outer layer of Ap space suits, and velvet (69004) to collect soil from the top ~100 and ~500 µm of the soil, respectively. Due to aspects of the sampling design and operational method, little material was collected (Fig. 1) and as a result little research has been done on these samples to date.

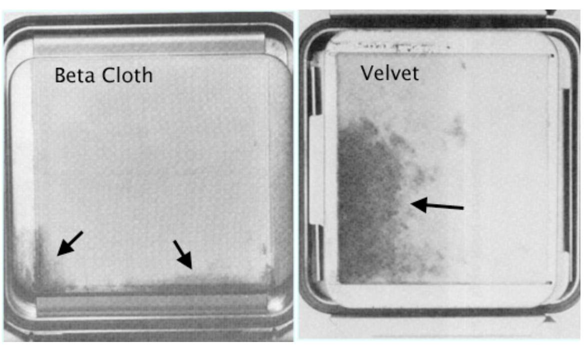

Figure 1. Apollo 16 Clam Shell Sampling Devices. Black arrows indicate the collected material.

Our initial studies collected material that had fallen off the fabrics and was residing inside the sample containers [3]. However, this material was found to be size fractionated, i.e. larger grains preferentially fell off, and it was therefore considered insufficient to provide a representative picture of the uppermost surface. Recently, samples obtained directly from the Beta cloth were examined, and although still fractionated, these samples provide a unique glimpse into the undisturbed soil exposed at the lunar surface. Initial results suggest that the surface may contain a higher proportion of fine grains (<2 µm) than the bulk soil. Future work will add samples from the velvet fabric to our dataset.

Methods: Samples were pulled from the Beta cloth (69003) using carbon tape on aluminum stubs and characterized by scanning electron microscopy (SEM). For comparison, characterization was also performed on the <250 µm size fraction of scoop sample 69941 that was collected at the same location, just centimeters away from the CSSDs. The scoop sample material was thoroughly mixed and deposited on a carbon tape substrate. SEM images were taken of both samples at the same resolution and analyzed using Image J software to determine the size distribution.

Initial Results: Representative SEM backscattered electron images and size distribution data for the Clam Shell Beta cloth and the 69941 scoop samples are shown in Figure 2.

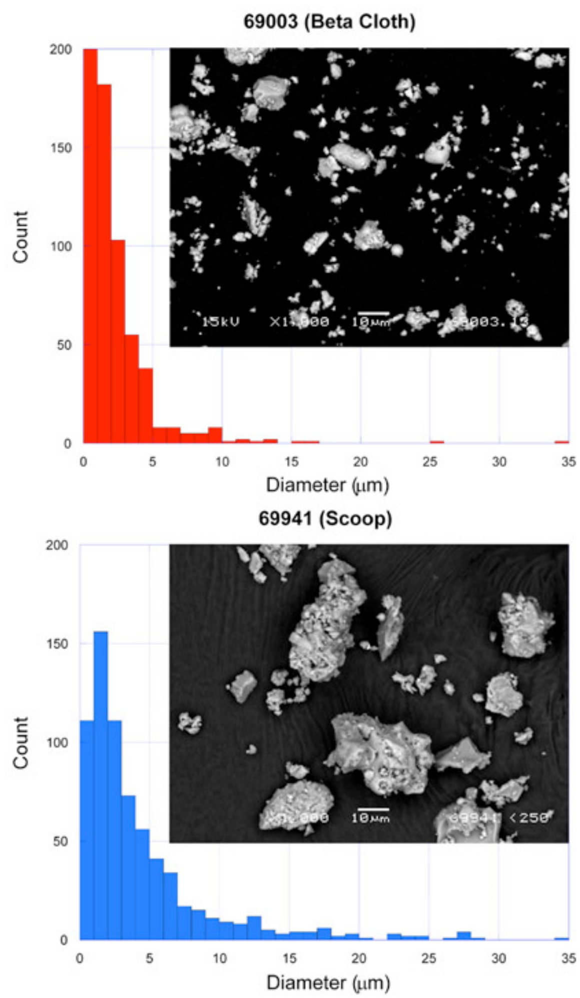

Figure 2. Size distributions for the Beta cloth sample and the associated scoop sample.

Our initial reconnaissance SEM work showed the Clam Shell Beta cloth sample to contain significantly more <2 µm grains compared to the scoop sample.

Further Testing: Because we were concerned that this finding may reflect several sources of sampling bias we performed additional tests on the grain retention properties of the Beta cloth. There is, for example, a sharp fall off in the number of grains larger than ~5 μm, which is likely due to larger grains preferentially falling off during transport and handling during the mission, or possibly never being picked up by the fabric in the first place. This is consistent with our initial studies of the material collected from inside the sample containers [2], which was noticeably depleted in <5 μm grains, as well as our study of space suit fabrics (also Beta cloth) which also showed a concentration of fine-grained material [4].

Because of these suspected biases for larger grains, we focused on the distribution among the finest grains using high magnification images (1000x). As a consequence, no grains larger than ~35 μm were included, but larger grains were present in both samples, with the largest grain observed on the Beta cloth being about 75 μm in diameter. The scoop sample contained many grains into the 100 and 200 μm range.

One final concern is that Beta cloth itself (composed of Teflon-coated fiberglass), may shed material when the carbon tape is pulled off. To explore these biases, samples were prepared using JSC-1a soil simulant. Beta cloth was gently pressed into JSC-1a and then pulled off with carbon tape (sample 1). The Beta cloth was then vigorously tapped and shaken to remove the loosely adhering material and samples were collected from both the remaining material (sample 2) and the material which had fallen off (sample 3). Finally a sample was produced by pulling carbon tape from "clean" Beta cloth with no JSC-1a (sample 4).

The first simulant sample demonstrated that grains from submicron to several tens of microns do indeed stick to the Beta cloth. The Beta cloth however, picked up few grains greater than ~80 μm, which is consistent with the largest grain on the Clam Shell fabric being about 75 μm. Samples 2 and 3 confirmed that larger grains preferentially fall off when the Beta cloth is disturbed (tapped) (Fig. 3), although several large grains did remain stuck to the fabric.

The carbon tape pull from the "clean" Beta cloth shows bits of Teflon and rods of fiberglass can be shed from the sample (Fig 4). Salts and other contaminants were also identified through EDX analysis, owing to the non-pristine nature of the fabric swatch used. There are particles present which are below the resolution necessary for EDX analysis (~1-2 μm); these might also be contaminants, or possibly fiberglass dust. EDX analysis of 69003 found no non-lunar particles down to the ~1 μm limit of the EDX.

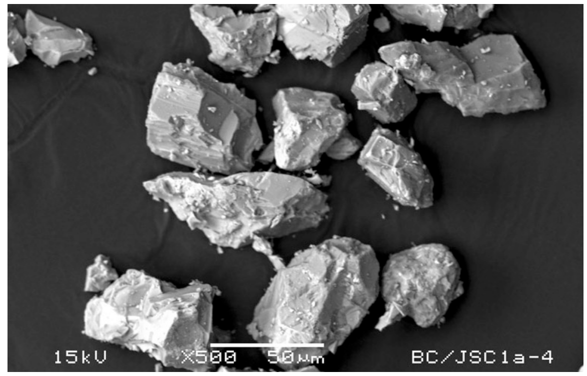

Figure 3. From sample 4, grains of JSC-1a that fell off of the sample which was tapped.

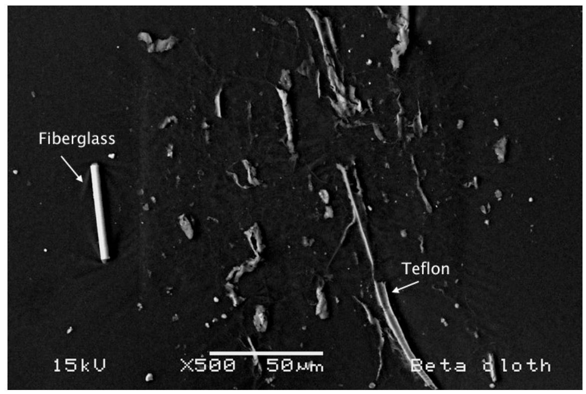

Figure 4. Carbon tape pull off of "clean" Beta cloth.

Conclusions: Initial results suggest that ultrafine (<2 μm) particles dominate the uppermost lunar surface, however, there are biases introduced by the sampling method that must be carefully considered. While larger grains were almost certainly preferentially lost from the Beta cloth, fines grains (<5 μm) do not appear to have been significantly fractionated and still indicate a significant enrichment in grains <2 μm vs. the scoop sample. Further analysis is necessary to determine whether material shed from the Beta cloth is contributing to the results, though to date, no non-lunar materials have been identified in 69003.

The Clam Shell samples are not perfect, but they represent the only attempt made to sample the uppermost lunar surface. It is clear that better sampling methods are needed for future missions to address this problem, however, in the meantime, we will continue to try to get the most information we can out of the available samples.

References: [1] Wendell W. W. and S. K. Noble (2010) *LPSC XLI (this volume)*. [2] Horz F. et al. (1972) *Apo 16 Prelim Sci Report*. [3] Noble S. K. et al. (2007) AGU Fall Mtng 2007, ab #P44A-06. [4] Christoffersen R. et al. (2009) NASA Technical Publication #21476.