CHARACTERIZING PHYSICAL AND ELECTROSTATIC PROPERTIES OF LUNAR DUST AS A BASIS FOR DEVELOPING DUST REMOVAL TOOLS. P.E. Clark¹, S.A. Curtis², F.A. Minetto², M. Moore², J. Nuth² ¹Catholic University of America (Physics Department), ²NASA/GSFC, all at NASA/GSFC, Greenbelt, MD 20771, Pamela.E.Clark@NASA.gov.

The Dust Problem:
The characteristic persistent adhesion and abrasion of lunar soil particles when interacting with surfaces introduced into the lunar environment resulted from the combined electrical and physical properties of the grains. These properties caused the particles to be almost impossible to dislodge by physical means alone a result of a combination of properties. Particles reentrant surface structure causes them to physically ‘hook on’ like velcro and be easily charged and electrostatically attracted. Here we present the results of our ongoing efforts to design and develop tools to remove dust based on our characterization of the nature of dust particles and forces affecting them.

Surface to Volume Ratio and Size Frequency Distribution: The high SVR of lunar grains relative to smooth spheres of equivalent size has been quantitatively established for bulk soils (Carrier et al, 1991). The exact nature of this relationship as a function of grain size is unknown, particularly for lunar fines (<20 microns) which, although representing only 20 to 30% of lunar soil, are thought to pose the greatest hazard. The relationship between surface and volume in lunar dust grains as a function of grain size is recognized as a characteristic that controls the interaction between lunar dust and its environment, and makes it dangerous to machinery covered with it or humans inhaling it. If a sizable portion of dust grains have diameters in the range of 3 microns or below, they pause the serious risk of silicosis.

Electrostatics: Field/charged particle/dust interactions on the Moon are complexly dependent on environmental conditions and compositional, mechanical, magnetic or electrical particle properties (e.g., Criswell, 1973; Berg et al, 1976; Sicafoose et al, 2001; Stubbs et al, 2005). Foundational simulation of dust behavior in fields has focused on individual grains (e.g., Horanyi et al, 1998;Cheng et al, 2002). Recent work (Immer et al, 2006) indicates that dust collectively responds to charge variations on an electrostatic mesh surface and can be collectively controllable with an electrostatically based approach. All of

Figure 1: SEM photo of grains comparing surface morphology of Lunar Dust (left) and simulant (right) at the same scale illustrating difficulty of creating a simulant with comparable morphology.

Figure 2 Simulant BET SSA measured as a function of size fraction. Icons represent three sets of measurements to generate errorbars. For comparison, see close packed sphere and bulk lunar soil data (Carrier et al, 1991), indicating that simulant like lunar soil is rougher than spheres of the same size and specific gravity, and has an SSA smaller or equivalent to lunar soil even when compared to a lunar larger particle size fraction.

Figure 2 Normalized frequency and cumulative frequency distributions for lunar simulant at t=0 (green, right) and at t=60 seconds (blue, left) when only the finest fraction remains in solution. Note the presence of an ultra fine component at or below 3 microns.

Based on controlling of surface potential, that we present here.

Characterizing surface to volume ratio and size frequency distribution for lunar fines. We are systematically measuring surface to volume ratio (SVR) throughout the grain size distribution but particularly for the smaller fractions (<50m) of both lunar soil and simulant to establish a basis for understanding the behavior and potential health risk associated with lunar dust (Figure 1). Grain size distribution will affect the protocols used to operate an electrostatically based dust removal device. If grains typically form clumps >3 microns in size, as some of our early SEM images suggested (Figure 2), the human health risk from dust exposure (silicosis) is minimal, and the dust mitigation
campaign can focus on keeping equipment clean and preventing dust from going further than the airlock environment. Prevalence of micron-scale grains, as indicated by our most recent results with the Horiba laser scattering particle size distribution analyzer (Figure 3), more frequent and extensive cleaning of longer duration.

The Plasma-based Solution: We are in the process of developing SPARCLE (Space Plasma Alleviation of Regolith Concentrations in the Lunar Environment), a NASA patent protected electrostatically-based tool for dust mitigation. SPARCLE leverages decades of spacecraft operations which successfully controlled spacecraft potential with charged particle beam technology (Comfort et al., 1988). The SPARCLE tool works by the same principles, attracting and removing dust from surfaces entering the airlock through the use of particle beams, and then disposing of dust in a proper receptacle through the use of oppositely charged particle beams to control the potential of the tool’s surface. The SPARCLE development team is already partnered with the lunar habitat airlock design team at JSC who see tremendous potential for SPARCLE to provide lunar dust removal from any object in the airlock with minimal expenditure of resources.

Ongoing Developments: The electron and ion gun development has been completed(Figure 42), and we are now designing the packaging needed to complete the first SPARCLE model so that we can test its ability to attract dust with from a variety of introduced surfaces with a range of positive and negative potentials in a simulated airlock environment under a variety of temperatures and pressures, thereby establishing a proof of concept.

We are preparing to determine the most effective protocols for varying the range and timing of the particle guns outputs in order to collect dust.

Design Strategy: The final design for SPARCLE will be based on the results of the airlock simulation tests. Our present concept (Figure 5) involves using a cleaning wand with internal electron or ion guns to control its surface potential and generate a setting that will predictably attract dust under the ambient conditions. We are experimenting with special coatings to determine which ones facilitate removal from soft (e.g., spacesuit) and hard (e.g., walls) surfaces. The dusty wand will be cleaned by being thrust into a receptacle with an opposite charge to electrostatically remove dust from the wand. Finally, we will construct a laboratory model of the dust removal based.