**Introduction:** Triboelectric charging is the exchange of electric charge that occurs when two objects contact or are rubbed together. Regolith on the lunar surface may become tribocharged during exploration operations including astronauts walking [1], wheel operation, and drilling or construction activities. Because there is no appreciable lunar atmosphere, the charge accumulated on grains can only be dissipated through contacts with other surfaces or the local plasma environment. Charged regolith grains may stick to spacesuits or vehicle surfaces, obscuring optics and causing mechanical abrasion.

In order to properly assess the risk of the adhesion of tribocharged regolith, it is necessary to accurately predict the amount of charge that will accumulate on regolith particles due to vehicle operations. However, the tribocharging of dielectric grains (like regolith) is currently very poorly understood. In fact, even the charge carrier (electrons vs. adsorbed ions) remains uncertain [2,3,4]. We have developed an experimental teststand that allows us to measure the electric charge of individual grains, following tribocharging in vacuum (as is necessary to simulate the lunar environment). We present the design of this experimental testbed, results showing the variation in charge levels as a function of mass fraction, and planned future investigations.

**Experimental Teststand:** Our experimental teststand design is based on that of [5] and described in [6]. Figure 1 shows the teststand, which is placed in a 24”x24”x30” vacuum chamber and evacuated to 30 microTorr prior to testing. The granular mixture of interest is loaded into a canister, the interior of which has been permanently coated in grains. Any granular mixture (size distribution, material properties) can be used, but the results present here were obtained using spherical, zirconia-silica beads (106-150 microns and 180-300 microns). The canister is attached to a speaker at the top of the test stand. The speaker is activated for approximately 5 minutes to thoroughly shake the grains, causing tribocharging to occur. Then the bottom of the canister is opened to allow a stream of grains to fall down between two electrodes (separated 60mm). One electrode is biased to 4kV, causing a lateral electric field. As the charged grains fall, they are accelerated laterally. The motion of the grains is observed using a high-speed camera (PCO Dimax CS3) that is also dropped when the canister is opened. Dropping the camera allows the grains to stay in frame longer by minimizing the relative vertical velocity of the grains. Image processing is conducted to calculate the grain size and lateral acceleration from the collected images. The charge on a grain is calculated from the grain’s mass, grain’s lateral acceleration and the electric field between the electrodes. The entire experiment, from grain shaking to camera impact is conducted in an evacuated vacuum chamber to minimize the effects of adsorbed water molecules on the results.

**Charging Results:** Figure 2 shows the measured charge-to-mass ratio of grains in a mixture where the mass of the large grains is four times larger than the mass of the small grains ($m_{\text{small}}/m_{\text{large}}$). There are several interesting results in Figure 2. Firstly, the small grains are noted to charge positively, with the large grains charging negatively. This is the opposite of many experimental tests [7]. Additionally, several possible charge transfer models were fitted to the data. The initial charge carrier density on the grains controls the fit of the model to the data. The majority of the models require a positive charge carrier (indicated by a negative $\sigma$ in Figure 2). It has been previously hypothesized that tribocharging might be caused by the transfer of adsorbed ions, rather than electrons [4]. Our experiments predict a positive charge carrier despite tribocharging in the absence of an atmosphere (experiments are conducted at 30 microTorr). Our experiments point towards positive charge carriers across a range of grain size distributions.

**Path Forward:** As there is no model that strongly matches the observed charging across a range of grain size distributions, we plan to characterize the sensitivity...
of the observed tribocharging to additional experimental parameters (e.g., duration of vacuum exposure, duration of shaking). We also plan to incorporate the ability to bake-out grains in vacuum, in order to further reduce the amount of adsorbed water on the grains. These additional experiments will inform our understanding of the charge exchange mechanism. Additionally, as part of LEADER, a NASA SSERVI node lead by NASA Goddard Space Flight center, we plan to incorporate an existing tribocharging model into LIGGGHTS, an open-source, soft-sphere discrete element method (SSDEM) code that models the interactions of hundreds of thousands of grains. We plan to experimentally investigate the tribocharging of granular mixtures containing different materials. LIGGGHTS simulations informed by experiments will enable predictions of tribocharging as a result of exploration activities on the Moon.

![Figure 2](5028.pdf)

Figure 2. Measured charge-to-mass ratio of for a mixture of spherical zirconia-silica grains. Several possible charging models are also fitted to the data, with varying required initial charge densities.

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