LUNAR REGOLITH , SOIL, AND DUST MASS MOVER ON THE MOON.

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Returning humans to the Moon in the near-future necessitates design and construction for many engineering projects for lunar exploration and In-Situ Resource Utilization (ISRU) activities. One factor common to all activities on the Moon is the ever-present, sharp, abrasive, glassy dust – i.e., the <20 µm portion of the lunar soil consisting of ~20 wt% of the soil. Various ISRU activities will entail large-scale gathering and transport of lunar regolith, but all conventional means will launch huge amounts of dust and produce numerous deleterious effects – e.g., as it falls back covering installations such as solar cells. The <5 µm portions can remain suspended in electrostatic levitation around the Moon – possibly negating effective astronomy [1]. Can this dust portion of the soil be kept from having such show-stopping effects? This is the subject of our study.

The lunar regolith is unique in its chemical and physical nature, providing the potential for greatly aiding the establishment of lunar bases [2]. Because of the presence of nanophase metallic Fe (as in an Fe nail) in the impact-produced glass, the typical "well-graded" soil can be sintered and melted into roads, landing pads, radiation covers, structural components, etc., with the application of microwave energy [3]. This will obviously aid in the dust abatement. Suspended dust, however, creates a plethora of problems, many experienced during the Apollo Missions, as discussed by Taylor et al. [2]. Therefore, it is imperative to develop methods of handling and collecting lunar regolith that mitigates against the possibility of stirring up too much dust into the lunar "atmosphere."

We have devised a potential scheme to minimize the dust problems, created by mining and transportation, and utilizing the soils ferromagnetic properties due to the presence of nanophase metallic Fe (np-Fe) in the ~40-50% impact glass of the lunar soil. The presence of 70-90% agglutinitic impact glass in the dust makes this portion of the soil capable of being attracted by a simple magnet [2]. The presence of this np-Fe bearing glass in larger agglutinates also renders a magnetic susceptibility to the larger grain-sized soil particles. It is possible to effectively "suck-up" the regolith using magnetic fields. This can be done in a similar fashion to the way maglev trains and coil guns (or gauss weapons) work. These two developing technologies ***use consecutive electromagnets to pull an object along.*** The largest advantage of these technologies is that there are no moving parts in these devices. Most importantly, such an attracting system applied to the Moon would not only pull the soil along, but even more importantly, effectively capture the dust as well.

The operation of this "Lunar Soil Magnetic Collector" (LSMAC) is conceptually simple (Fig. 1). This device consists of a series of wound coils individually controlled to generate magnetic fields in sequence. Soil is picked up by a 'nose coil' and pulled through the center of the coil. As this moving soil approaches this first coil, the coil is powered down, and the next coil in the sequence is powered up and attracts the particles of soil further into the tube. As the soil approaches this second coil, it too is powered down, and the next coil in the sequence is powered up to 'tractor' the soil further down the line. **This process of turning coils on and off continues in a "caterpillar/millipede effect", moving the soil particles along this electromagnetic-conveyor belt [4].**

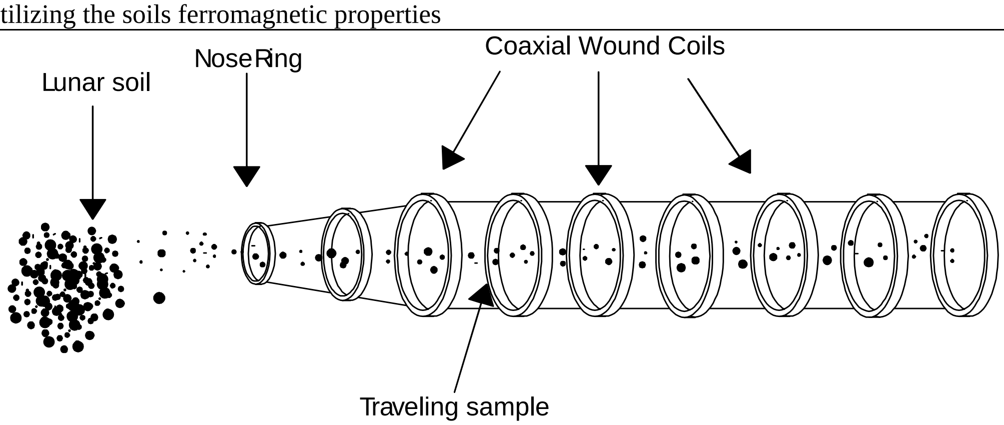

Figure 1. Diagram of our "Lunar Soil Magnetic Collector". Coaxial rings are sequentially powered up and down in a rippling effect to move ferromagnetic lunar soil to the right.

Conceptually a lunar surface-mining operation might use this device to gather and transport soil (+dust) across great distances to processing plants. One possibility is to have a 'Trunk Line' that is capable of large magnetic fields and moving large amounts of material with several flexible feeder lines into it (Figure 2). The feeder lines would branch off of the Trunk Line pulling in material from the surrounding area. This allows for several areas to be excavated simultaneously, and as the regolith is exhausted in one large area, the Trunk Line can be extended to new areas. In this way, large amounts of regolith can be gathered to a central location without endangering surrounding equipment or people with high concentrations of suspended dust [4].

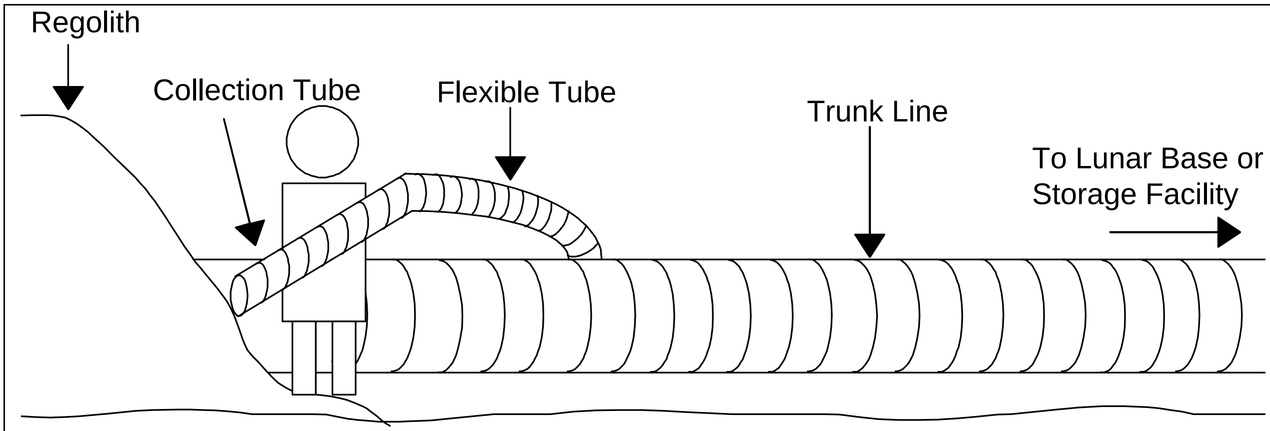

Figure 2. Conceptual drawing of possible method of collecting lunar soil using the "Lunar Soil Magnetic Collector" (LSMAC). The astronaut/robot uses a slightly flexible coil 'sucker tube' to collect soil, which is in turn fed into a "Trunk Line" that is capable of higher flow rates, these trunk lines are also movable. Multiple collection branches would feed into one trunk line.

To make the LSMAC a reality requires several issues to be overcome. First, the magnetic fields must be sufficiently strong as to attract the soil from a reasonable distance and accelerate it to a speed sufficient to carry it to the next coil through momentum. In the case of the Moon, this is eased somewhat by both the absence of atmosphere and the 1/6th G gravity (easier to pick up vertically, and less friction in horizontal transport). Second, it will be necessary to determine the on-off timing needed to energize and relax consecutive rings, in order to keep a continuous flow of soil through the tube.

Current-generation prototype LSMAC coils have sufficient power to attract lunar dust distances of the order of the coil width, allowing for transport between coils. Fields on the outside of the coils are contained by surrounding the outer portion of the coils with an Fe 'cowl' that directs the magnetic fields to the inside of the coils, eliminating the problem of dust being attracted to the outside of the LSMAC. This cowl also helps to boost efficiency, lowering the power requirements needed to draw the lunar soil. Currently timing of the coils is controlled by a simple timing circuit. Future generations would be controlled by a closed feedback-loop to maintain optimal efficiency.

The mitigation of the inherent dust on the Moon is one of the major environmental challenges that we face in returning to the lunar surface. However, this dust can be of great use in making life on the Moon possible. It is a matter of perspective and attitude that can change this liability and curse into an invaluable asset and resource. Indeed, besides the microwaveability of the soil and dust, the surfaces of theses grains contain abundant solar-wind particles, providing a potential source of hydrogen for rocket propellant and combined with oxygen, water for humans. By using properties that are inherent in the lunar soil, it is possible to eliminate the potential hazard of having this dust suspended above the lunar surface.

References: [1] Stubbs, T.J., et al., 2005, Proc. Lunar Planet. Sci. Conf. 36th, 2277-2278. [2] Taylor, L.A., et al., 2005, AIAA, 1st Space Explor. Conf., Orlando, FL, CD-ROM. [3] Taylor, L.A., and T. Meek, 2005, Jour. Aerospace Engr. **18,** 188-196. [4] Taylor, L.A., and B.C. Eimer, 2006, SRR VIII.