INTEGRATING BENEFICIATION INTO REGOLITH CONVEYANCE SYSTEMS. P. T. Metzger[1], J. G. Mantovani[1], I. I. Townsend[2], and R. P. Mueller[1], [1]NASA Granular Mechanics and Regolith Operations Lab, NE-S, Kennedy Space Center, FL 32899, Philip.T.Metzger@nasa.gov, [2]ASRC-Aerospace, Kennedy Space Center.

Introduction: Regolith conveyance includes hauler/dumpers, hoppers, augers, pneumatic transport subsystems, and other elements. The features of the conveyance and the time the material stream spend in conveyance may be used synergistically to perform beneficiation, pre-processing (such as heating), and other tasks, thus reducing the mass and complexity of the overall ISRU system. Since the cost of spaceflight is largely driven by the cost of launching mass out of Earth's gravity well, the conveyance system should be leveraged in this way to the maximum extent.

Beneficiation in Excavators and Hoppers: Excavation systems can perform minimal beneficiation by using grizzlies or screens to filter out gravel or rocks over a certain size before the regolith enters a hopper. In recent lunar analog field tests this has been omitted, performed instead by hand using sieves before excavating and transporting the soil to a hopper. Screen filters on excavator buckets or hopper inlets can be enhanced by vibration. The gravel and rocks can be retained for building roads, landing pads, berms, or structures, or for scientific evaluation. Pneumatic excavation systems used in lieu of traditional mechanical excavators provide additional beneficiation, as discussed below with pneumatic conveyance. Hopper discharge provides a second opportunity for beneficiation. Crushers or a next-level size sorter may operate on the discharge stream. Lunar soil is superparamagetic due to the nanophase iron in the surface patina, which dominates magnetic response for the fines fraction of the soil. For larger particles 90 – 150 μm, the diamagnetic behavior of the minerals dominates over the superparamagnetic response of the patina, and beneficiation splits can be made [1]. The finest particles may be pulled out of the soil via the strong paramagnetic response for uses where fines are advantagous, such as sintering into bricks [1]. Putting magnetic beneficiation into a hopper gravity discharge stream may be synergistic because pulsed electromagnetics can clear jams at the hopper orifice as demonstrated by recent experiments in our lab, allowing commonality of hardware. These magnetic discharge experiments were performed using nanophase iron mixed in water with lunar soil simulant NU-LHT-2M and then dried, as shown in Fig. 1

Augers and Other Mechanical Conveyance: In industry, grizzlies and screens are used in mechanical conveyance paths to remove oversized materials. Vibrated screens and washers are commonly used along conveyors, and washers may be integrated with screws. Magnets may pull out ores or metals. On the Moon or Mars we have not identified a need for washing or its analog. Electrostatic and magnetic beneficiation may work better in freefall or pneumatic conveyance. However, augers are used in many of our recent designs for hopper discharge, transport from hopper to processor, and transport within processors, and we should continue seeking to leverage those portions of the material stream.

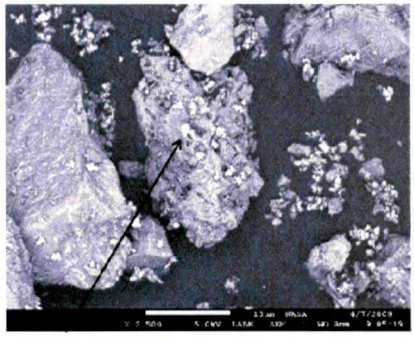

Figure 1. Arrow indicates nanophase iron particles clinging to NU-LHT-2M soil grain.

Pneumatic Conveyance: Pneumatic conveyance is particularly useful for performing beneficiation tasks. At its terminus, the regolith stream is separated from the working gas using cyclones in several stages, which separate the increasingly finer fractions. Thus, size separation is provided automatically as demonstrated in recent experiments in our lab and in reduced gravity flights. Size sorting has also been integrated successfully into pneumatic excavation by Honeybee Robotics and tested in reduced gravity flights [2]. In that case, the sizes were separated ballistically due to the size-dependent moment transfer with the gas. Electrostatics and magnetics are also naturally integrated into pneumatic subsystems within the two-phase flow, or in the cyclones, or at their outlets. Tribocharging can be provided and controlled in the pneumatic subsystem so the material stream enters the beneficiator already charged. Pre-heating, some chemical processing, and/or volatile extraction may be performed by judicious choice of the pneumatic subsystem's working gas.

References: [1] L.A. Taylor et al, AIAA 2005-2510, 1st Space Exploration Conf., Orlando, FL, Jan. 30 – Feb. 1, 2005. [2] K. Zacny et al, AIAA-2008-7824, Space 2008, San Diego, CA, Sept. 9-11, 2008.