Vertical Lunar Regolith Conveying as a Flight Experiment in Simulated Lunar-Gravity. J. G. Mantovani[1], A. D. Olson[2], B. Kemmerer[1], A. G. Langton[1], and J. R. Gleeson[3], NASA KSC, [1]UB-E, [2]UB-G, and [3]KSC-LASSO, Kennedy Space Center, FL 32940. (Email: James.G.Mantovani@nasa.gov, Aaron.D.Olson@nasa.gov, Beverly.Kemmerer@nasa.gov, Austin.G.Langton@nasa.gov, and Jonathan.R.Gleeson@nasa.gov).

Introduction: Regolith conveying will be an essential task for supplying regolith feedstock to In-Situ Resource Utilization (ISRU) reactor systems (Fig. 1) for regolith processing on the Moon and Mars [1, 2]. The Vertical Lunar Regolith Conveyor (VLRC) is a technology being developed at NASA Kennedy Space Center (KSC) as a regolith transport task for the GCD ISRU FLEET project led by NASA Glenn Research Center (GRC).

Single test loop versions of the VLRC are also being developed at NASA KSC as a technology demonstration for a flight experiment. The NASA Flight Opportunities program selected the VLRC for a technology demonstration opportunity on a future Blue Origin New Shepard suborbital launch vehicle to study regolith transport physics in a relevant environment in a vacuum chamber under simulated lunar gravity conditions in order to advance its technology readiness level (TRL) for future space applications.

The VLRC system (Fig. 2) includes four primary subsystems to achieve the objectives of the lunar gravity (Lunar-G) flight experiment. (1) An eccentric vibratory conveyor stack to convey regolith particles consisting of three single-loop helical surface conveyors (Fig. 3) with each actuated by two vibratory motors that vibrate in unison. One of the three single-loops contains a 0.8°-3.1° inclined helical path and the other two contain a 1.6°-6.2° incline. (2) A stick-slip conveyor stack to convey regolith particles consisting of three single-loop helical surface conveyors with each actuated by the same motor to move in unison in a stick-slip motion. One of the three single-loops contains a 0.8°-3.1° inclined helical path and the other two contain a 1.6°-6.2° incline. (3) A regolith containment system to contain the regolith in each single-loop track during launch before the start of the experiment using containment caps that will be lifted in unison at the start of Lunar-G. (4) COTS cameras will record the motion of regolith and tracer particles. Post-flight analysis of the videos will be used to determine convey speeds and flow rates. The VLRC experiment will use the well-known technique of Particle Image Velocimetry (PIV) image analysis to determine the velocity of tracer particles entrained in the regolith flow. This velocity will be used to calculate the mass flow rate of the regolith being conveyed.

Additional features of the Lunar-G VLRC experiment include: (1) Nominally, 15 grams of granular mineral material per track will be used consisting of particles of diameter <1 mm. These materials include lunar highlands regolith simulants and non-pristine Apollo 14 regolith samples along 2 or 4 tracks per conveyor stack depending on availability. (2) Vacuum chamber to house the experiment and maintain a stable pressure of 0.1 - 10 Torr during operation in Lunar-G. The chamber will be directly mounted to the Blue Origin payload locker. (3) COTS cameras and LED lighting to record particle motions along each of the twelve regolith conveying tracks.

Ground testing of the Lunar-G VLRC at NASA KSC and testing of the full-scale VLRC for the GCD FLEET project at NASA GRC and future flight testing in a simulated lunar-gravity environment will provide data on particle convey speeds and mass flow rates as a function of particle size and shape, frequency of oscillation needed to inform Discrete Element Modeling (DEM) of regolith conveying in a lunar gravity environment which will enable the VLRC's performance to be optimized for conveying regolith on the lunar surface.

This presentation will discuss the objectives and current status of the VLRC lunar-gravity flight experiment, including the types of granular mineral materials that will be conveyed.

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References: [1] Mantovani, J. G.. and Townsend, I. I. (2013) *J. of Aerospace Engineering*, *26*, 169–175. https://ntrs.nasa.gov/citations/20160003324 [2] Linne, D. et al. (2019) *10th Joint Mtg. of SRR&PTMSS, Golden, CO.* https://ntrs.nasa.gov/citations/20190029197

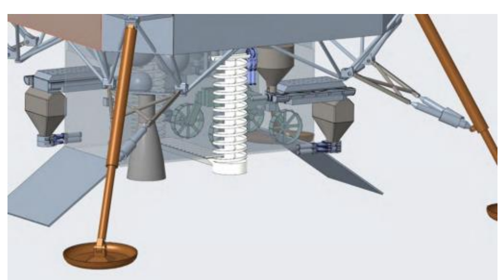

Figure 1: Concept for a spiral vibratory regolith conveyor that was illustrated in the 2019 NASA ISRU COMPASS study [2]. (NASA Public Use Graphic)

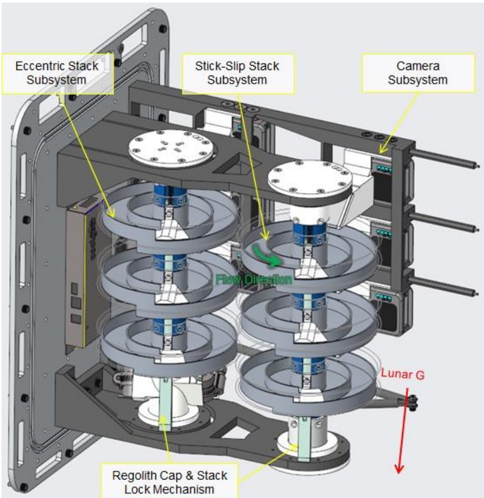

Figure 2: The two types of VLRC conveyor stacks (attached to the vacuum chamber base plate) are shown in their orientation when operating in a simulated lunar-gravity environment with each stack containing three single-loop helical surfaces. Six videos cameras record particle motions within each track per single-loop. (NASA KSC graphic)

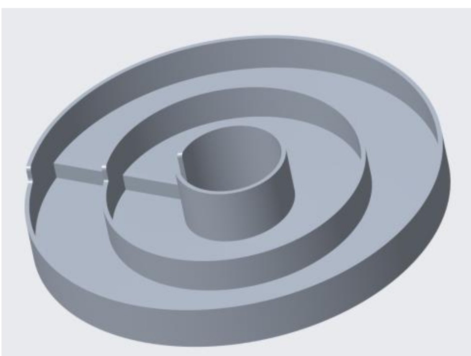

Figure 3: A VLRC single-loop helical surface includes inner and outer tracks for conveying two granular material samples separately but simultaneously as a function of path radius under the same conditions of motion actuation. (NASA KSC graphic)