Grain Shape Characterization as an Enabling Capability for Lunar Surface Technologies. K. M. Cannon[1], R. Garvey[2], and S. R. Deitrick[1,3], [1]Colorado School of Mines, Golden CO 80401, [2]Outward Technologies, Broomfield CO 80020, [3]NASA/Jacobs, Houston TX 77058. (Contact: cannon@mines.edu)

Introduction: Lunar regolith has unique physical and geotechnical properties compared with familiar granular materials on Earth, and most lunar simulants as well. Specifically, the cohesion,angle of repose, and compressibility are much higher, and flowability is much lower for lunar regolith than otherwise similar terrestrial-derived materials [1,2]. There is confusion in the literature about the relative importance of vacuum, gravity, and inherent grain characteristics in driving these differences. Here we emphasize the importance of characterizing grain types and shapes for designing and testing lunar surface technologies, including for rover mobility, material handling, soil sampling, and heat transfer analyses. We demonstrate laboratory capabilities and preliminary studies, and outline further work to better characterize and simulate lunar grains to reduce risks for surface activities.

The Importance of Shape: The flowability and geotechnical properties of a granular material are controlled by how grains behave when they try to move past one another: this includes the coefficient of sliding friction and the coefficient of rolling friction. In turn, these properties are influenced by particle size distribution, particle shape, and the cohesive force between two grains. Grain shape is not simple to define, and is usually described in terms of different 2D and 3D shape properties such as aspect ratio, roundness, and concavity.

Characterization Capabilities: We have commissioned and begun tests with a Microtrac SYNC particle analyzer that is located in-house at the Colorado School of Mines. The SYNC is a new type of instrument that combines tri-laser diffraction with Dynamic Image Analysis (DIA) to measure particle size distributions from 10 nm to 2 mm, and 30 different 2D and 3D grain shape characteristics from 5 μm to 2 mm for ~10^5 particles per sample. Fig. 1 shows data from synthetic agglutinate samples created by Outward Technologies, designed specifically to mimic the branching and dendritic morphologies of irregular lunar agglutinates.

We have a pending request through ExMAG to measure 4 Apollo soil samples of differing composition (highlands, mare), and maturity as a proxy for agglutinate content (immature, mature) using these capabilities. These measurements would characterize detailed shape properties for >500,000 lunar grains, study the changes in shape properties after compressive forces are applied to the regolith, and compare with lunar simulants that both do and do not have synthetic agglutinates.

Implications for Lunar Surface Technology: All technology that interacts with the lunar surface will involve regolith. This includes excavation and construction, ISRU, and mobility/access to extreme environments. The poor job that most existing simulants do in replicating geotechnical properties (angle of repose, flowability) is extremely concerning as activity ramps up for design and testing of new surface hardware. Further detailed studies of grain characteristics and efforts to better simulate them will serve as an important technical capability to better predict behaviors on the Moon.

References: [1] Calle C. I. and Buhler C. R. (2020) *Lunar Dust 2020, #5030*. [2] Carrier W. D. et al. (1991) *Lunar Sourcebook, Ch.9*.

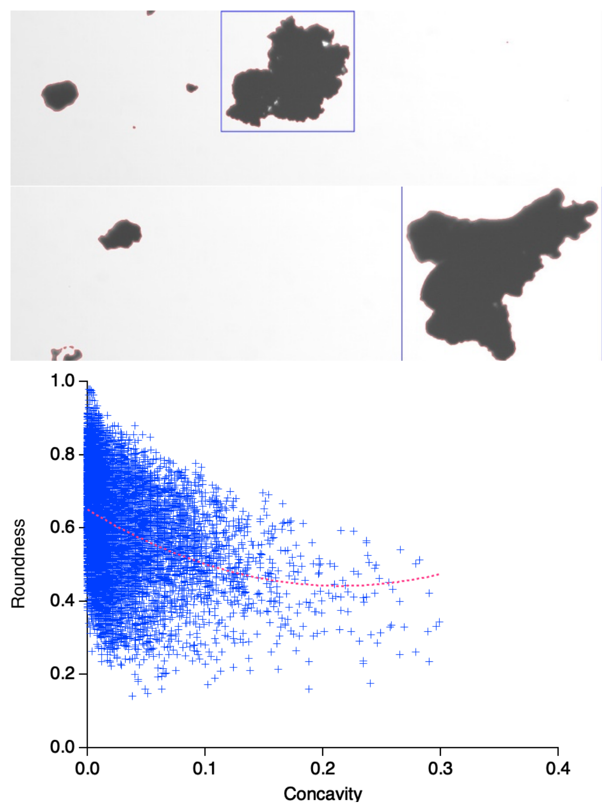

Fig. 1. Top: single grains of Outward Technologies synthetic agglutinates imaged using DIA on the Microtrac SYNC. Bottom: a plot of roundness vs. concavity for the same sample.