Inversion Algorithms to Determine Likely 3D Solids from a Population of Particles. J. Knicely[1] and D. Rickman[2], [1]Texas A&M University (knicely_joshua@yahoo.com), [2]Marshall Space Flight Center (doug.rickman@nasa.gov).

Introduction: Shape is a fundamental property of particles, with engineering and scientific significance. While there is a need to know the 3D geometry of the particles composing the lunar regolith, the only available shape measurements are taken in two dimensions. It has been accepted wisdom in stereology, that with very few exceptions, unique relationships between measurements in 2D and solids do not exist. However, Rickman et al. (unpublished) found a probabilistic relationship between 3D solids and the 2D measures aspect ratio (AR) and Heywood factor (HF). A forward, probabilistic model can be created wherein the likelihood of all possible AR and HF measures for a given solid can be obtained. The probability distributions for a given solid are apparently unique. An inverse model, therefore, attempts to determine the solids given an observed probability distribution of AR and HF. Two inversion algorithms were developed to determine sets and proportions of 3D solids which approximate the 2D measurements of a population of particles. These sets of solids can be used to quantitatively predict the physical characteristics of the lunar regolith and lunar simulant.

Method: The lunar regolith and lunar simulant are poorly characterized. The lunar regolith experiences weathering unlike anything on Earth. This requires a large variety of 3D solids to be considered in the inversion. Forward models of the AR and HF values for sets of 3D solids are calculated and saved into text files. The inversion algorithms read from these pre-calculated forward models to avoid lengthy forward model calculations. The inversion algorithms use only those forward models whose most populated areas in AR/HF space are shared by the input set of data. Non-linear, global inversion methods are used. These type of inversions are time-consuming, but necessary due to the poor constraints of the problem. The methods used are Monte Carlo, simulated annealing, genetic algorithm, particle swarm optimization, and differential evolution. In addition, a finite number of 3D solids are needed to approximate the lunar regolith and lunar simulant. The inversion algorithms include a function to modify the model complexity by allowing only a finite number of forward models to be considered during each iteration.

Results: Two inversion algorithms, TRADEOFF_MCSA and TRADEOFF_GOD, were developed in MATLAB. TRADEOFF_MCSA uses Monte Carlo and simulated annealing methods. This algorithm has the ability to re-anneal to escape locally optimal models found late in the annealing process. TRADEOFF_GOD uses simulated annealing, genetic algorithm, particle swarm optimization, and differential evolution. This algorithm coordinates the different optimization methods. If any method reaches a stopping criterion, its best found set of forward models is introduced to another method. The introduced set of forward models will be used by the new method if it results in a better fit to the data, or it will be eliminated if it results in a poorer fit to the data. Preliminary testing versus fabricated data sets show TRADEOFF_GOD to be more efficient. It finds similar sets of forward models that produce equivalent or better fits to the test case in significantly less time than TRADEOFF_MCSA. This is attributed to its coordination between the different optimization methods.

These inversion algorithms can be used with the forward models (once fully developed) to approximate the lunar regolith and lunar simulant (or any population of particles) with sets of 3D solids. These sets of 3D solids allow for a quantitative prediction of the bulk physical properties of the population of particles.

References: [1] Rickman, D., Lohn-Wiley, B., Knicely, J. “Probabilistic Particle Shape Measuremen,” Unpublished. [2] Everett, M. (2013) *Near-Surface Applied Geophysics*. Cambridge University Press, New York.