DEVELOPMENT OF CRUSHING AND SIEVING TECHNOLOGIES FOR USE IN SAMPLE PREPERATION IN MARS EXPLORATION. J. Herman[1], K. Zacny[1], R. Morris[2], K. Davis[1], [1]Honeybee Robotics, LLC 460 W. 34th St. New York, NY 10001, [2]NASA Johnson Space Center, Houston, TX 77058.

Introduction: **S**ubsurface investigation is one of the fundamental aspects of exterrestrial exploration. [2] Two general methods of studying the subsurface include in situ instrumentation and remote sample evaluation. This research investigates methods to crush core samples and prepare them for in remote analysis. Specifically, this research develops methods to comminute a core sample or regolith to produce small particles which are subsequently sieved to separate particles smaller than 150µm (fines) for use in scientific study.

Comminution technologies were evaluated on size, power, and effectiveness to reliably produce large percentage fines (particles of 150µm diameter or smaller) from a single core sample or an amount of regolith. Research was conducted to investigate whether or not the composition of the crushed fines varied from the composition of the original core sample. In addition, the power necessary to crush different types of rocks was evaluated.

Once suitably crushed, samples were sieved to separate the fines from the larger crushed particles. On-going investigations will determine low energy approaches to sieving. In addition, the designed crushing, sieving, and material handling system will be evaluated in regards to contamination. The key metrics in system effectiveness are identifying stray particles from the equipment itself as well as cross contamination from between samples.

Crushing Technologies: Size reduction, also called comminution, is the separation of a particle into two or more parts. This can be achieved in principle by changing a particle shape beyond certain limits such as pulling it apart (as in tension), pushing it in (as in compression), twisting it (as in torsion) etc. Many types of equipment exist that perform size reduction and they can be classified according to comminution process. In general, there are five distinct categories: compression, impact, tumbling, cutting and attrition [1]. Before deciding which of the types of equipment to use, it is highly important to clarify the nature of the task based on the size of feed, degree of size reduction required and the rate of comminution. In addition, further constraints on the selection of most suitable equipment might be imposed by environmental factors. In space applications, these factors will include power consumption, size, mass, and complexity of a crusher, which is often related to reliability with a more complex design having a large number of parts being more prone to breakage.

Taking into account the above mentioned factors, a strong choice for a crusher for space applications (such as on the surfaces of extraterrestrial planets, and in our case Mars) will be a hybrid piston-die press / attrition mill. A main advantages were the fact that a large percentage of material type can be produced in very small sizes (at or below 150 microns), suitable for delivery to various instruments such as TEGA or MECA, and that product size range can be very narrow [1], and that the crusher could be used to give accessibility to unaltered surfaces. See Figure 1.

Figure 1: Core sample after single operation to gain access to unaltered surfaces.

Another good alternative, namely a jaw crusher (particle reduction through compression), was disqualified based on the fact that a reduction ratio (ratio of particle feed size to product size) is only of the order of 10 or less [1]. Impacting, tumbling and cutting machines were disqualified because they could not be easily scaled down with respect to size, mass or power

Results: A number of tests were performed. The first determined whether this approach to comminution changed the composition of the resultant fines relative to the composition of the initial sample. The results showed only minimal changes in composition due to the crushing. See Figure 2. Note that the composition of the fines tracked very closely to the rough fines of Oak Grove Basalt.

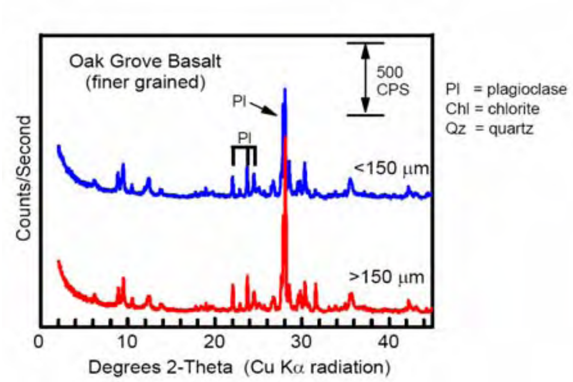

Figure 2: sample composition of rock crushed in attrition mill. (courtesy D. Morris)

Testing was also performed to determine the amount of fines created given a set crushing protocol. This is a measure of the energy required to crush different types of rocks. The results (Figure 3) show harder rocks do require more energy to crush, but they also show that established protocol produces sufficient fines for scientific study regardless of rock type. In this research, the goal was to produce 0.5cc of fines from a core sample.

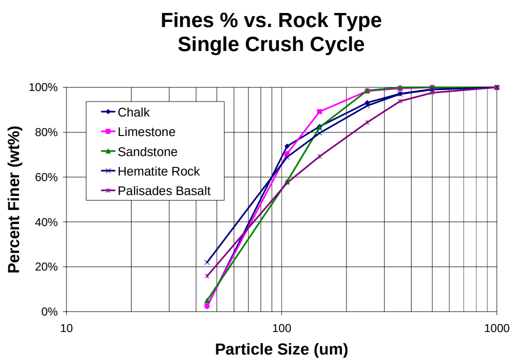

Figure 3: As the compressive strength of the rock increases, the amount of fines decreases.

Sample Sieving: Once the samples were crushed, the samples were sieved to separate the 150µm particle sizes from the other particles. Honeybee is currently designing an automated sieving and material handling system to work in conjunction with the crusher. The resultant design will be evaluated around the following metrics: sieving efficacy, sieving power, and contamination.

It is imperative the sieving process works for multiple rock types and, as such, testing will be conducted to evaluate whether different rock types or compositions work similarly with the crushing mesh.

Sieving power is also an important parameter and different methods of agitation will be evaluated for power requirements and efficacy.

Finally, minimizing and understanding the contamination is paramount to delivering quality samples to scientific equipment. Studies will be performed to determine the signature and extent of contamination that comes from the crushing equipment as well as the cross contamination between the samples. This testing will be performed in a Mars analog environment.

Conclusions: The development of core crushing and sieving hardware for use in a Mars analog environment allows for remote scientific study of the subsurface environment. Honeybee's research increases the knowledge in the areas of crushing technologies, sieving strategies and the contamination associated with those designs.

References: [1] Lowrison G., (1974) Crushing and Grinding – The Size Reduction of Solid Materials. [2] Hansen, C. (2005) SPADE: A Rock Crushing and Sample Handling System Developed for Mars Missions.