ICEBREAKER DRILL CUTTINGS SIZE ANALYSIS FROM MARS ANALOG ICY-SOILS. D. Bergman[1], K. Zacny[2], A. Davé[1], G. Paulsen[2] and B.J. Glass[1], [1]NASA Ames Research Center (Moffett Field, CA, 94035 Email: dean.bergman@nasa.gov), [2]Honeybee Robotics (398 W Washington Blvd, Suite 200, Pasadena, CA, 91103).

Introduction: The Mars Icebreaker mission is a Mars mission concept with the goal of landing at the Mars Northern Polar Caps (the same location as the 2008 Mars Phoenix lander), drilling to at least 1 m depth in the icy permafrost and analyzing captured cuttings for extinct and extant life [1, 2].

The mission will use the 1 meter Icebreaker drill with auger based sampling system, to capture approx. 20 cc of sample. The typical maximum particle size required by onboard instruments is approx. 1 mm. Larger particles could potentially clog inlet ports. Although the sample delivery system will include an in-line 1 mm screen for capturing and disposing of particles larger than 1 mm, the instrument designers would benefit from knowing the particle size distribution of samples produced by the rotary percussive drill. Successful sieving methods for icy sample are also discussed. This abstract reports on a number of tests conducted in a range of Mars analog simulants. The size distribution of captured samples in each type of simulant is reported.

Icebreaker Mission - Sample Delivery: The sampling chain starts with the Icebreaker drill. The drill penetrates a formation by breaking down strong, cohesive material and crushing individual particles. The sample is captured on the auger deep flutes just above the bit. Once a 10 cm section of the auger flutes is full, the auger is pulled out of the hole and material is brushed off using a passive brush onto a 1 mm screen or directly into a sample delivery scoop [3]. This sample handling chain must work with a range of soil types expected in the northern regions of Mars. This range of soils includes modestly cohesive 'crusty to cloddy' materials seen by the Viking 2 lander [4] and the Phoenix lander [5], and strongly cohesive icy soil as seen by the Phoenix lander [5]. The extreme cases include non-cohesive soil, as might be expected should the drill penetrate solid rock, or sample material similar to the weakly cohesive loose 'drift' material seen at lower latitudes by Viking 1 [4].

There are various soils on Earth that resemble that of Mars. The soils chosen to be analyzed here are: JSC-1a, Mojave Mars Simulant (MMS), University Valley soil (Dry Valleys, Antarctica), Devon Island soil (Canadian High Arctic), and McMurdo soil (Antarctica). The materials were saturated with 7.4wt% and 10wt% water, and frozen to below -20°C temperatures.

Test Approach: In order to gain insight into the effects of sieving soil on Mars, two tests were performed, namely, the Freezer Test and the Vacuum Chamber Tests.

The first test was undertaken in a walk-in freezer. The Icebreaker auger was connected to a rotary percussive Hilti drill and samples were manually drilled and captured. After drilling to a target depth, the samples were transferred from the drill auger to a stack of sieves. This process is seen in Fig. 1. These sieves were then shaken by hand and the particle size distribution of captured sample was measured. The screen sizes of the sieve stack were: 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.15 mm, 0.125 mm, and 0.053 mm. The material types used in these tests included: JSC1a, MMS, Dry Valley soil, and pure ice. Each soil was saturated to approx. 7.4wt% water, except the pure ice (100% water). All samples, drill, and sieves were left overnight to cold soak at –20 °C (freezer temperature).

Figure 1: Experimental technique for Freezer Tests

The second test involved drilling into soils at Mars low pressure conditions (6.4 Torr) in a Mars chamber. The drill and sample were set up inside a vacuum chamber and were surrounded by liquid nitrogen cooled coils. The stack of sieves was then placed next to the foot of the drill to gravity capture material augered to the surface (Fig. 2). The sieve stack had screen sizes of 2.8 mm, 2 mm, 1.4 mm, and 0.7 mm. During sample capture on the sieve surface, it was observed that percussive action of the drill helped with initial sample sieving. Once the drill test was completed, the sieves were removed from the chamber, shaken by hand and then the sample was actively brushed through each screen. The samples used in these tests were JSC-1a with 10wt% water, Dry Valley with 10wt% water, and Devon Island with 10wt% water. The soils were cooled to below -30 °C in the chamber.

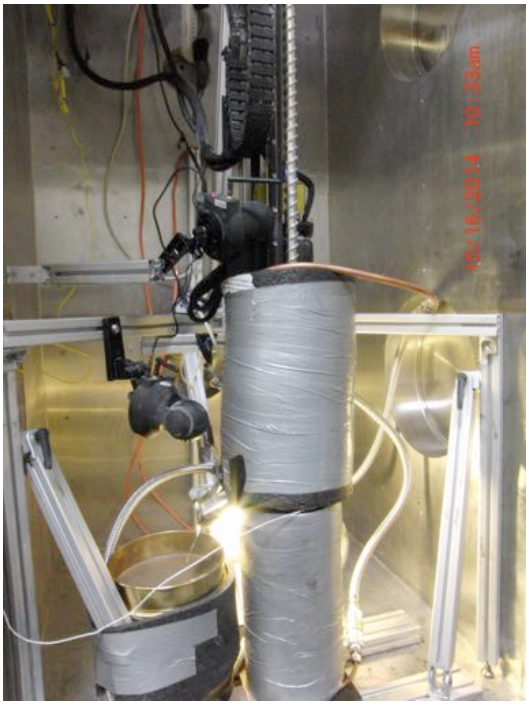

Figure 2: Icebreaker drill setup with sieves in vacuum chamber

Sieving Results: Figure 3 shows a comparison of the results from the Freezer Test along with previously obtained results for Mcmurdo soil after being drilled into by the Icebreaker drill. Size distribution of cuttings for Indiana Limestone captured using the Crux drill are also plotted for comparison. Since the samples remained cold (-20 °C) during the sieving process, they did not stick to and clog the screen and in turn it was not necessary to actively brush the soil through the screens. Shaking the sieves by hand exerted enough agitation to screen the samples thoroughly.

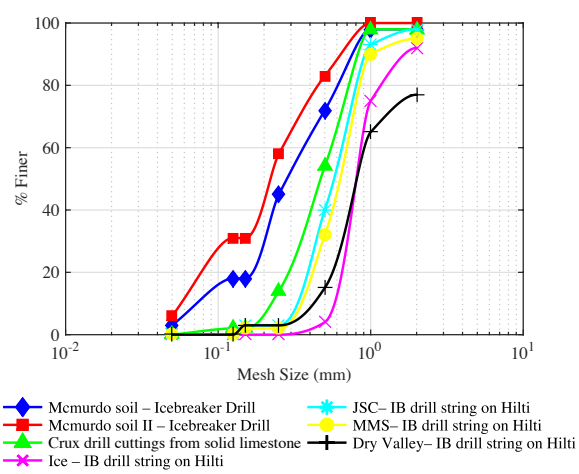

Figure 3: Particle size distribution for Freezer Test experiments.

Figure 4 shows the results of the Vacuum Chamber Tests. It must be noted that JSC-1a results are slightly skewed since the sieving was done at room temperature where cuttings thawed and clogged the screens (the other samples were successfully sieved at Mars conditions with the help of the percussion of the drill). As such JSC-1a samples had to be brushed through the sieve screens (especially for screens 1.4 mm and below).

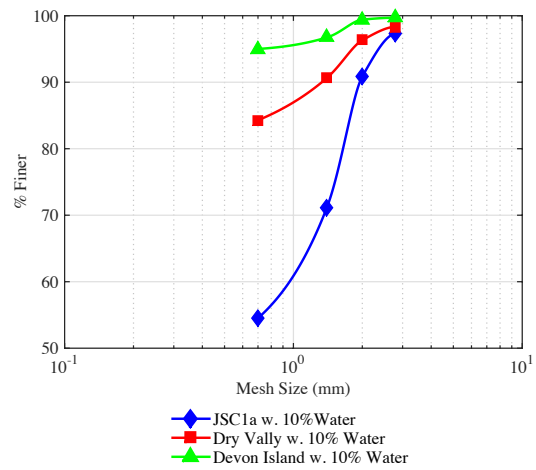

Figure 4: Particle size distribution for Vacuum Chamber Testing

Conclusion: Results from both tests show that a significant number of particles are larger than 1 mm and thus need to be screened and discarded on Mars. The results also illustrate that sieving is possible on Mars as long as the ice in the soil does not thaw causing it to become sticky. Some sort of agitation is needed to sieve the samples through 1.4 mm screens.

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References: [1] McKay et al (2013), Astrobiology, 13(4): 334-353, [2] Bonitz et al. (2008), JGR, 113, E00A01, [3] Zacny et al (2013), Astrobiology, 13(12): 1166-1198, [4] Moore and Jakosky (1989), Icarus, 81(1): 164-184, [5] Arvidson et al. (2009), JGR, 114, E00E02