THE ICEBREAKER: ONE METER CLASS MARS DRILL AND SAMPLE DELIVERY SYSTEM. K. Zacny[1], G. Paulsen[1], C. McKay[2], B. Glass[2], A. Davila[2], M. Marinova[2], A. Dave[2], J. Heldmann[2], [1]Honeybee Robotics, 398 W. Washington Ave, Pasadena, CA 91103, zacny@honeybeerobotics.com, [2]NASA ARC, Moffett Field, CA.

Introduction: One of the goals of NASA's Mars Exploration Program is to determine if life ever arose on Mars. To answer this question we need to search for both extinct life formed when conditions were more hospitable, and for extant life, if it still exists. In order to search for extinct or extant life, we need to drill into the ground ice or ice-rich soils (since water is an important requisite for life as we know it) and acquire samples for analysis. Samples need to be acquired from greater depths (> 1 meter) where they have been relatively protected from the high levels of radiation that reach the surface of Mars.

For the past 3 years, we have been developing a prototype Mars drill called the IceBreaker. The IceBreaker is a one meter class drill and sample acquisition system.

The IceBreaker Mars Drill: The drill consists of a rotary-percussive drill head, a sampling auger with a bit and integrated temperature sensor, a Z-stage for advancing the auger into the ground, and a sampling station for moving the augered ice shavings and soil cuttings into a sample cup. The drill employs rotary-percussive action, which reduces both the required Weight on Bit (WOB) and the energy consumption [1, 2, 3, 4]. This is especially important if the drill is deployed from a low-mass platform in a low gravity environment and with limited energy supply.

In November/December of 2010, the IceBreaker drill was tested in University Valley (within the Beacon Valley region of the Antarctic Dry Valleys). University Valley is a good analog for both polar and mid-latitude regions on Mars because a layer of dry but always below freezing layer of soil lies on top of either ice-cemented ground or massive ice (depending on the location within the valley). Most of the ice in the soil has been vapor-deposted, as is also expected on Mars.

The IceBreaker system demonstrated drilling in ice-cemented ground and in massive ice at the 1-1-100-100 level; that is the drill reached ~1 meter in ~1 hour with ~100 Watts of power and ~100 Newtons of Weight on Bit. This corresponds to an average energy of ~100 Whr. At the same time, the bit temperature measured by the bit thermocouple did not exceed the formation temperature by more than 10 °C. The temperature also never exceeded freezing, which minimizes chances of freezing the bit in the hole or of altering the material that is being sampled for analysis. Cuttings were acquired in sterile bags at 10 cm intervals.

The IceBreaker was also tested in a vacuum chamber at Mars pressure, and penetrated to a depth of 1 meter in both water-ice at -20°C and water-ice with 2% perchlorate at -20°C.

Figure 1. The IceBreaker drill in the Mars chamber.

IceBreaker Sample Delivery: We tested two sample delivery systems: 1) Pneumatic tubes, and 2) Drill with a 3-Degree of Freedom (DOF) deployment boom. In both approaches there is an air-gap between the sterilized drill (which penetrates subsurface) and the sample transfer hardware (which is not going to be sterilized). The air gap satisfies the planetary protection requirements.

The pneumatic sample delivery system uses compressed gas to move the sample directly into the instrument (Figure 2). At the drill side, the sample falls through an open door into a small chamber. The chamber door then closes, and compressed gas is injected into the sample chamber, moving the sample through the gas line into a cyclone separator, and finally into the cup (instrument). This approach allows very simple point-to-point sample transfer. Previous work has demonstrated that with 1 gram of gas at 6 psia, over 6000 grams of soil can be moved at high speed [5].

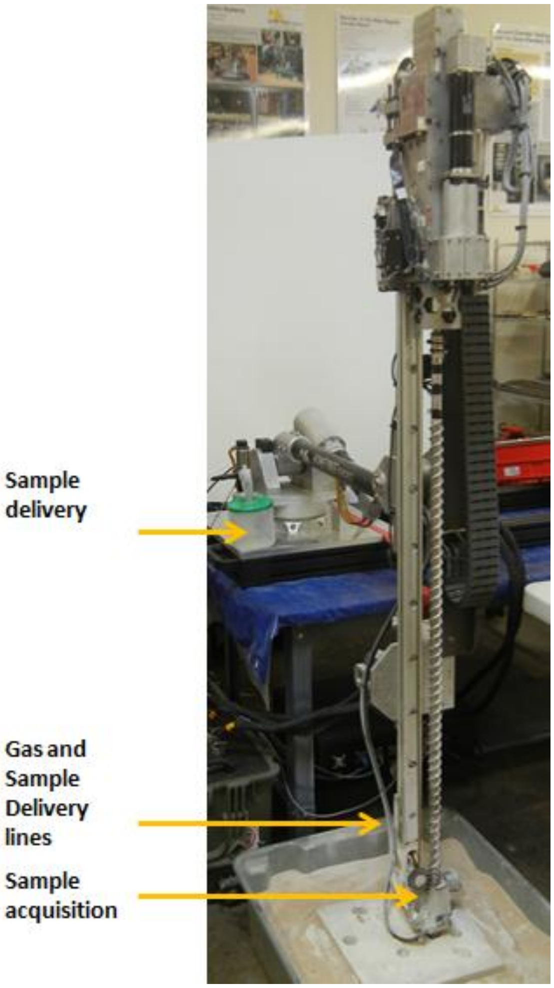

Figure 2. Pneumatic sample transfer.

The second approach uses the drill itself to deliver the samples into the instrument. Since the drill is deployed using a 3 DOF boom, it can be moved from its position over the borehole to a position over a sample inlet port (Figure 3 and 4). As the drill penetrates into the subsurface the sample is augered up the auger tube. After drilling to a depth of say 5 cm, the drill is retracted back up the hole, while the sample on the auger flutes is kept inside the fixed auger tube, preventing sample loss. The drill is then moved over the sample inlet port and the sample is discharged by rotating and advancing the drill with respect to the auger tube. A brush attached to the instrument can enhance sample discharge. Once sample delivery is complete, the drill is moved back into the hole to acquire another sample.

Conclusions: The IceBreaker drill and sample delivery system has achieved high enough technology readiness to be considered as a viable option for future Mars missions such as a Discovery mission to any area with subsurface ice or ice-cemented ground.

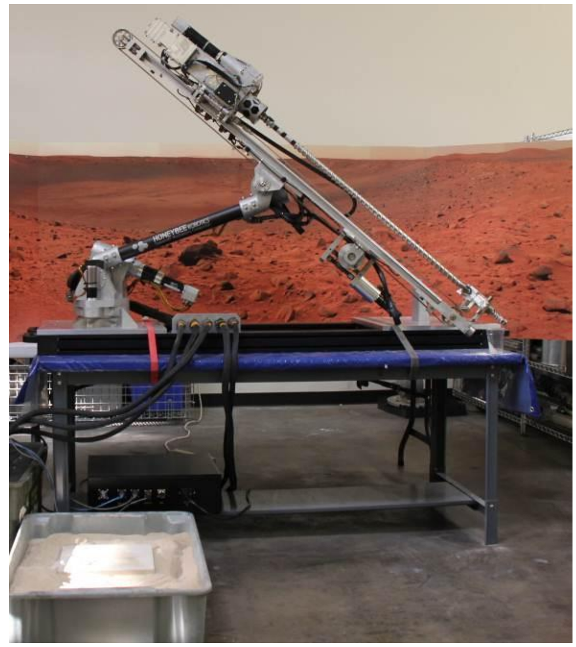

Figure 3. 3 DOF boom enabled sample delivery.

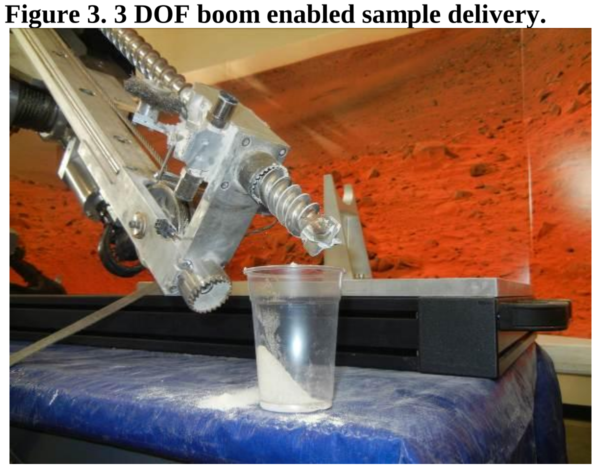

Figure 4. Sample stored within the Auger Tube and on the flutes being droped off into a cup.

References: [1] Zacny et al., LunarVader: Development and Testing of a Lunar Drill in a Vacuum Chamber and in the Lunar Analog Site of the Antarctica. JAE ; [2] Paulsen, et al., Testing of a 1 meter Mars IceBreaker Drill in a 3.5 meter Vacuum Chamber and in an Antarctic Mars Analog Site, AIAA SPACE 2011 Conference; [3] Zacny et al., The Icebreaker: Mars Drill and Sample Delivery System, Abstract 1153, LPSC 2012; [4] Glass et al., (2011) Automated Mars Drilling for "IceBreaker", IEEE Conference ; [5] Zacny et al.. Investigating the Efficiency of Pneumatic Transfer of JSC-1a Lunar Regolith Simulant in Vacuum and Lunar Gravity During Parabolic Flights. AIAA Space 2010.