THE ICEBREAKER: MARS DRILL AND SAMPLE DELIVERY SYSTEM. K. Zacny[1], G. Paulsen[1], B. Mellerowicz[1], J. Craft[1], C. McKay[2], B. Glass[2], A. Davila[2], M. Marinova[2], A. Dave[2], S. Thompson[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 the 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 had 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 or soil cuttings into a sample cup (Figure 1). The drill employs rotary-percussive action, which reduces both the required Weight on Bit (WOB) and the energy consumption [1, 2]. 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 the University Valley (within the Beacon Valley region of the Antarctic Dry Valleys). University Valley is a good analog to the Northern Polar Regions of Mars because a layer of dry soil lies on top of either ice-cemented ground or massive ice (depending on the location within the valley). The valley also includes vapor-deposited ice.

The 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 in 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.

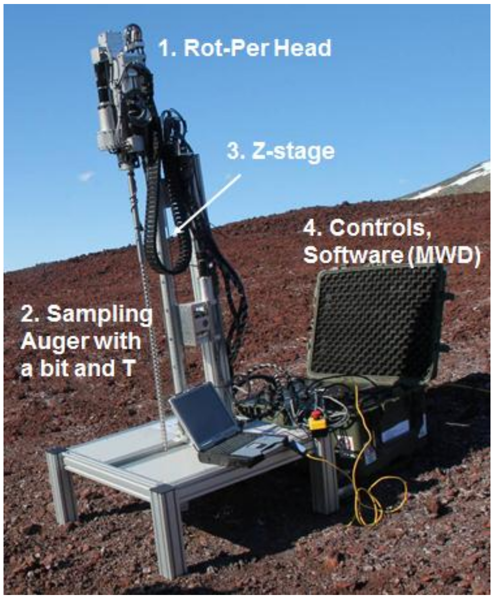

Figure 1. Components of the IceBreaker Mars Drill. The IceBreaker drill in the University Valley, Antarctica was used to drill 1 meter in ice-cemented ground and collect drill cuttings.

The IceBreaker Sample Delivery: We tested three sample delivery systems: 1) Robotic arm with a scoop, 2) Pneumatic tubes, 3) Drill with a 3-Degree of Freedom (DOF) deployment boom. In all three 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 is required for planetary protection.

The robotic arm has a scoop at the end that can be placed underneath the brush (Figure 2). As the cuttings are being augered to the top of the auger tube (which is an extension of the borehole) they either fall (if not sticky) or are brushed off and then fall (if sticky) directly into the scoop underneath. The scoop can then be moved above an instrument port and tilted to discharge the sample.

The pneumatic sample delivery system uses compressed gas to move the sample directly into the instrument (Figure 3). 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 [3].

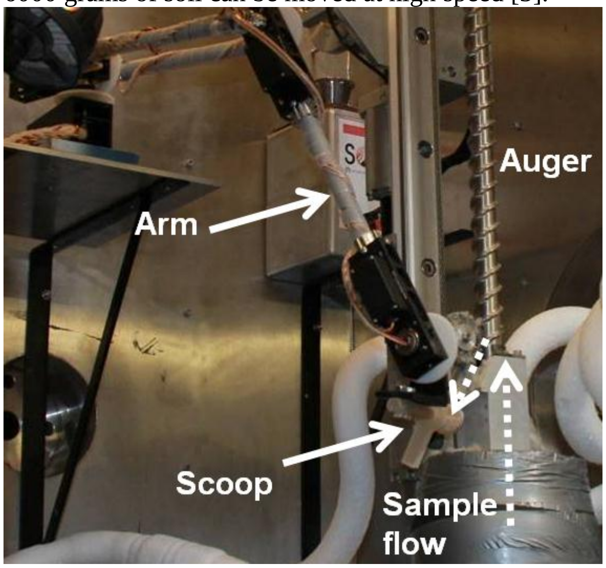

Figure 2. Sample transfer using a robotic arm with a scoop.

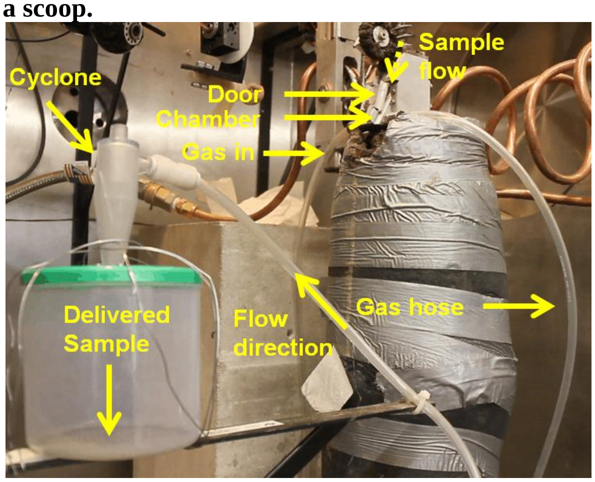

Figure 3. Pneumatic sample transfer.

The third 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 4 and 5). 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. The auger tube prevents the 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.

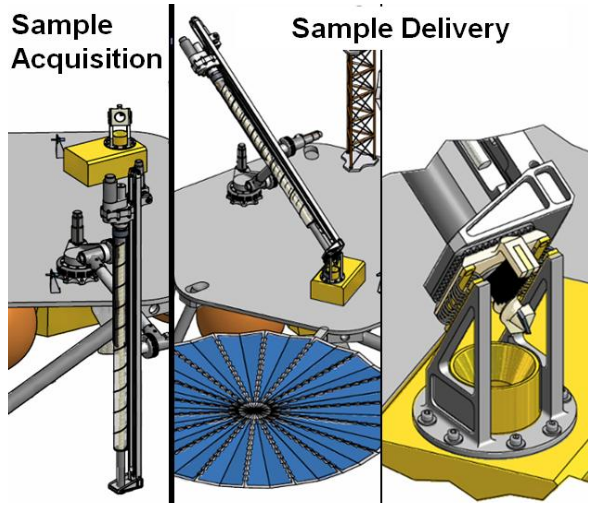

Figure 4. 3 DOF boom enabled sample delivery.

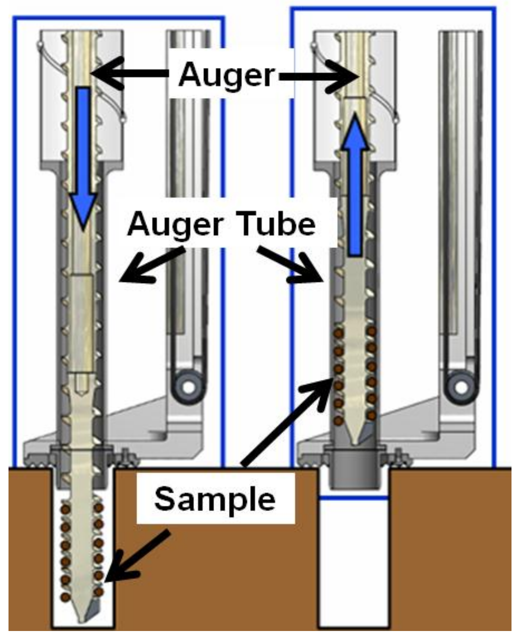

Figure 5. Sample acquisition and storage within the Auger Tube.

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.

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. J. Aero Eng.. [2] Glass et al., (2011) Automated Mars Drilling for “IceBreaker”, IEEE Aerospace Conference [3] 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.