LIFE IN THE ATACAMA: THE DRILL AND SAMPLE DELIVERY SYSTEM. K. Zacny[1], G. Paulsen[1], J. Craft[2], D. Wettergreen[3], A. Long[3], N. Cabrol[4], and the Life in the Atacama Project Team, [1]Honeybee Robotics, Pasadena, CA, zacny@honeybeerobotics.com, [2]Honeybee Robotics, New York, NY, [3]Carnegie-Mellon University, Pittsburgh, PA, [4]SETI/NASA Ames, Moffett Field, CA

Introduction: The Life in the Atacama (LITA) project has a goal of demonstrating autonomous roving, sample acquisition, delivery and analysis operations in Atacama, Chile [1]. Honeybee Robotics was tasked to develop a rover-deployed, autonomous drill, called the LITADrill, capable of penetrating to 100 cm depth and acquiring and delivering subsurface samples. The drill had to have mass and power requirements consistent with a flight system. At the end of the project, the sampling drill will be at the TRL 5/6 and hence suitable for being considered for future Mars, and other extraterrestrial bodies missions.

The "Bite" Sampling System: The LITADrill acquires powdered rocks and soil samples for analysis. To achieve that, the sampling auger has been designed with two distinct stages as shown in Figure 1. The lower part has deep and gently sloping flutes for retaining of powdered sample, while upper section has shallow and steep flutes for preventing borehole collapse and for efficient movement of cuttings and fall back material out of the hole. The lower section has also a protective outer sleeve (called the auger tube) that helps in retaining powder.

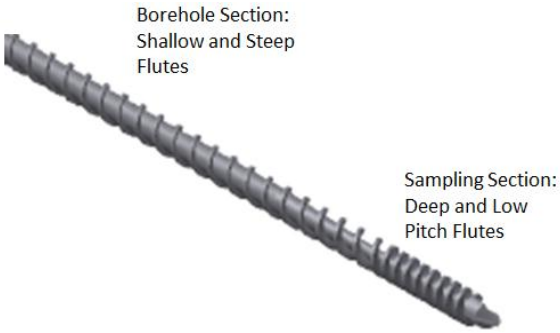

Figure 1. Dual stage auger. The lower section was designed to capture cuttings while the upper section was designed to prevent borehole collapse and efficiently clear cuttings and fall back material out of the hole.

The auger can move up/down within the auger tube. The drill uses the so called "bite-sampling" approach that is samples are taken in short, 5-10 cm bites [2, 3]. To take the first bite, the drill is lowered onto the ground and upon drilling of the first bite it is then retracted into an auger tube. The auger with the auger tube are then lifted off the ground and positioned next to the sample drop off tray. To deposit the sample, the auger is rotated and retracted above the auger tube. The cuttings retained on the flutes then will either gravity fall or be brushed off by a side brush onto the tray (Figure 2). After the sample from the first bite has been deposited, the drill is lowered back into the same hole to take the next bite. This process is repeated until a target depth is reached. The bite sampling is analogous to peck drilling in the machining process where a bit is periodically retracted to clear chips. If there is some fall back into the hole once the auger has cleared the hole, this fall back material will be augered out during auger re-insertion. The next bite will be taken only once the auger has reached the true bottom.

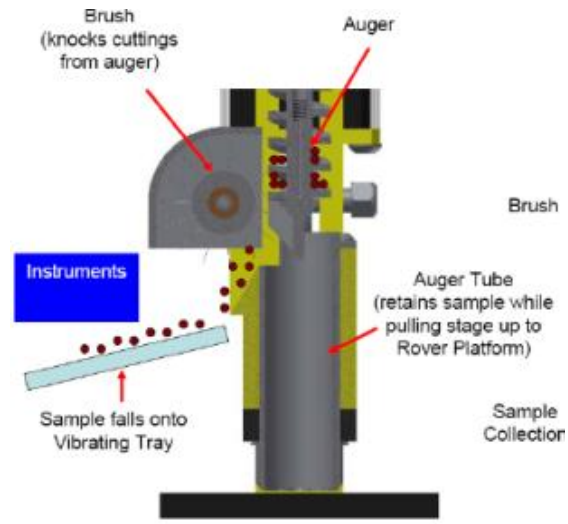

Figure 2. The sample either gravity falls off the auger flutes or is brushed off by a passive brush onto a tray leading to a sample cup.

In the bite sampling approach the stratigraphy is preserved since every time the sample is taken, it more or less represents the depth interval in the hole. There is going to be some level of cross contamination due to smearing of cuttings on the flutes against the borehole as the auger is being pulled out, but as we found during our tests this is minimal. The method also offers 'graceful failure' in that unless the drill breaks before acquiring its first sample, the system will always be able to deliver a sample for analysis.

The First Field Deployment: The goal of the first drill campaign in Atacama in May of 2012 was to demonstrate successful operation of the bite sampling method and in particular acquisition and deliver of sample onto a sample transfer ramp (Figure 3). The secondary task was demonstration of the vibration-assisted sample transfer down the ramp.

To determine the optimum auger diameter and bit type, five sampling augers with 3 diameters and 2 bit types were tested (Figure 4). We found that the optimum design was a half inch diameter auger with a rock bit. That diameter auger provided sufficient sample for analysis while the rock bit worked well in both soils and rocks. The soil delivery sample onto the Sample Ramp was successful each time. However, the transfer of sample down the ramp only occurred at steeper than 20 degree ramp angle and with vibrations in excess of 2500 rpm. As an added bonus, a small window was placed within the floor of the ramp. The goal was to determine if a camera or other instruments could image and analyze the sample from underneath the ramp. The window proved to be an excellent method for non-contact sample analysis and could potentially be used for such techniques as Raman and IR Spectroscopy.

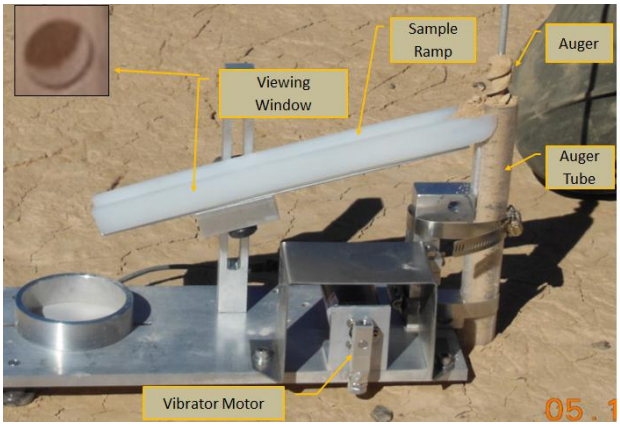

Figure 3. Side view of the sample delivery system.

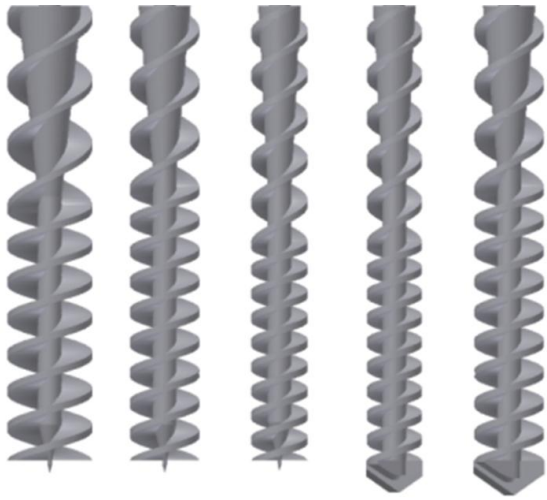

Figure 4. Five different auger/bit combinations were tested during the field trials. The augers differed in diameter and type of bits.

LITA Drill: The LITA Drill represents the 3rd generation of Honeybee Robotics Rotary-Percussive 1 m class drills. The first generation, the CRUX drill, was a 2kW system not capable of operation in vacuum [4]. The 2nd generation, the IceBreaker drill, has been thoroughly tested in vacuum chambers, in the Arctic and Antarctica and demonstrated drilling at 1-1-100-100 level; that is 1 meter in 1 hour with 100 Watts and 100 Newton Weight on Bit [2-4]. The drill weighed over 40 kg. The LITA Drill shown in Figure 5, is almost as powerful as the IceBreaker (~300 Watt), with percussive energy of 2 J/blow, but weighs only 10 kg. The drill will be integrated with the CMU Zoe rover in Q1 '13 and field tested in Q2/Q3 of 2013 in Atacama.

Figure 5. The 3rd Generation Rotary-Percussive Drill, the LITA Drill, weighs 10 kg and penetrates to 1 m depth.

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References: [1] Cabrol et l., Life in the Atacama: Science and Technology Pathways to the Robotic Search for Life on Mars, 44th LPSC, [2] The Icebreaker: One Meter Class Mars Drill and Sample Delivery System, Abstract 4259, Concepts and Approaches for Mars Exploration, 2012, Houston, TX, [3] 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, [4] Zacny, et al., Lunar-Vader: Development and Testing of a Lunar Drill in a Vacuum Chamber and in the Lunar Analog Site of the Antarctica. J. Aerosp. Eng., 2013.