LIFE IN THE ATACAMA - THE DRILL AND SAMPLE DELIVERY SYSTEM: RESULTS FROM THE 2013 FIELD CAMPAIGN. K. Zacny[1], G. Paulsen[1], S. Yoon[1], D. Wettergreen[2], N. A. Cabrol[3], and the Life in the Atacama Project Team, [1]Honeybee Robotics, Pasadena, CA, zacny@honeybeerobotics.com, [2]Carnegie-Mellon University, Pittsburgh, PA, [3]SETI Institute Carl Sagan Center/NASA Ames, Moffett Field, CA

Introduction: The Life in the Atacama (LITA) is a NASA ASTEP funded project with a goal of demonstrating autonomous roving, sample acquisition, delivery and analysis in the Atacama, Chile [1]. Honeybee Robotics was tasked with the development of a sampling system that consisted of two subsystems: the LITADrill and a 20 cup carousel (**Figure 1**). The following sections describe the drill, the carousel, and the 2013 field results.

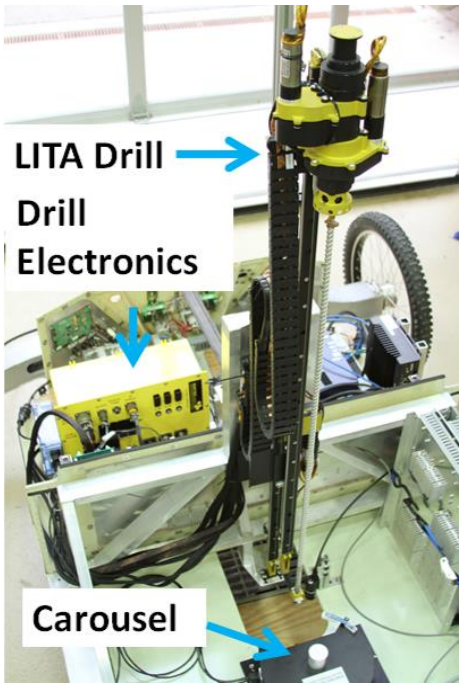

Figure 1. LITA Sampling System consists of a drill and a carousel.

The LITADrill: The LITADrill is a 10 kg, 300 Watt, rotary-percussive and fully autonomous drill designed to capture powdered rocks and soil samples for analysis. The LITA Drill represents the 3rd generation of Honeybee Robotics Rotary-Percussive 1 m class drilling systems [2-4].

The drill consists of following subsystems: 1. Rotary-Percussive Drill Head, 2. Sampling Auger, 3. Brushing station, 4. Z-stage, 5. Deployment stage.

The drill head has been designed with rotation and percussion decoupled. This allows the use of more energy intensive percussive system only when required (e.g., to penetrate through harder formations). Both rotary and percussive motors are approximately 150 Watt each.

To reduce sample handling complexity, the drill auger was designed to capture cuttings and soils as opposed to cores. High sampling efficiencies are possible through a dual design of the auger (**Figure 2**). The lower section of the auger has deep and low pitch flutes. This geometry creates natural cavities ideal for retaining granular materials (cuttings and soil). The upper section of the auger has been designed to efficiently move the cuttings out of the hole.

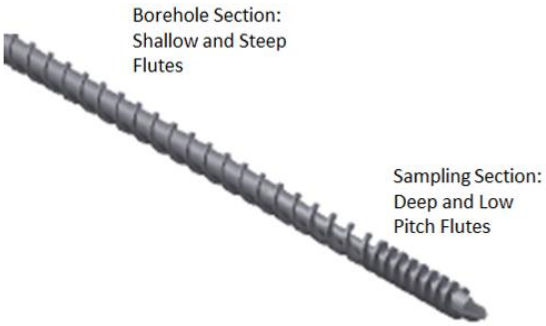

Figure 2. Dual stage auger.

The drill uses a "bite" sampling approach where samples are captured in ~10 cm intervals [2, 3]. That is, after drilling 10 cm, the auger with the sample is pulled out of the hole, and the sample is brushed off into one-cc cups by a passive brush within the Brushing station (**Figure 3**). An advantage of the "bite" sampling approach is that stratigraphy is preserved because a sample comes from a known depth.

Figure 3. The sample either gravity falls off the auger flutes or is brushed off by a passive brush into a cup.

The Deployment stage is used to lower and preload the drill system on the ground. The Z-stage, on the other hand, is used to advance the auger to a depth of approximately 80 cm. Both the Z- and Deployment stages are pulley-based to reduce system weight and vibration to the rover.

Carousel: The carousel is a single degree of freedom system designed to move the 20 cups underneath the drop off spout, Raman (MMRS) and the Imager (MMRS) as shown in **Figure 4**. An integral part of the system is a cantilevered (and in turn fully passive) scraper that smooths out and compacts the top powder in each cup. The placement of a particular cup under the target instrument is done fully autonomously.

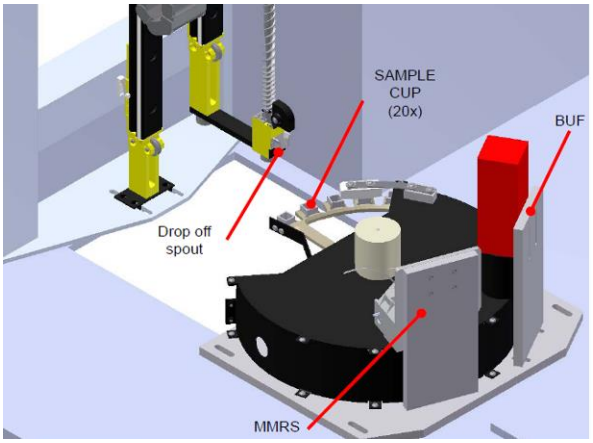

Figure 4. The LITA Carousel with 20 cups.

2013 Field Deployment: The field campaign took place in Atacama Desert near Antofagasta, Chile from June 10 – July 1, 2013 (**Figure 5**). One of the technology goals was to demonstrate full autonomy of the end-to-end sample acquisition and delivery from a variety of soils and rocks. (For the science goals, see Cabrol et al., this LPSC). During the course of the field deployment 6 holes were drilled [5]. The autonomy has been successfully demonstrated every time, however, sampling effectiveness in some cases was challenging.

Figure 5. The LITA drill in Atacama.

It was observed that drilling in poorly consolidated, coarse-grained soils, such as shown in **Figure 6**, is relatively easy, but capturing and retaining of samples within auger flutes is difficult. In most cases, the soil would be pushed aside as the drill was lowered into the ground and in turn no soil would be captured. If some soil fell into the auger flutes, it would quickly fall down the flutes because of low friction angle and lack of cohesion. (Coarse grain and well-rounded materials have low friction angle and low or no cohesion and hence flow easily – e.g. dry beach sand. Wet beach sand on the other hand is cohesive – it sticks together). Various operational changes were implemented to solve this issue, including drilling without percussion and drill retraction without rotation. These changes helped in retaining more sample, but were not sufficient to guarantee the required 1 cc sample.

More consolidated, fine grained soils such as those shown in **Figure 7**, were successfully sampled each time.

Figure 6. This drill site had poor borehole integrity (Locale 11).

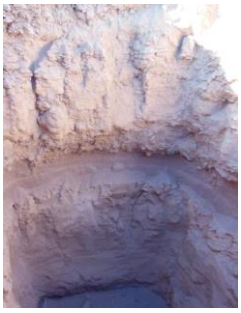

Figure 7. Pit dug at Locale 12. The soil was easy to sample.

In all cases, the average drilling power was less than 15 Watts because the percussive system did not have to be engaged most of the time. The Weight on Bit was also low, at 50 N or less. A sampling operation that included drilling and sample delivery from 10 cm, 30 cm, and 80 cm depths took 2 hours and 10 min.

For the 2014 field campaign, a number of changes have been implemented. These include larger diameter auger (0.75 inch as opposed 0.5 inch) to enable greater sampling volume, stepper flutes to help with sample retention, and optimized drilling software to shorten the sampling time.

References: [1] Cabrol et al., 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, Concepts and Approaches for Mars Exploration, 2012, Houston. [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., Reaching 1 m Deep on Mars: The Icebreaker Drill, Astrobiology, 1166-1198; [5] http://www.youtube.com/watch?v=QE7aYUnAA9o

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