DEMONSTRATION OF THE CORE ACQUISITION AND CACHING FOR THE MARS SAMPLE RETURN MISSION. G. Paulsen[1], K. Zacny[1], A. Steele[2], P. Conrad[3], P. Chu[1], M. Hedlund[1], J. Craft[1], T. McCarthy[4], and C. Schad[4], [1]Honeybee Robotics, 398 W. Washington Ave, Suite 200, Pasadena, CA 91103, zacny@honeybeerobotics.com, [2]Carnegie Institution of Washington Geophysical Laboratory, 5251 Broad Branch Rd. NW, Washington, DC 20015, [3]NASA Goddard Space Flight Center Mail Code 699, Greenbelt, MD 20771, [4]MDA Information Systems, Inc., 1250 Lincoln Ave., Suite 100, Pasadena, CA 91103

Introduction: The goal of the 2018 Mars Sample Return mission (called the Mars Astrobiology Explorer-Cacher, or MAX-C rover) is to acquire rock cores and regolith samples and hermetically seal them within the earth return cache [1]. We present an approach to core acquisition and caching as well as a suite of drill bits that will enable sample interrogation prior to sample selection for caching.

Approach to Core Acquisition and Caching: Figure 1 shows the proposed Core Acquisition and Caching system in its deployed position. The system includes:

1. Drill
2. Bit Carousel and Cache
3. 5 Degree of Freedom Robotic Arm

In the proposed architecture, the cores are stored in individual bits i.e. the cores are never taken out of their bits once acquired (Figure 2). This significantly reduces sample handling complexity and almost entirely eliminates cross contamination.

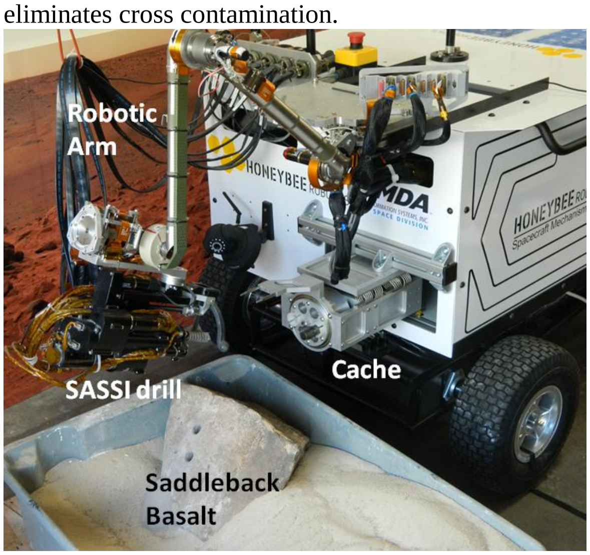

Figure 1. Sample Acquisition and Caching system.

After acquiring a rock core or regolith sample, the bit with the sample inside it is inserted directly into the cache and a new drill bit is acquired.

In order to demonstrate the entire sequence of core acquisition and caching, we integrated the existing SASSI rotary-percussive coring drill [2, 3] with the robotic arm and the cache.

The SASSI is a ~100 Watt, 5 kg rotary-percussive drill. It has five actuators for the following motions: Rotary, Percussive, Z-axis, Core Break-Off system, and the Bit Change Out (Chuck). The drill was deployed from the Engineering Model of the Mars Exploration Rover (MER) Instrument Deployment Device (IDD) provided by MDA Robotics (previously ASI). Since the drill has its own Z-axis, it requires no additional arm actuation once positioned and preloaded against a rock (Weight on Bit and pull forces are decoupled from the arm).

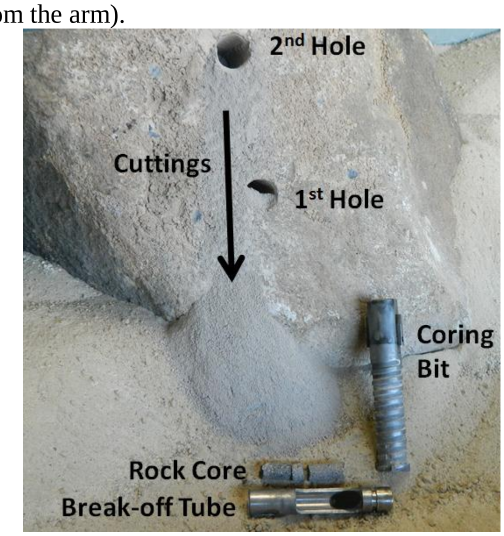

Figure 2. Each core is stored in individual core bits which are cached for sample return.

The drill bits were designed to acquire cores 1 cm in diameter and up to 5 cm long. Note however, that the same drill can also be used to brush and abrade rock surfaces with a special brushing and abrading bit. Likewise, it can also acquire rock powder, regolith, or 2.5 cm long cores for in-situ analysis using special purpose bits [4].

The cache has 6 bit pockets (for demonstration purposes only) and it has two actuators: one for rotating the cache around its axis and one for advancing/retracting the bit-housing sleeves.

Demonstration of the End-to-End Sequence: The demonstration included the following steps: 1. Docking the Drill with the Cache, 2. Acquiring a coring bit from the Cache, 3. Placing the Drill against the rock surface using a Robotic Arm, 4. Drilling to a 5.5 cm depth and acquiring a 5 cm long by 1 cm diameter core, 5. Docking the Drill with the Cache, 6. Depositing the core-containing bit into the Cache, and 7. Acquiring a new bit from the Cache.

The entire end-to-end sequence as described above can be viewed on YouTube at the following address: http://www.youtube.com/watch?v=oweysce_D6c

The robotic arm is teleoperated, and so positioning and docking with the cache were performed through teleoperation. All other steps (drilling and core acquisition, bit acquisition and deposition) were autonomous.

The entire sequence took 52 minutes to complete, including 18 minutes of actual drilling. The average drilling power was 45 Watts, while the Weight on Bit (WOB) was 25 Newtons. The energy required to acquire a single core was approximately 15 Whr.

Additional Drill Capabilities: To enable analyzing rock samples in-situ before returning them to earth, we have developed five bits: a combined Brushing and Abrading Tool (BAT), a core PreView Bit, a Powder and Regolith Acquisition Bit (PRAB), and finally the Caching bit for acquiring rock cores ~ 1 cm diameter and 5 cm long for sample return.

The BAT uses the same approach as the Rock Abrasion Tool on the MERs to brush and abrade rocks (Figure 3).

The PreView bit acquires a 2.5 cm long core which can be viewed through the slot inside the bit or placed onto an observation tray (Figure 4).

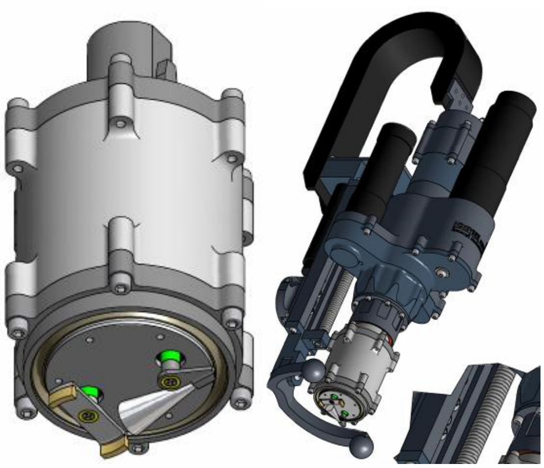

Figure 3. Left: Concept of Brushing/Abrading Tool (BAT) based on MER Rock Abrasion Tool. The Abrading bit is on the left, while the Brushing Bit is on the right. Right: The BAT attached to a prototype MAX-C drill.

The PRAB acquires regolith or rock powder during drilling (Figure 5). The sample can be stored for sample return or dispensed into an instrument cup. The PRAB has integrated sieves and can either acquire particles below sieve size, retain particles above certain sieve size. All the bits are deployed using the same drill shown in Figure 3.

Figure 4. The Preview Bit. Left: after reaching the target depth of 2.5 cm, break-off tube is rotated to shear and capture the core. Once the tube is fully closed (Center), the core cannot fall out. To view the core, the drill is moved to a horizontal position and the inner break-off tube is rotated back to expose it. (Right)

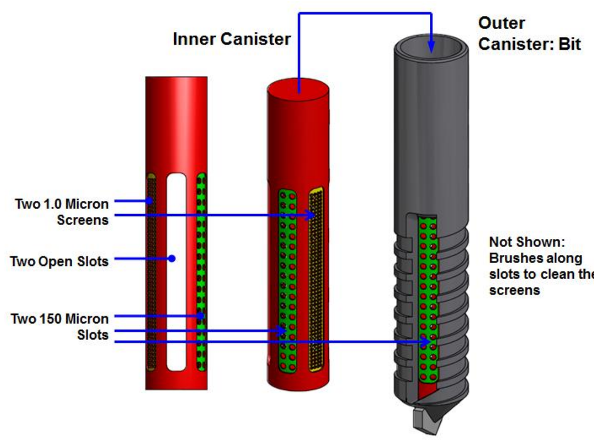

Figure 5. Powder and Regolith Acquisition Bit (PRAB) with integrated sieves.

Acknowledgements: Funding for the end-to-end demo was provided by the NASA ASTEP program.

References: [1] Beaty et al. (2010) The Proposed Mars Astrobiology Explorer-Cacher (MAX-C) Rover: First Step in a Potential Mars Sample Return Campaign, 41st LPSC. [2] Zacny et al., (2011) Approach to the Sample Acquisition and Caching Architecture for the 2018 Mars Sample Return Mission, Paper #1573, IEEE Aerospace Conf [3] Zacny et al., (2011), Prototype Rotary Percussive Drill for the Mars Sample Return Mission, Paper #1125, IEEE Aerospace Conf [4] Zacny et al., (2011) Development of the Brushing, Abrading, Regolith, Core PreView and the Coring Bits for the Mars Sample Return Mission, AIAA SPACE 2011.