**ROTARY PERCUSSIVE CORING DRILL AND CACHING ARCHITECTURE FOR MARS SAMPLE RETURN MISSION.** K. Zacny[1] , P. Chu[2], J. Wilson[3], G. Paulsen[4], A. Avanesyan[5], J. Craft[6], [1]Honeybee Robotics, 398 West Washington Blvd, Suite 200, Pasadena, CA 91103, zacny@honeybeerobotics.com, [2]Honeybee Robotics, 1110 Nasa Parkway, Suite 440, Houston, TX 77058, chu@honeybeerobotics.com, [3]Honeybee Robotics, 460 West 34th Street, New York, NY 10001, wilson@honeybeerobotics.com, [4]Honeybee Robotics, 398 West Washington Blvd, Suite 200, Pasadena, CA 91103, paulsen@honeybeerobotics.com, [5]Honeybee Robotics, 398 West Washington Blvd, Suite 200, Pasadena, CA 91103, avanesyan@honeybeerobotics.com, [6]Honeybee Robotics, 460 West 34th Street, New York, NY 10001, craft@honeybeerobotics.com.

**Introduction:** Every ten years National Research Council carries out a "decadal survey" for planetary science [1]. This survey is the primary input that NASA and National Science Foundation use to design their programs of planetary science and exploration. The recent Planetary Science Decadal Survey recommended to begin NASA/ESA Mars Sample Return campaign with the first of the three missions called the Mars Astrobiology Explorer-Cacher (MAX-C). The goal for the MAX-C rover is to perform in situ science investigations and collect and cache samples (rock cores, soil, and atmosphere). The cached samples would be returned back to Earth by another mission [2].

We have developed a core drill and sample acquisition and caching architecture for the MAX-C mission. The architecture includes a drill with various bits, a deployment device (i.e. robotic arm), and a cache. The main advantage of the system is that each core is housed in individual bits, which are stored in a cache for sample return. Having individual bits for each core simplifies the sample manipulation process, adds redundancy to the sampling system, and reduces cross contamination.

**Mars Sample Return Rotary-Percussive Corer:** The core drill employs a low thrust, low-speed rotary-percussive drilling approach [3]. This enables efficient cutting of rocks at low power and modest preloads. The coring bit is a hollow tube with custom-designed cutting teeth and flutes along the outside of the bit for cuttings transport. Once a desired depth is reached a core is sheared and captured by the core break-off actuator using Honeybee's patented core break-off technique.

The drill includes five actuators (Figure 1). The drill requires <100 Watt to acquire 50 mm long and 10mm diameter cores in hard rocks such as basalt with strength of 120 MPa. The core acquisition operation takes less than 10 minutes when 40 Newton Weight on Bit is applied or approximately 20 minutes using 20 Newton Weight on Bit. The total drilling energy per core is less than 30 Whr.

The drill weighs 5 kg.

**Figure 1. Rotary-Percussive coring drill undergoing testing in 120 MPa basalt. The drill can reach 5cm depth, break-of the core and capture it in 10 minutes**

**Mars Sample Return Architecture:** The proposed architecture consists of three elements: (1) a rotary percussive drill with integrated core break-off and retention system, (2) a 5-DOF robotic arm for positioning of the drill on a rock, and (3) a bit carousel with an earth return cache [4]. The drill acquires and retains 1 cm diameter and 5 cm long cores. The core, together with a drill bit, is inserted into an Earth return cache or a bit storage carousel (Figure 2). A new drill bit is attached to the drill for acquisition of the next rock core. Once the cache is full, the arm places the cache on the ground, to be later picked up by a fetch rover.

The same drill also uses custom drill bits for brushing and abrading of rock surfaces, for rock powder acquisition and for acquisition of short cores for in-situ analysis. These bits are used for rock interrogation prior to acquisition of cores for sample return. After the cache is placed on the ground and primary mission is over, these bits enable further exploration of the Martian near subsurface (Figure 3).

The sample acquisition operation may follow the following steps. First, the rock will be analyzed by non-contact instruments. If the rock is of interest, the surface will be brushed and re-analyzed. If the results are encouraging, the surface will be abraded and analyzed again (this is the approach currently used on Mars Exploration Rovers using Rock Abrasion Tools). If the results on the abraded surface are encouraging, the core drill can be used to acquire small core for in situ analysis. This can be followed by a powder acquisition drill. Powder could be analyzed by instruments such as X-Ray Diffraction or Mass Spectrometer. Once the results from all the investigations confirm the rock represent a high scientific interest, the 5 cm drill bit is used to acquire a 5 cm core. The bit with the core inside is then cached for return to Earth.

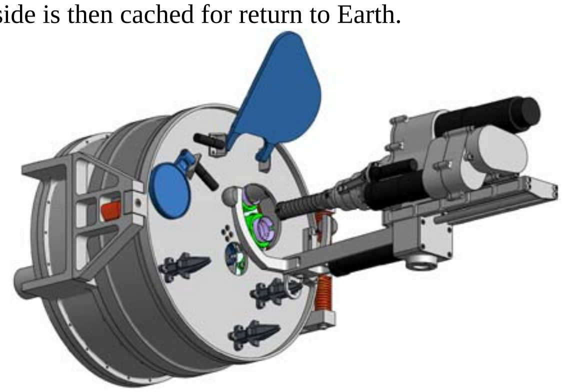

**Figure 2. Drill mates with the Cache and deposits a bit (with a core inside it) directly into the Cache. A new bit is then acquired for the next core.**

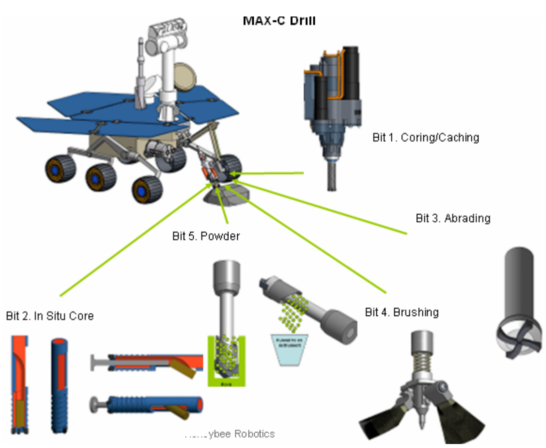


**Figure 3. Example of the suite of bits that can be used with the MAX-C drill.**

**References:** [1] Planetary Science Decadal Survey, http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412, [2] Mattingly Mars Sample Return as a Campaign, IEEE Aerospace conference. [3] Zacny et al., (2011), Prototype Rotary Percussive Drill for the Mars Sample Return Mission, Paper #1125, IEEE Aerospace conference. [4] Zacny et al., (2011) Honeybee Approach to the Sample Acquisition and Caching Architecture for the 2018 Mars Sample Return Mission, Paper #1573, IEEE Aerospace conference

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