DRILL MISSION WITH 5 BITS: BRUSHING AND ABRADING BIT, POWDER AND REGOLITH BIT, PREVIEW BIT AND CACHING BIT: PRECURSOR TO THE MARS SAMPLE RETURN MISSION. K. Zacny[1], P. Conrad[2], P. Mahaffy[2], W. Brinckerhoff[2], A. Steele[3], D. Blake[4], S. Anderson[5], [1]Honeybee Robotics - Pasadena, zacny@honeybeerobotics.com, [2]NASA GSFC, [3]Carnegie Institution of Washington, [4]NASA ARC, [5]Southwest Research Institute.

Introduction: The goal of the future MSR mission 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. The mission concept presented here might not be 'low-cost' but given additional funding, it would offer great scientific value and technology demonstration.

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. This significantly reduces sample handling complexity and almost entirely eliminates cross contamination. 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.

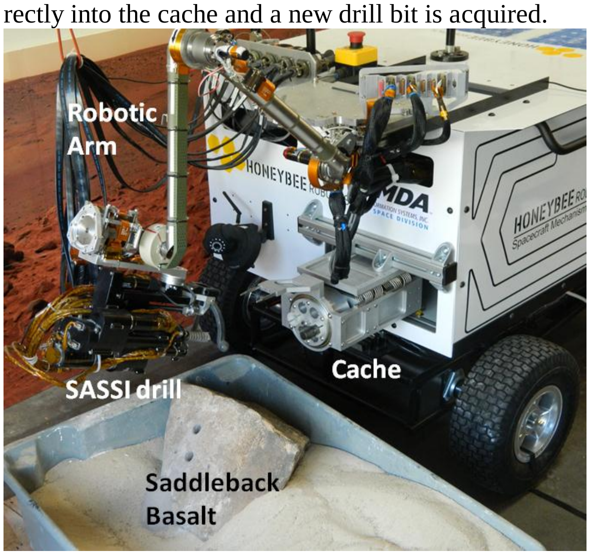

Figure 1. Sample Acquisition and Caching system.

Bits for In-Situ Investigations: To enable in-situ rock and regolith analysis we developed three bits: a combined Brushing and Abrading Tool (BAT), a core PreView Bit, a Powder and Regolith Acquisition Bit (PRAB), and caching bit as shown in Figure 2 [2, 3, 4]. The sequence of operation is shown in Table 1.

The BAT uses the same approach as the Rock Abrasion Tool on the Mars Exploration Rovers to brush and abrade rocks. 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. The PRAB acquires soil or rock powder for analysis.

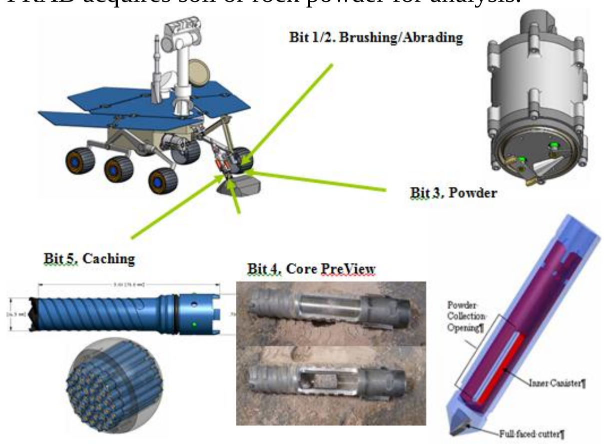

Figure 2. 5in1 approach: 5 unique bits for different tasks deployed form the same drill.

Table 1. Possible rock interrogation scenarios.

Step	Action	Bit Type
1	Analyze a rock surface	
2	Brush and Analyze a rock surface	Brushing Bit (e.g. DRT on MSL or RAT on MER)
3	Abrade and Analyze a rock surface	Abrading bit (e.g. RAT on MER)
4	Take a short core and Analyze the core	Preview Bit
5	Take powder and Analyze powder	Powder bit (e.g. MSL drill)
6.	Take 5 cm core and place it inside a cache	

Brushing and Abrading Tool (BAT): The BAT is based on the MER RAT (see Figure 3) and takes an advantage of its flight heritage and quantifiable performance on Mars in various rock types, ranging from soft to hard (the RAT Spirit performed 15 grinds in harder rocks, the RAT Opportunity performed 38 grinds in softer rocks).

The BAT creates a surface ~35 mm in diameter and weights ~ 360 grams (this can be further optimized). An estimated life of the bit based on the RAT-data and increasing the grinding bit volume is 45 operations in hard rocks and 120 operations in softer rocks. The RAT on MER Spirit performed close to 100 brushings, hence BAT will be able to perform at least as much.

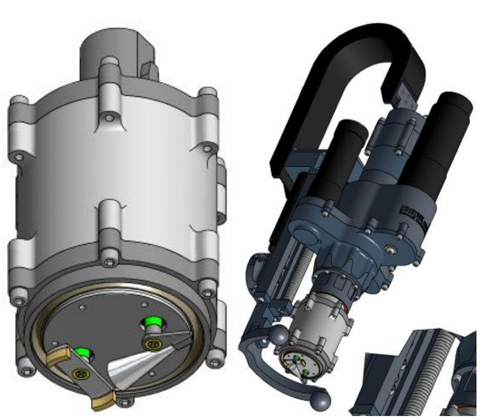

Figure 3. Concept of Brushing/Abrading Tool (BAT) based on MER Rock Abrasion Tool.

Core PreViewBit. The PreView bit acquires short cores and directly enables point-by-point analysis by laser-based instruments such as the Mars Organic Molecule Analyzer (MOMA) [5], an in situ geochronology instrument [6], or other active techniques such as LIBS or Raman spectroscopy. The PreView Bit has side slots in the break-off tube and the auger tube as shown in Figure 4. The bit takes advantage of the Honeybee break-off system utilizing two rotary-systems: an inner rotating sleeve to shear and capture the core and outer auger/bit. During drilling, the internal break-off tube is rotated to open the side slot. During the break-off stage, the inner tube is rotated so as to close the side slot and at the same time shears and captures the core. Hence the captured core cannot fall out. During the core dispensing stage, the break-off tube is rotated to open up the slot.

Figure 4. The Preview Bit. (L): after reaching the target depth, break-off tube is rotated to shear and capture the core. Once the tube is fully closed (C), the core cannot fall out. To view the core, the break-off tube is rotated back to expose it. (R)

Powder and Regolith Acquisition Bit (PRAB): The Powder/Regolith Bit can be used to acquire rock cuttings during the drilling process (as is done by the MSL drill), and it can also be used to acquire regolith for XRD (e.g. CheMin see also [7]) (see Figure 5). Once the bit acquires rock powder or planetary regolith, the sample can be either dispensed into an instrument inlet port, observation tray, or cached for earth return along with rock cores.

The principle of the bit operation is very similar to that of the PreView bit in that there are slots within the break-off tube and the auger. When the slots are aligned, the regolith or rock powder can flow into the inner cavity. When the slots are closed (the inner tube is rotated with respect to the outer auger) the powder inside the bit is retained.

The PRAB has integrated sieves and can either acquire particles below sieve size, retain particles above certain sieve size.

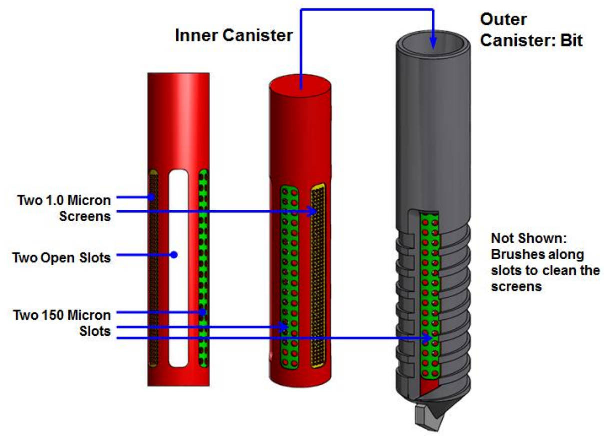

Figure 5. Powder and Regolith Acquisition Bit (PRAB) with integrated sieves.

References: [1] Beaty et al. (2010) Proposed Mars Astrobiology Explorer-Cacher (MAX-C) Rover, LPSC. [2] Zacny et al., (2011) Approach to the Sample Acquisition and Caching Architecture for the 2018 MSR, #1573, IEEE [3] Zacny et al., (2011), Prototype Rotary Percussive Drill for the MSR, #1125, IEEE [4] Zacny et al., (2011) Development of the Brushing, Abrading, Regolith, Core PreView and the Coring Bits for the MS , AIAA Space. [5] Brinckerhoff et al., (2012), Mars Organic Molecule Analyzer Mass Spectrometer for 2018 and Beyond, LPI. [6] Anderson et al., (2012) A Laser Desorption Resonance Ionization Mass Spectrometer for Rb-Sr Geochronology: Sr Isotope Results, IEEE, [7] Blake et al., (2012) Quantitative Mineralogy, Sample Acquisition and Analysis on Smaller and More Capable Rovers and Landers in the Post MSL Era, LPI