ASTRONAUT DEPLOYABLE SAMPLING, DRILLING, AND GEOTECHNICAL TOOLS. K. Zacny, G. Paulsen, S. Indyk, P. Chu, Z. Mank, Honeybee Robotics (zacny@honeybeerobotics.com).

Introduction: Over the past three decades, Honeybee Robotics has been developing numerous geo-related tools for robotic exploration [1]. Some of these tools have been modified and deployed in various planetary analog field sites around the Earth. The knowledge gained from these deployments helped to design tools for astronaut deployment.

Surface (Rock) Coring Drill: The surface coring drill has been designed specifically for capturing rock cores from large boulders or rocks too large to be transported back to Earth.

The coring bit is using Honeybee-patented core break off technology – the core is not just broken at the bottom, but also securely retained inside the core bit [2]. This technology has been selected by NASA JPL for its Mars2020 coring drill (first step in the Mars Sample Return campaign). The diameter and length of a core can be modified to meet science requirements. However, we selected baseline dimensions of 1 inch in diameter and 4 inch long to allow fabrication and testing. The coring bit is deployed using rotary-percussive drill based on our surface robotic systems, such as RoPEC [3].

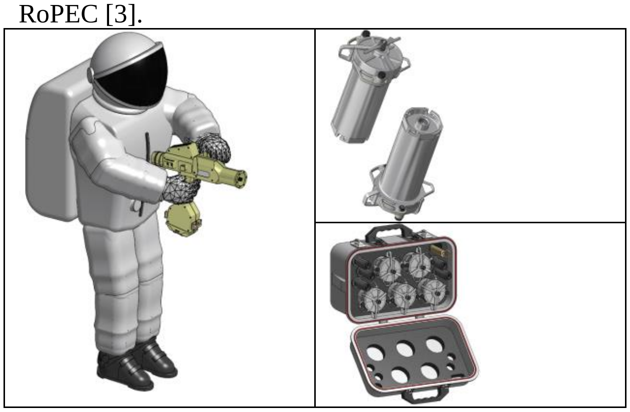

Figure 1. Astronaut deployable coring drill and hermetic seal canister.

In the nominal operation, astronaut would preload the drill against the surface and pull the trigger (Figure 1). Drill would then automatically rotate/hammer and extend the drill bit according to pre-defined drilling parameters. As such, the astronaut would just need to keep the drill preloaded (we call it 'preload and forget'). Once the drill bit has reached its target depth, astronaut would reverse drill rotation to break off and capture the core.

To store the core, each bit would be sealed inside its own canister. This provides a secure containment of the entire bit assembly and the rock core. The sealing system is hermetic and has already been designed and tested for sample return mission [4].

A prototype coring system has been developed and tested in the Atacama, Arizona, and Hawaii (Volcano National Park), as well as laboratory [5]. It uses commercial hammer bit (for cost reduction purposes) and Honeybee custom coring bit (Figure 2).. The system went through 4 design/field test iteration. The final design has been shown to capture rocks from very hard rocks (basalt) and friable material.

Figure 2. Prototype core drill system has been tested in several planetary analog field sites.

Deep Coring Drill: The deep coring drill (Figure 3) is based on the TRIDENT drilling system developed for VIPER rover [6]. The TRIDENT bit is full faced for capture of fines, but can be easily substituted for a coring drill. The system has a lot of similarities with the Apollo Lunar Surface Drill but it solves some of the problems that astronauts encountered while drilling on the Moon.

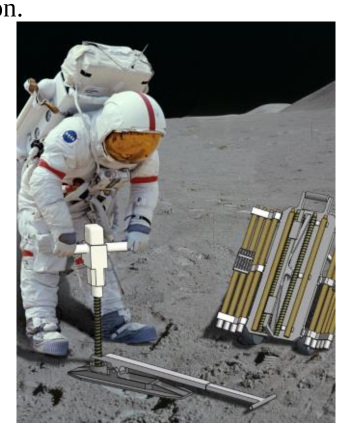

Figure 3. Concept of a deep drill.

Honeybee developed several man-deployable prototypes ranging from 1 m to 5 m depth. The 1-2 m coring system was deployed in the Atacama, Greenland, Antarctica, the Arctic, and Dumont Dunes while the 5 m was deployed in Hawaii on the slopes of Mauna-Kea in volcanic tephra (Figure 4). The drill auger was deployed using commercial hammer drill, but for the lunar purposes, a custom drill based on TRIDENT drill head would be built. The power of the drill head will be in the 500 Watt range, mainly to address auger torque requirements.

Figure 4. 1-5 m class drill deployed in various locations in planetary analog sites.

Geotechnical systems: Honeybee Robotics developed several types of near surface (trafficability) and deep (ISRU, mining, construction) geotechnical tool for measuring soil cohesion and friction angle (two fundamental properties from which soil strength and density can be derived) [7]. These tools have bee deployed and tested in the Atacama as well as the Arctic (Devon Island – see Figure 5). The field deployment allowed testing of the concept of operation as well as ease of operation.

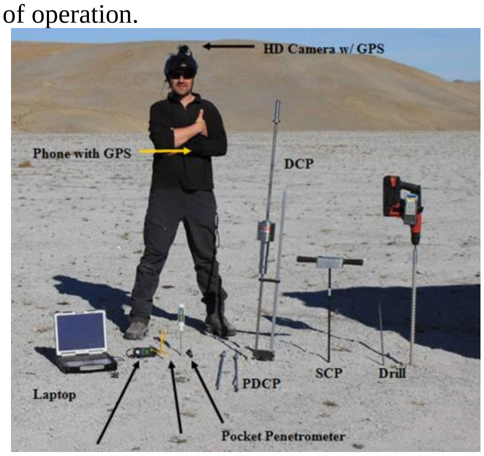

Figure 5. Geotechnical tools deployed in the Arctic.

The systems include traditional push-cone penetrometer – similar to the one deployed by the Apollo. This approach required significant push force. Another tool called Percussive Dynamic Soil Penetrometer (PDCP) used percussion to help drive the rod into the soil – this significantly reduced push force.

The Stinger has been initially developed as a robotic tool and has been tested in the Atacama on a NASA Ames KREX2 rover. The tool allows for measuring of the bearing capacity and shear strength independently (and in turn more accurately). Figure 6 shows a concept for manual deployment.

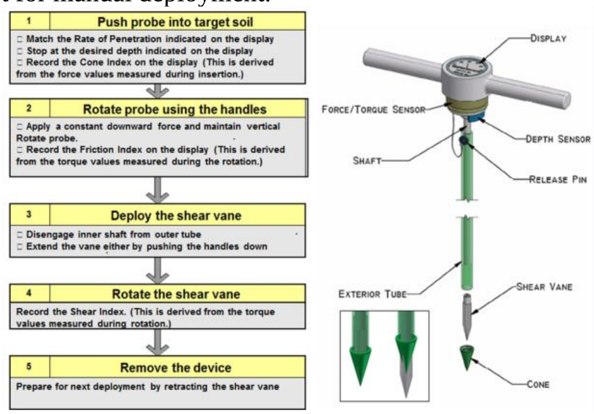

Figure 6. Stinger allows measuring of bearing capacity and shear strength independently.

Corner Cube Reflector: The corner cube reflector for lunar ranging was pneumatically deployed to 50 cm depth in Hawaii, on the slope of Mauna Kea in volcanic tephra (Figure 7). The anchoring of the corner cube at >50 cm depth on the Moon, would provided constant thermal environment and in turn significantly improvement (order of magnitude) in ranging accuracy.

Figure 7. Pneumatic deployment of a corner cube reflector.

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References: [1] Bar Cohen and Zacny, 2009, [2] Myrick, T (patent), 1998, [3] Chu et al., AMS, 2014 [4] Zacny et al., IEEE, 2013, [5] Zacny et al., LPSC 2017, [6] Paulsen et al., AMS, 2018 [7] Zacny et al., Earth and Space, 2010, [8] Zacny et al., PSS, 2012.