LUNAR RESOURCE PROSPECTOR DRILL. K. Zacny[1], G. Paulsen[1], Kleinhenz[2], J. Smith[3], J. Quinn[3], [1]Honeybee Robotics, Pasadena, CA, zacny@honeybeerobotics.com, [2]NASA Glenn Research Center, Cleveland, OH, [3]NASA Kennedy Space Center, FL

Introduction: The goal of the Lunar Resource Prospector Mission (RPM) is to capture and identify volatiles species within the top meter of the lunar regolith [1]. Water and volatiles are not only of interest for science investigations but also as source of valuable resource. The RPM drill has been designed to 1. Generate cuttings and place them on the surface for analysis by the the Near InfraRed Volatiles Spectrometer Subsystem (NIRVSS), and 2. Capture cuttings and transfer them to the Oxygen and Volatile Extraction Node (OVEN) coupled with the Lunar Advanced Volatiles Analysis (LAVA) subsystem.

The RPM drill is based on the Mars Icebreaker drill developed for capturing samples of ice and ice cemented ground on Mars [2-4]. The drill weighs approximately 10 kg and is rated at ~400 Watt. It is a rotary-percussive, fully autonomous system designed to capture cuttings for analysis. The drill consists of: 1. Rotary-Percussive Drill Head, 2. Sampling Auger, 3. Brushing station, 4. Z-stage, 5. Deployment stage (**Figure 1**).

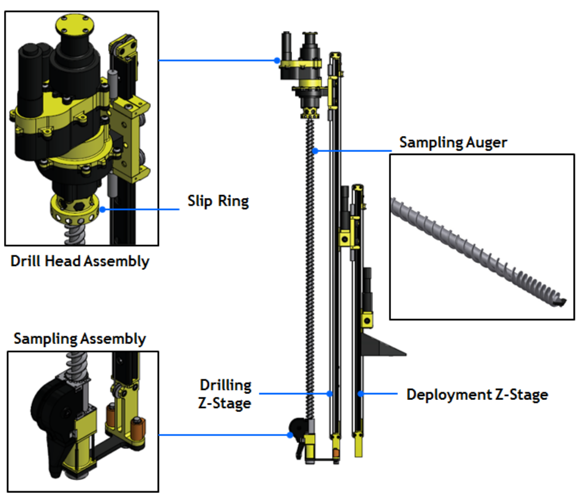

Figure 1. Lunar Resource Prospector Drill subsystems.

To reduce sample handling complexity, the drill auger is designed to capture cuttings as opposed to cores. High sampling efficiency is possible through a dual design of the auger. The lower section has deep and low pitch flutes for retaining of cuttings. The upper section has been designed to efficiently move the cuttings out of the hole. The drill uses a "bite" sampling approach where samples are captured in ~10 cm intervals (**Figure 2**). The drill penetrates subsurface in 10 cm depth intervals and upon capture of a 10 cm sample, it retracts back to the surface. The sample is then either discarded or transferred to an instrument cup. A Near Infrared Spectrometer could view the cuttings as they fall onto the ground to determine if the sample is volatile rich and in turn decide whether to send a sample to a GCMS. To capture next sample, the drill is lowered back into the same hole and the process repeats. This approach has many advantages. The stratigraphy is somewhat preserved because a 1 meter hole is now represented by 10 samples. Lowering the drill into a hole each time allows measuring of subsurface temperature and in turn plotting of thermal gradient. When a sample is being analyzed, the drill is above the hole and in turn in a safe position. Moving the drill out of the hole also allows the drill and the subsurface to cool down.

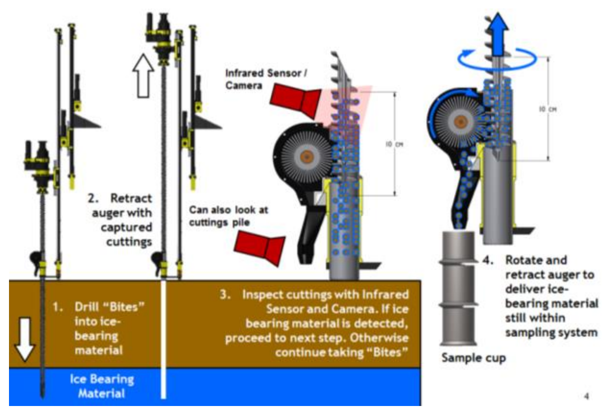

Figure 2. "Bite" Sampling approach.

The first generation drill was tested in Mars chamber as well as in Antarctica and the Arctic. It demonstrated drilling at 1-1-100-100 level (1 meter in 1 hour with 100 Watt and 100 N Weight on Bit) in ice, ice cemented ground, soil, and rocks.

The second generation drill was deployed on a Carnegie Mellon University rover, called Zoe, and tested in Atacama in 2012. The tests demonstrated fully autonomous sample acquisition and delivery to a carousel.

The third generation drill was tested in NASA GRC's vacuum chamber, VF13, at 10-5 torr and approximately 200 K (**Figure 3**). The RPD successfully delivered six samples to the six crucibles. The average drilling power was 30 Watt (including actuator losses), Weight on Bit was ~10 Watt or less, while Penetration Rate was software limited to 2 mm/sec. Percussive actuator engaged only several times during the process, while majority of drilling was done with rotary approach, only. The bit temperature while the drill was in the hole was approximately – 80 °C and no temperature increase was observed during drilling indicating the thermal changes to the sample due to the drilling process were minimal.

Figure 3. Lunar Resource Prospector Drill mounted inside VF13 lunar chamber facility at NASA Glenn Research Center.

In early 2015, the drill has been modified for integration onto the NASA JSC RPM rover prototype. In the summer of 2015, the drill has been undergoing numerous tests at NASA JSC to show autonomous sample capture and delivery from a roving platform (**Figure 4**).

Figure 4. Lunar Resource Prospector Drill mounted on the NASA JSC rover.

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Acknowledgements: The project has been funded by the NASA Small Business Innovation Research and NASA Advanced Exploration Systems.