TRL6 LUNAR RESOURCE PROSPECTOR DRILL. G. Paulsen[1], K. Zacny[1], D. Kim[1], Z. Mank[1], A. Wang[1], T. Thomas[1], C. Hyman[1], B. Mellerowicz[1], B. Yaggi[1], Z. Fitzgerald[1], A. Ridilla[1], J. Atkinson[1], J. Quinn[2], J. Smith[3], J. Kleinhenz[4] [1]Honeybee Robotics, Pasadena, CA, zacny@honeybeerobotics.com, [2]NASA Kennedy Space Center, Florida, 32899, jacqueline.w.quinn@nasa.gov, [3]NASA Kennedy Space Center, Florida, 32899, james.t.smith@nasa.gov, [4]NASA Glenn Research Center, Ohio, julie.e.kleinhenz@nasa.gov

Introduction: For over a decade, Honeybee Robotics has been developing a 1 m class sample acquisition drill for acquisition of volatile rich samples from planetary surfaces. The latest drill system is at TRL6 and ready to be infused into future missions requiring acquisition of samples from up to 2 m depth (the drill is scalable with respect to the depth). The near term mission with the requirement for capturing of volatile rich samples is the Resource Prospector or RP.

TRL development: The technology for 1 m class drill started with the development of the TRL4 Icebreaker drill for the Mars Icebreaker mission [3, 4]. The drill has been extensively tested in the Arctic, Antarctica, and Mars chamber. The system demonstrated drilling in rocks, ice cemented ground, and ice with low power (100-200 Watt), low Weight on Bit (<100 N) and high penetration rate (1 m/hr). The next generation drill called the LITA drill (Life In The Atacama) achieved TRL 4/5 through significant reduction of mass (the Icebreaker drill weighed 40 kg while the LITA drill weighed 10 kg). The LITA drill has been deployed from a CMU rover in Atacama and in Greenland. A LITA drill has been modified to reach TRL5. It has subsequently been deployed from a Resource Prospector rover at NASA JSC and has undergone thermal vacuum tests at NASA GRC [7]. During these vacuum tests, the drill captured volatile rich samples (NU-LHT-3M with 5wt% water) at -100 °C and deposited them into cups. The drill has also been placed on a vibrating table to determine needed location for launch locks. The latest drill, called the Resource Prospector drill (after the mission it was originally designed for), is at TRL 6.

Resource Prospector: The goal of the Resource Prospector (RP) is to land at the Southern Polar Regions of the Moon, traverse into volatile-rich areas, and perform detailed analysis of volatile content in lunar regolith to a depth of 1 meter [1]. This is a natural next step in lunar exploration, since vast volatile resources have been identified on the Moon in recent years. This reconnaissance missions would also pave the way for any future science and In Situ Resource Utilization (ISRU) endeavors to the Moon and also Mars.

The roving platform is a powerful reconnaissance vehicle; with carefully selected instruments to achieve required goals in the shortest time possible (Figure 1).

The Neutron Spectrometer Subsystem (NSS) is mounted at the front of the rover with a goal of searching for hydrogen rich hot spots [2]. Since hydrogen is an excellent proxy for water, NSS will guide the rover in search for water. Once hydrogen hot spot has been identified, the rover will park directly above it and deploy Resource Prospector Drill or RPD.

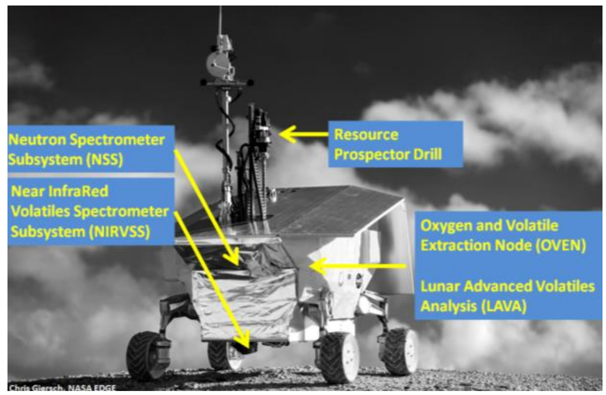

Figure 1. The Resource Prospector (RP) with its five subsystems.

The goal of RPD is to penetrate up to 1 meter depth, deliver cuttings to the surface and capture subsurface volatile rich sample for analysis. The RPD uses a sampling technique called “Bite” sampling which is akin to peck drilling or pecking in machine shop terminology. To enable efficient drilling, machinist frequently lifts a fast spinning drill bit out of the hole and clears the hole of metal chips. In the similar way, during “Bite” sampling, the RPD retracts every 10 cm or so (could be more or less depending on mission requirements and material being drilled) and empties cuttings onto the surface or into a sample delivery receptacle [3, 4]. This particular approach has many advantages. Drilling power can be kept to minimum since parasitic losses driven by auger convening samples from the depth to the surface are eliminated. Upon retracing, the mission can take time analyzing the sample while the drill is above the hole – in its safe location. Periodically lifting the drill out of the hole allows the hole to cool down (if drilling generates a lot of heat). Since drill bit has an integrated temperature sensor to monitor bit temperature during drilling, the same sensor could be used to capture thermal data of the hole every time the drill is lowered back into the hole. This is an opportunistic science data that would contribute to the heat flow measurements on the Moon.

The samples deposited onto the ground during drilling are first analyzed by the Near InfraRed Volatiles Spectrometer Subsystem (NIRVSS). NIRVSS is mounted so that its sensor is pointed to the location where the drill deposits the sample [5]. The goal of NIRVSS is to characterize hydrocarbons, mineralogical context for the site, and the nature of water ice and in turn determine whether the sample should be further analyzed or not.

If the sample is of high scientific and exploration value, the RPD is commanded to deposit sample into the Oxygen and Volatile Extraction Node (OVEN). The OVEN will heat up captured sample and transfer evolved volatiles into the Lunar Advanced Volatiles Analysis (LAVA) subsystem [6]. LAVA is a Gas Chromatography Mass Spectrometer (GC/MS) instrument which will in turn quantify and characterize volatile species. The OVEN has a secondary goal to demonstrate hydrogen reduction process, while LAVA will perform Water Droplet Demonstration (WDD).

The TRL6 RP Drill: The TRL6 RP Drill can be divided into four main components: Drill Head, Auger/Bit Assembly, Deployment Stage, and Feed Stage. The Drill Head weighs approx. 5 kg and uses two actuators for Percussion and Hammer. Percussive actuator is rated for 300 Watts and can deliver up to 4 Joules per blow at 1160 blows per minute. The Auger actuator is rated at approx. 300 Watts and it can rotate the auger at 120 rpm. The maximum auger continuous torque capability is 15 Nm. The Drill Head includes a four channel slipring for transmitting temperature signals from RTD embedded inside a drill bit to an electronic box in the rover.

The drill bit diameter is 1 inch (2.54 cm) and auger length is 119 cm which is sufficient to penetrate at least 102 cm below the surface. The diameter is sufficient to capture desired volume of cuttings (12 cc) per 10 cm depth.

The drill Deployment Stage has a stroke of 80 cm and as such, the drill can be placed on the rover deck up to 80 cm above the ground. Both the Deployment Stage and the Feed Stage are rated for 500 N pull/push forces. Both stages use cable-pulley architecture which helps with vibration attenuation and is also dust tolerant (an important factor on the Moon covered with highly abrasive regolith).

The drill weighs 15 kg, however, for flight the estimate is 20 kg since additional hardware (e.g. launch locks etc.) need to be added. The mass estimate does not include drive electronics. Current volume (when stowed) is 176 cm x 21.5 cm x 27.1 cm. The drill has been designed for a max and min survival temperatures of +70°C and -233°C, respectively. The operational max and min temperatures (assuming heaters can be used to elevate the temperature on mechanisms) are +50°C and -60°C, respectively.

Figure 2. TRL6 Resource Prospector Drill (RPD).

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