LUNAR RESOURCE PROSPECTOR DRILL. K. Zacny[1], G. Paulsen[1], A. Wang[1], B. Yaggi[1], J. Quinn[2], J. Smith[3], [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

Introduction: 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.

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 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 underneath the belly of the rover and 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).

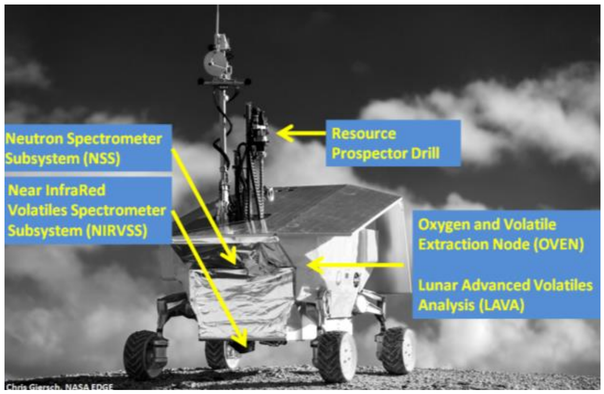

Figure 1. The Resource Prospector (RP) with its five subsystems.

The RP Drill Development: Over the past decade, we have been developing one meter class rotary percussive drill systems designed for acquisition of volatile rich samples from approx. 1 meter depth on the Moon and Mars. The technology readiness level or TRL, slowly climbed through various drill iterations: CRUX (TRL3), IceBreaker (TRL4), and LITA (TRL5). The latest drill, the Resource Prospector Drill (RPD) is currently being developed with a goal of reaching TRL 6 in 2016.

As the technology climbs up the TRL ladder, it's important to take advantage of the lower TRL technology to have a head start on the higher TRL system. The LITA drill system has undergone minor modifications to enable testing under lunar like conditions in the NASA Glenn Research Center lunar vacuum chamber [7] and integration and testing on the RP rover at

NASA Johnson Space Center. The next critical tests included vibration testing and slope testing as described below.

Vibration Testing: The goal of vibration testing is to subject hardware to the same vibrations it will experience on route to its destination and in turn to determine if it will survive it. This includes for example vibrations during launch while on top of a launch vehicle; during burns while changing trajectory in space; and during Decent and Landing on the Moon. Each of these steps has characteristic vibration frequency and amplitude.

The first step towards understanding the systems vibration response was to use finite element analysis (FEA) to determine the vibration modes of the system, stresses in the structure, and deflections of the structure. The second step was to perform actual vibration tests at NASA KSC (Figure 2). Vibration tests have been completed in December of 2015. The results are still being analyzed in detail, however, the major outcome is that the drill survived all vibrational environments and validated the preliminary FEA.

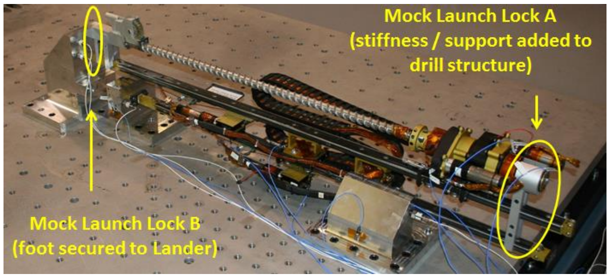

Figure 4. LITA drill setup for Vibration Tests at NASA KSC.

Slope Tests: During operation on the Moon, there is some possibility that the rover will need to climb up a steep slope and capture samples at this position. In order to determine whether drilling on a steep slope is possible, a series of tests were performed in a laboratory simulating these off-nominal scenarios. The main risk of steep slope deployment is possibility of rover slip that would create high side loads on the drill auger. In the worst case scenario, one can imagine the drill might get stuck permanently if rover slip is significant and side loads are high.

Both LITA drills were used so tests could be performed at two locations. One of the LITA drills was mounted to the RP rover for the gravity off load tests and slope tests at NASA JSC using the Active Response Gravity Offload System (ARGOS). The second drill was mounted to the Honeybee mockup rover at Honeybee facilities in Pasadena, CA (Figure 3). The purpose of the tests in Pasadena was to determine drill response and recovery to off nominal cases and in turn guide the system level tests at NASA JSC off RP rover.

At Honeybee tests, the drill was commanded to penetrate to 75 cm depth. In each test, the drill was retracted and also rotated at 20 rpm since rotation reduces auger torque if side forces are applied. The maximum auger current was 2.9 A at 20° lunar equivalent slope, while the maximum side force was 162 N. The drill successfully retracted in each test.

During ARGOS tests, the rover did not slip even on the 20° slope. As such, a force of 150 N was applied to induce slip. The drill successfully penetrated to a 40 cm depth and was retracted back out of the hole.

Figure 3. Slope tests at Honeybee (left) and JSC (right).

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