LUNAR PROSPECTING ROVER UTILIZING SAMPLING DRILL THE MOONBREAKER, PNEUMATIC EXCAVATOR, AND JET TRENCHER. K. Zacny[1] , P. Chu[2], G. Paulsen[3], J. Craft[4], [1]Honeybee Robotics, 398 West Washington Blvd, Suite 200, Pasadena, CA 91103, zacny@honeybeerobotics.com, [2]Honeybee Robotics, 1110 Nasa Parkway, Suite 440, Houston, TX 77058, chu@honeybeerobotics.com, [3]Honeybee Robotics, 398 West Washington Blvd, Suite 200, Pasadena, CA 91103, paulsen@honeybeerobotics.com, [4]Honeybee Robotics, 460 West 34th Street, New York, NY 10001, craft@honeybeerobotics.com.

Introduction: Lunar In Situ Resource Utilization (ISRU) requires groundtruthing of the water-ice deposits in 3D (lateral and below the surface). This requires the lunar prospecting mission to be mobile (rover, hopper etc.), and have a suite of instruments enabling downhole access and acquisition of icy samples for analysis.

We developed a rover-based system that combines three independent instruments for groundtruthing of water-ice deposits. These include Sampling Drill called the MoonBreaker, Pneumatic Excavator, and Jet Trencher. All three systems are at Technology Readiness Level (TRL) of 5 or higher.

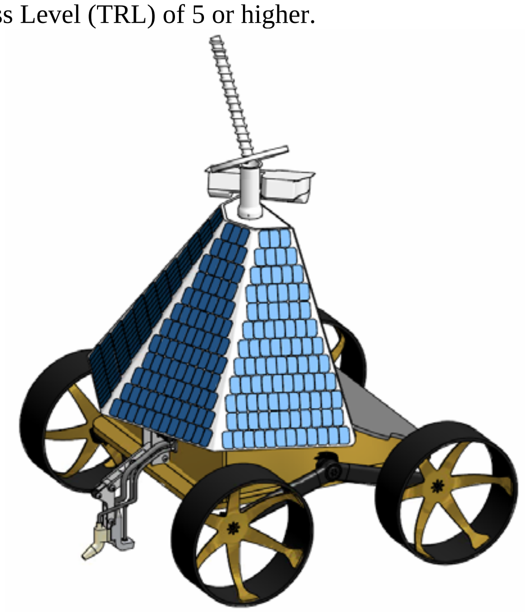

Figure 1. Lunar Mobile Prospector with Honeybee Robotics MoonBreaker Drill, Pneumatic Excavator and Jet Trencher. The three excavation systems were baselined for Astrobotic rover.

The MoonBreaker drill: The MoonBreaker drill was designed to fit a low mass rover system, such as Astrobotic rover, though the system can be deployed from any other mobility or static planetary platforms (Figure 1). The drill could potentially fly to the Moon during 2014 mission opportunity, which will be the first lunar drilling missions since the Soviet Luna 24 sample return mission in 1976.

The MoonBreaker was designed to account for all environmental and technical challenges associated with lunar drilling [1]. The drill will be able to drill over 50 cm into the lunar subsurface and retrieve samples in the form of cuttings. Samples will be transferred into a belly of the rover where they can be analyzed by various instruments (Figure 2).

The system was tested in a vacuum chamber under lunar-like conditions of low temperature, vacuum, and analog formations such as ice saturated JSC-1a lunar soil simulant, ice, and rock. It was also tested at the lunar analog site in the Antarctic in ice cemented tephra [2]. The MoonBreaker demonstrated drilling at 1-1-100-100 level; that is the drill penetrated 1 meter in 1 hour with 100 Watts and 100 Newton Weight on Bit. At the same time, the temperature of the drill bit measured by an embedded thermocouple did not exceed more than 10 °C above the formation temperature. This difference of 10 °C between the cuttings and the formation is crucial for volatiles retention and shows that the temperature of the cuttings acquired by the drill will not change drastically from their in-situ temperature.

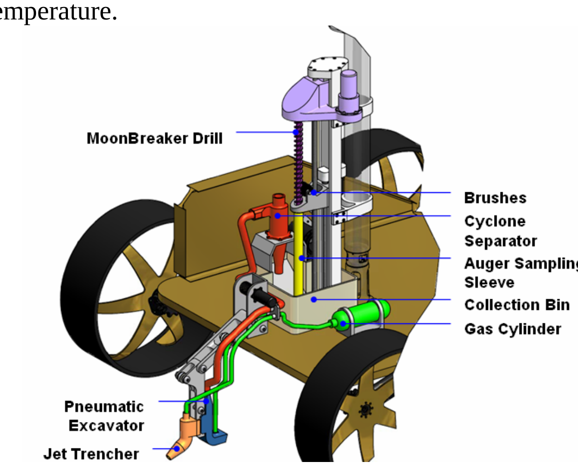

Figure 2. Details of the MoonBreaker Drill, Pneumatic Excavator and Jet Trencher.

The drill system uses two passive ways of sample acquisition. The cuttings are being conveyed all the way to the deck of a rover, where they either gravity fall or are brushed off directly into an instrument or In Situ Resource Utilization plant or some over sample transfer or processing system. This sampling system has been shown to work with sticky and non-sticky samples.

The drill was operated semi-autonomously with only three basic commands being issued by the drill operator: seek, drill, and pull-out. The actual drill health monitoring utilizing drilling telemetry and bit temperature was done autonomously by the drill software. The MoonBreaker drill was also teleoperated in the Antarctic from California, demonstrating potential teleoperation of the lunar drill from Earth [3].

Pneumatic Excavator: The goal of the pneumatic excavator is to acquire the top regolith layer into a sample bin onboard of the rover. The system is similar to a conventional vacuum cleaner; however instead of creating suction at the nozzle mouth, a compressed gas is injected. The gas essentially accelerates the soil within the nozzle up the tube and through the cyclone separator into a soil bin. The K10mini rover based pneumatic excavator has been tested in a vacuum chamber in GRC-1 lunar soil simulant and successfully acquired soil into a rover mounted bin [4]. The main advantage of this system is that it has essentially no moving parts and in turn it is well suited to the abrasive lunar environment. It can also acquire larger volumes of regolith than a drill system.

The efficiency of gas in vacuum has been tested in a vacuum chamber and lunar gravity during reduced gravity flights [5]. The test results showed that 1 gram of nitrogen gas at 6 psia can loft 6000 grams of JSC-1a lunar soil simulant at high velocities. Since the tests were conducted at 3 torr vacuum, the actual efficiencies in hard lunar vacuum will be much higher. The main reason for these high efficiencies is that gas exit velocity from the gas canister is controlled by the pressure ratio. If pressure on the outside is zero, as is the case on the Moon, the exit velocity reaches choking velocity, and hence momentum of gas molecules reaches a very high value. In fact cold jet thrusters use compressed gas for attitude control and are often preferable to fuel based rocket thrusters.

Jet Trencher: The jet trencher uses compressed gas to remove the top granular overburden and excavate a deep and wide trench with a goal of exposing icy layers. The system is analogues to using compressed air or high pressure water-jets to clean or cut into surfaces on earth. The jet trencher is a passive system. The depth of the trench is varied by varying gas pressure exiting the nozzle. The nozzle shape will also define the shape of the trench. A flat nozzle can excavate wider trench, while a round nozzle will excavate a deeper trench. Once excavated the trench walls and bottom of the trench will be examined by rover based instruments and cameras and look for signature of water-ice.

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