

**3.5m VACUUM CHAMBER FACILITIES ENABLING FULL SCALE DIGGING, DRILLING AND PENETROMETRY TESTS.** K. Zacny<sup>1</sup>, G. Paulsen, J. Craft, J. Wilson, and M. Maksymuk. <sup>1</sup>Honeybee Robotics Spacecraft Mechanism Corp. (zacny@honeybeerobotics.com).

**Introduction:** In order to bring the sampling technologies into the required Technology Readiness Level (TRL) of 6, the hardware has to be extensively tested under relevant environmental conditions. These conditions are always much different than the conditions we find on Earth, and the exact conditions depend on where (what extraterrestrial body) the system will be deployed on. For example, if the target planet is Venus, the hardware has to be tested at ~90 bar pressure, CO<sub>2</sub> atmosphere and 460 °C temperature. For Mars, the conditions are more benign: low pressure of 1-11 torr, and temperature of the order of -80°C.

Simulating accurate environmental conditions not only is required for demonstrating the hardware, but also to investigate how a sample is behaving during a sample acquisition. Sticking of sample onto a scoop surface on the Mars Phoenix lander would not have occurred if the same sampling system was deployed on the Moon, for example.

In addition to atmospheric conditions (pressure, gas, temperature), it is also important to simulate the appropriate formation (soil, rock, ice). For example, drilling into icy-soils will be different than drilling into icy-soils containing salts (as found by the Phoenix lander). Salts depress freezing point of water and in turn make a sample stickier at even sub-freezing temperatures. Sample acquisition of icy-soils will also be different than sample acquisition of rocks.

In order to address environmental testing of drills, diggers and penetrometers for Mars applications (and to some extent the Moon, and the Asteroids) we developed a large environmental chamber system.

**Vacuum Chamber Description:** Vacuum chamber consists of two smaller chambers assembled on top of each other in such a way that the inner walls are flush (Figure 1). The bottom chamber is 84in tall by 38in x 38in, while the top chamber is 48in by 38in x 38in. Having two chambers instead of one allows the two smaller chambers to be used independently of each other.

The chamber has 20inch flanges on the top and the bottom. This allows inserting additional cylindrical vacuum extension on top in order to accommodate longer penetrometer stage. Putting a similar 20in diameter cylindrical extension at the bottom, allows the vacuum chamber to extend below the floor (into a trench, for example). A rock or a soil sample could be placed in this lower cylindrical section.

The chamber reached 0.01 torr with two pumps. Current pumping system allows the chamber to reach ~1 torr with just one roughing pump and while the chamber was filled with sand (Figure 1). A pressure of 5 torr (Mars pressure) can be reached in just under 15 minutes. The cooling of sample is achieved via a closed loop cooling system.

The chamber so far has been used to test different Mars and Lunar drill systems to a depth of >1 meter.

The chamber was also placed in a horizontal position (Figure 2) to test lunar mining system.



Figure 1. Vacuum chamber in an upright position for testing drills and penetrometers.



Figure 2. Vacuum chamber in a horizontal position for testing lunar mining systems.