RESULTS AND LESSONS LEARNED FROM TESTING OF THE PLANETARY VOLATILES EXTRACTOR (PVEx) AND RELATED ISRU CONCEPTS. P. D. Morrison[1], K. A. Zacny[2], and V. R. Vendiola[2], A. Paz[2] [1]Honeybee Robotics, 398 W. Washington Ave, Suite 200, Pasadena, CA 91103, pdmorrison@honeybeerobotics.com, [2]NASA Johnson Space Center.

Introduction: Honeybee Robotics has a long history of developing prototype and flight surface-preparation, sampling, and sample-processing systems for Martian, Lunar, and other space applications. More recently, Honeybee Robotics has explored a number of In Situ Resource Utilization (ISRU) concepts including the Mobile In-Situ Water Extractor (MISWE) [1], the World Is Not Enough (WINE) water-extraction system [2], and various low-TRL designs [3].

Among these ISRU concepts, the most mature is a system referred to as the Planetary Volatiles Extractor (PVEx) [4].

Planetary Volatiles Extractor (PVEx) consists of a coring auger with an internal heated sleeve that sublimates ice or bound water within a regolith core, and a cold trap with associated plumbing that condenses the released water vapor for capture (Figure 1). The nominal dimensions of the coring auger is 5 cm in diameter and 50 cm long. As such, every time the PVEx is deployed, it captures a volume of material approximately 1000 cc.

However, PVEx can be easily scaled up depending on the volumes of the material required. As such, it can serve as initial reconnaissance tool and a production system. For example PVEx 20 cm in diameter and 1 m long, can capture 3 kg water/hour (assuming 5wt% and 2 g/cc regolith density). A Curiosity size rover with four PVEx systems will therefore capture 12 kg water/hour or 50 MT water / year (assuming 50% duty cycle: 50% water extraction and 50% driving, drilling).

The main attribute of the PVEx approach is that it can perform well in dry and ice cemented regolith. If the subsurface strength is unknown, this type of drilling based ISRU system is one of the few that could be used without worry that the system will not work. Based on our tests, even a small fraction of water (1%) is sufficient to sinter soil grains together forming a competent and strong material that can not be broken up by a scoop [5].

The PVEx system has been tested in limestone rock and solid ice under ambient and cold conditions, and in ice-bearing regolith simulant under vacuum conditions. During all tests, Weight on Bit was kept significantly less than 100 N. The test data is shown in Table 1. It can be seen that PVEx can reach a depth of 50 cm in 6-10 minutes with ~100 Watt of power. It has been therefore shown to be mechanically robust and also capable of efficiently collecting near-surface and subsurface water in various forms. PVEx consistently collected more than 80% of the water within an ice-bearing sample with energy input predominantly going toward ice sublimation (Table 2).

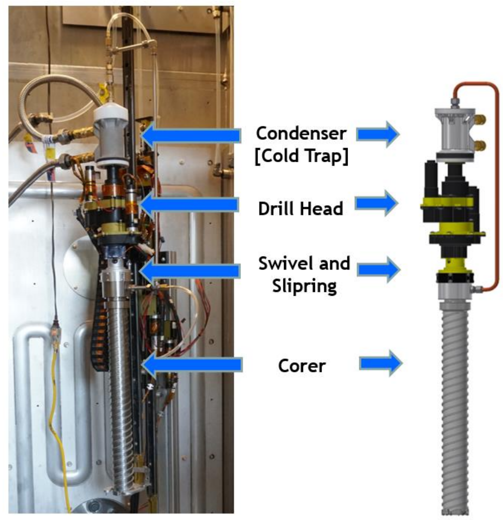

Figure 1. Prototype PVEx and drilling system during setup for vacuum chamber testing.

Table 1. PVEx drilling test results.

Material		Ice at -20C	Limestone
Strength	**MPa**	5	45
ROP	**cm/min**	8	120
Power	**W**	105	5

Table 2. PVEx water extraction test results.

Data Points		15
Energy Efficiency [Whr/g]	**Min**	1.5
	Max	4.4
	Avg	**2.2**
	StDev	0.8
Water Recovery [%]	**Min**	31
	Max	87
	Avg	**65**
	StDev	17

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References: [1] Zacny, K., et al., AIAA Space, 2012-5168. [2] Zacny, K., et al., AIAA Space, 2016-5279. [3] Zacny, K., et al., ASCE Earth and Space, 2016. [4] Vendiola, et al., ASCE Earth and Space, 2018, [5] Atkinson and Zacny, ASCE Earth and Space, 2018.