PAST, PRESENT, AND FUTURE LUNAR DRILLING TECHNOLOGIES

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Introduction: On 22 August 1976, 170 grams of lunar samples were returned to Earth by the Soviet Luna 24 mission. This marked an end to lunar exploration for almost two decades and it was also the last landed lunar mission to date.

The 1990s saw three orbiter missions, of which Lunar Prospector was the most significant. The Neutron Spectrometer data revealed large, potentially water ice deposits in the polar craters. This renewed interest in lunar exploration with eight missions launched between 2003 and 2010. The 2009 LCROSS mission provided direct evidence of ground ice. This water reservoir could be an enabling resource to support human presence on the Moon and human exploration of other Solar System.

Drilling Technologies: Since 1990s, Honeybee Robotics has been developing numerous drilling and sample acquisition technologies [1, 2]. These could be either fully autonomous or astronaut-deployable. The latest systems are at TRL of 5/6 and include a 1 meter rotary percussive and fully autonomous drilling system weighing 10 kg, a numerous surface core drills at TRL 4-5 weighing from 1 kg to 3 kg. The excavation systems include pneumatic and vibratory/percussive which make sampling much faster and easier to do.

In addition, we have developed planetary several geotechnical systems that enable measurement of soil strength from near surface to 1 m depth.

Other systems include fully autonomous Heat Flow Probe weighing just 1.5 kg and anchoring system with a Corner Cube reflector.

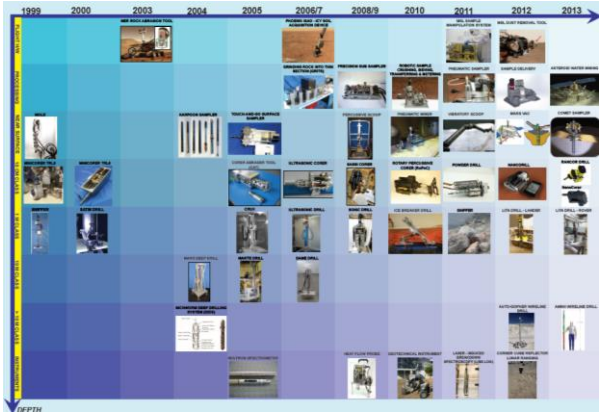

Figure 1. Honeybee Robotics range of drilling, sampling, geotechnical systems, and instruments developed for planetary applications. These could be either deployed robotically or by astronauts on the Moon.

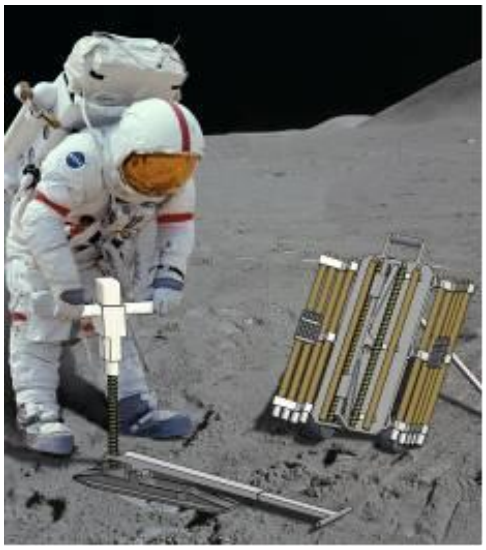

Figure 2. Astronaut deployable deep drill.

Since the early 2000s, we have been extensively testing our hardware across various planetary analog field sites.

Table 1. Analog sites for testing Honeybee drills

Analog Site	Drill Name	Year
Rio Tinto, Spain	MARTE	2005
Devon Island, Arctic	Dame	2004-07
Devon Island, Arctic	CRUX	2007-09
Devon Island, Arctic	Icebreaker	2010-13
Antarctica	Icebreaker	2010-13
Mauna Kea, Hawaii	Lunar Anchor, Lunar Heat Flow, Lunar 5 m drill	2010
Mojave	SASSI	2011
Greenland	Sniffer	2012-13
Atacama, Chile	LITA	2012-13
Borrego Springs	AutoGopher	2012

During the presentation, we will discuss past, present, and future technology developments as well as as challenges of drilling, regolith and rock acquisitions on the Moon.

References: [1] Zacny et al. "Drilling and excavation for construction and in situ resource utilization", in Moon: Prospective Energy and Material Resources, Badescu (ed), Springer, 2010. [2] Bar-Cohen and Zacny, Drilling in Extreme Environments - Penetration and Sampling on Earth and Other Planets, Wiley, (2009).