WIRELINE DEEP DRILL FOR THE EXPLORATION OF ICY BODIES. G. Paulsen1, K. Zacny1, B. Mellerowicz1, J. Craft1, Y. Bar-Cohen2, L. Beegle2, S. Sherrit2, M. Badescu2, F. Corsetti3, Y. Ibarra3, 1Honeybee Robotics, 398 W. Washington Ave, Suite 200, Pasadena, CA 91103, 2JPL/California Institute of Technology, Pasadena, CA, 3University of Southern California, Los Angeles, CA

Introduction: One of the most pressing current questions in space science is whether life has ever arisen anywhere else in the universe. Water is a critical prerequisite for all life-as-we-know-it, thus the possible exploration targets for extraterrestrial life are bodies that have or had copious liquid: Mars, Europa, and Enceladus. Due to the oxidizing nature of Mars’ surface, as well as subsurface liquid water reservoirs present on Europa and Enceladus, the search for evidence of existing life must likely focus on subsurface locations, at depths sufficient to support liquid water or retain biologic signatures.

To address these questions, an Auto-Gopher sampler has been developed that is a wireline type drill. This drill is suspended on a tether and its motors and mechanisms are built into a tube that ends with a coring bit. The tether provides the mechanical connection to a rover/lander on a surface as well as power and data communication. Upon penetrating to a target depth, the drill is retracted from the borehole, the core is deposited into a sample transfer system, and the drill is lowered back into the hole.

Wireline operation sidesteps one of the major drawbacks of traditional continuous drill string systems by obviating the need for multiple drill sections, which add significantly to the mass and the complexity of the system (see Figure 1).

Auto-Gopher: The AutoGopher (see Figure 2) employs a piezoelectric actuated percussive mechanism for providing impacts and a cluster of 3 actuators for rotating a coring bit and an auger. The bit allows acquisition of 57 mm diameter 100 mm long cores. This wireline drill allows coring and core removal from depths limited only by the length of a deployment tether.

The Outside Diameter of the coring bit is 72 mm. The length of the drill is 2 m and it weighs 20 kg. Drilled cuttings are moved up the auger flutes and fall into the cuttings chamber above the core chamber. Upon drilling 100 m core, the drill is retracted and the cuttings chamber is emptied. The Auto-Gopher currently does not have core catching capabilities. This feature was removed in order to reduce drill complexity and risk of drill getting stuck if the core cannot be sheared. However, future generation of the Auto-Gopher will have auto-core catching feature employing core-dogs or similar.

The drill uses a set of three plates to push against a borehole and anchor itself within the hole. The Wob is provided by internally actuated ballscrew. An integrated load cell provides a force feedback.

Auto-Gopher Testing: The system level testing of the Auto-Gopher was performed in a 2 meter block of Texas Limestone having strength of 25 MPa (Figure 3). We performed two tests to 2 meter depth. In the first test, we used rotary-only mode of drilling, while during the 2nd round of tests, we used rotary-percussive drilling (with percussion being piezo-driven).

During the rotary-only test, the average power was 90 Watt at 25% efficiency – i.e. the power required to drill was 25 Watts while the rest was attributed to electrical/mechanical losses. The rotational speed was 90 rpm and it took 15 minutes to drill 10 cm long core.
(i.e. penetration rate was 40 cm per hour). Drilling to 2 meter depth and recovering of cores every 10 cm took a total time of 15 hours (a single step of drilling 10 cm and retrieving the core was 45 minutes). Total energy to reach the 2 m depth was 500 Whr. The Weight on Bit was limited to less than 70 Newton. The core recovery was 100%.

**Figure 1.** The AutoGopher Drill above the 3 m deep hole (note the yellow tape). The 32 rock cores are placed inside the 4 protective tubes.

**Figure 3.** Drilling progress into a 2 m limestone column.

**Figure 4.** The recovered core samples were 57 mm diameter and 100 mm long. Core recovery was 100%.

**Field Testing:** The Auto-gopher has also been successfully tested in a field environment in 40 MPa Gypsum in the US Gypsum Quarry outside Borrego Springs, CA to a depth of 3 m [3]. The average drilling power was in the range of 100-350 Watt (depending on the duty cycle of the percussive system), while penetration rate was between 30 cm/hr (no percussion) to 160 cm/hr (percussion at 100% duty cycle). The energy required to penetrate 1 m depth range from up to 20 Whr/m (percussion at 100% duty cycle) to 450 Whr/m (no percussion). Also, the Auto-Gopher was tested in the field drilling gypsum and reached 3-m depth. The most energy efficient drilling was found when the percussive mechanism was activated continuously. It required approximately 200 Whr to drill 1-meter. The rotary drilling with no percussion was found to be the least efficient approach.


**Acknowledgements:** Research reported in this abstract was conducted at Honeybee Robotics and the Jet Propulsion Laboratory (JPL), California Institute of Technology, under a contract with National Aeronautics Space Administration (NASA), Astrobiology Science and Technology for Exploring Planets (ASTEP) program.

We would also like to thank Brett Webster, Quarry Manager and the staff at the US Gypsum for assisting in the AutoGopher field deployment at the US Gypsum quarry in Borrego Springs, CA.