WIRELINE ROTARY-PERCUSSIVE CORING DRILL FOR DEEP EXPLORATION OF PLANETARY BODIES.

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Introduction: The main question we are posed with is whether life ever arose on another planetary body. Since water is an important requisite for life as we know it, the possible exploration targets are Mars, Europa, and Enceladus. Because of oxidizing nature of Mars atmosphere, as well as increased radiation at the surfaces of Mars, Europa and Enceladus, samples have to be acquired at greater depths.

For the past 3 years, we have been developing the prototype wireline coring drill, called the Auto-Gopher, for drilling as deep as 3 to 5 meters and potentially capable of sample acquisition from hunderds of meters deep.

Drill Approches: The main feature of the Auto-Gopher is its wireline operation [1]. The drill is essentially suspended on a tether and all the motors and mechanisms are built into a tube that ends with a coring bit (**Figure 1**). The tether provides the mechanical connection to a rover/lander on a surface as well as power and data communication. Upon reaching the target depth, the drill is retracted from a hole by a pulley system, which can be either on the surface or integrated into a top part of the drill itself.

The competing drill design includes a continuous drill string system, i.e. as the drill gets deeper, new drill sections have to be added on top. This of course requires drill sections, which add to the mass of the system very quickly, and requires a drill string feeding mechanism such as a carousel and mating connections between each drill string, which increase the system complexity. The added disadvantage of the continuous drill string system is that power required to convey the cuttings from great depths will be prohibitively large due to auger drag. The wireline approach solves this problem, since the power required for conveying the sample to a caching chamber located above the drill assembly is always the same.

Generally, wireline systems involve mechanical complexity of packaging motors and actuators into a slim tube. In addition, as opposed to a continuous drill string system, where the Weight on Bit (WOB) also known as a preload, is provided by a lander or a rover, the WOB in a wireline system is provided by anchoring the drill to the borehole wall (it locks the upper section of the drill) and using an internal screw to push on the drilling mechanism and the drill bit itself. This is an added advantage; the WOB of the continuous drill system is limited by the weight of the lander/rover itself and no such limitation exist for the wireline drill system.

The Auto-Gopher also overcomes challenges that are inherent to deep ice drills including melting or hot-water drills that are used to drill pure ice [2]. The main disadvantage of the prior drills is their high mass and complex fixtures that cannot be carried with a small rover. Hot-water drills and other melt probes do not provide core, they require a source of large amount of ultra-clean water, they have high power requirements and they are difficult to operate in ice with sediments or permafrost, or when large rocks are present.

Other, non-traditional drilling technologies (laser, electron beam, microwave, jet, etc.) usually are competitive only in applications that are time limited and not power/mass limited as is typical for space science applications. Generally, future space missions will not have enough power (or rather electrical energy) to employ these “modern” drilling technologies. In contrast, the proposed low mass Auto-Gopher uses low power and low WOB or preload and it is not constrained by the mass of a lander/rover to penetrate a formation and acquire cores. Acquired cores will retain the stratigraphy (and volatiles if present) to provide significant scientific information about the layered structure with inclusions and potential organisms.

The main disadvante of the wireline system is a possibility of bore-hole collapse. However, since the drill will be deployed in ice or ice-cemente ground, the risk is low.

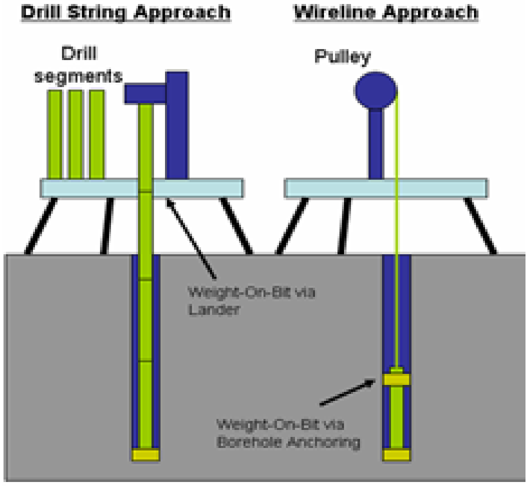

Figure 1. Conventional drill string vs. wireline drilling approach.

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. Opon 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 emplying 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.

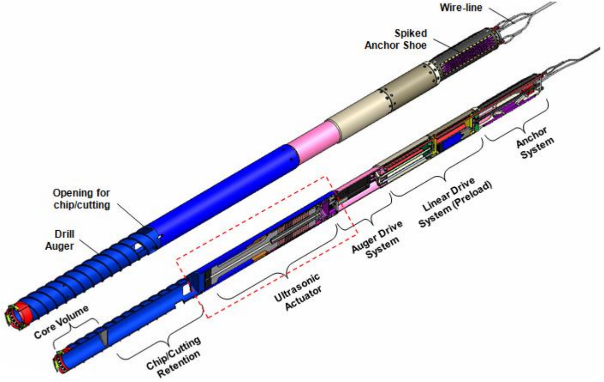

Figure 2. Components of the Auto-Gopher.

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%.

When the piezo-based percussive system was turned on the auger power decreased by 20% probably due to reduced torque required to move cuttings up the auger and reduced auger drag. The piezo system vibrated at 5 kHz and required approximately 60 Watts of power. We also noticed that cuttings would pack up in the cuttings chamber. Hence, the cuttings chamber could be made smaller in the next generation system.

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%.

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