# The European Ultrasonic Planetary Core Drill: Preliminary Results from Field Trials at the Haughton Mars Project.

K. Worrall[1], R. Timoney[2], X. Li,[3] P. Harkness[4] and M.Lucas[5]

[1] Research Associate, University of Glasgow, Scotland, UK. G12 8QQ. Kevin.Worrall@gla.ac.uk
[2] Ph.D. Researcher, University of Glasgow, Scotland, UK. G12 8QQ. r.timoney.1@research.gla.ac.uk
[3] Research Assistant, University of Glasgow, Scotland, UK. G12 8QQ. xuan.li@gla.ac.uk
[4] Senior Lecturer, University of Glasgow, Scotland, UK. G12 8QQ. Patrick.harkness@gla.ac.uk
[5] Professor, University of Glasgow, Scotland, UK. G12 8QQ. Margaret.lucas@glas.ac.uk

**Introduction:**

The European Ultrasonic Planetary Core Drill (UPCD) project has developed a sampling and caching technology for the subsurface exploration of low-gravity rocky and icy bodies within our Solar System. The ultrasonic/percussive technique utilized by the drill system, pioneered by NASA JPL at the turn of the century [1] has been optimized and further explored by the University of Glasgow [2], resulting in the development of an architecture which allows for the connection and disconnection of multiple drill bits through the novel application of a bayonet system [3, 4] and an autonomous control loop for maintaining progress of the drill as it penetrates the terrain [5]. The complete UPCD Campaign Architecture is as detailed in Figure 1.

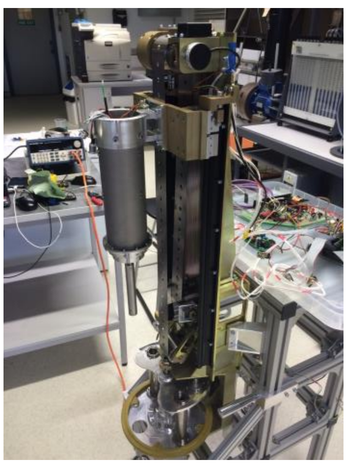

**Figure 1: UPCD Campaign Architecture**

The culmination of UPCD efforts will be a field test campaign at the Haughton Mars Project, Devon Island, Canadian High Arctic (Figure 2), in summer 2016. The Haughton Mars Project (HMP) is located at the rim of a historic asteroid collision, resulting in a thick layer of ice-bound fallback breccia and shocked terrain [6]. These conditions ensure that the test site is an excellent analog for the Mars Polar Regions, though compromises are made on temperature and atmospheric pressure. Furthermore, HMP have played host to a number of planetary drilling systems over its history [7], thus, are well prepared for the requirements of such a campaign.

In order to ensure success at the field trials, the complete UPCD hardware (Drill System, Sample Caching Carousel, Z-Axis Vertical Actuator and Drill Bit Restraining Clamp) must be used in unison, and in a mostly autonomous manner. The criterion for success states that the hardware must successfully retrieve permafrost core samples from 300 mm deep, before disconnecting the individual components of the drill string and caching these individual drill bits in the Sample Caching Carousel. It is hoped that the test campaign, coupled with relevant testing in Mars and Lunar test chambers in the laborary, will allow the key components of the UPCD architecture to receive a classification of TRL 6, allowing the system to be considered for future missions to the surface of planetary bodies.

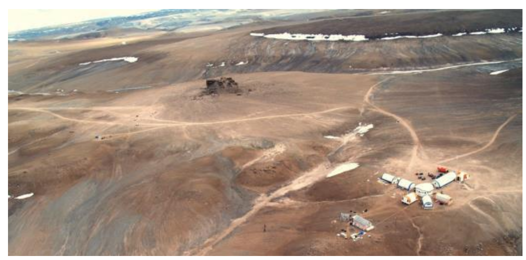

**Figure 2: Haughton Mars Project (HMP)**

**Field Trial Preparations**

As part of the process of preparing for the test campaign at the HMP, the University of Glasgow have undertaken a series of testing in the laboratory, aiming to further develop confidence in the drilling of simulated permafrost. This simulated permafrost, consisting of characterized regolith, mixed with water (to various percentages by weight) and frozen, is a fair, if imperfect, substitute for testing in the field [8]. Relevant literature [9] has shown that altering the ratio of regolith to water significantly affects the mechanical properties of the mix. (Figure 3). As the percentage of water in the regolith mix increases to saturation, the uniaxial compressive strength (UCS) of the permafrost mix increases to a maximum value. Subsequent oversaturation results in a reduction in UCS, reducing to the value of pure ice. This allows us to conclude that the water component of the regolith acts as a binder, allowing the permafrost to behave like a 'composite' material, whereby the mix is stronger than the components which are used to produce it. In order to ensure that the UPCD architecture is capable of drilling in permafrost terrain of any water content, laboratory drilling of 10-20% (saturated) water/weight have been carried out, with encouraging results.

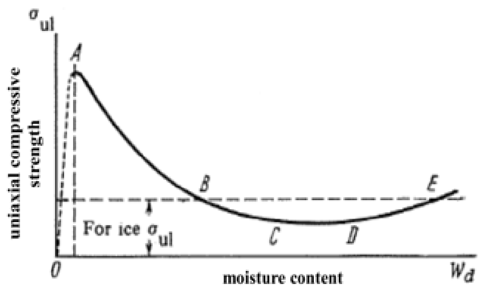


**Figure 3: Permafrost UCS with varied water content [9].**

Perhaps the greatest challenge when drilling in icy-bound regolith is the possibility of melting liquid-state volatiles, such as water. This is of particular concern when drilling at temperatures and pressures above the triple point. There exists the possibility that drilled cuttings, rich in slushy, melted water, could refreeze on to the drill bit shaft. This has been experienced under laboratory conditions and has nearly always resulted in a complete seizure of the drill string. An example of such an incident is seen in Figure 4. Note, a chisel is often required to free the seized drill bits from the permafrost simulant.

**Figure 4: Drill Bit Seizure in Icy Regolith**

Analysis of the results from seized drilling runs has allowed the team to predict the early onset of these seizing events through observation of the power (thus, torque) requested by the auger of the drill bit (Figure 5). This knowledge has allowed the team to further advance the capability of the autonomous drilling controller, and it is hoped that this will ensure an increased fault tolerance of the system in time for the field trials.

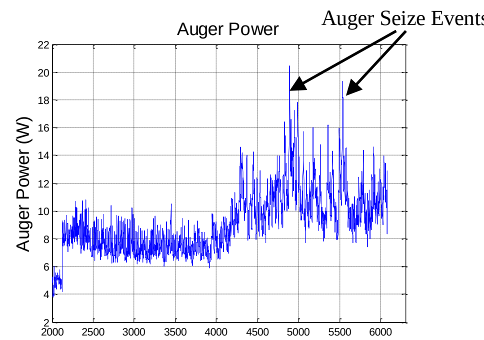


**Figure 5: Lab Drilling Data. Auger Seizing Events**

**Conclusions:**

This paper shall contain the results of the UPCD field campaign at the Haughton Mars Project, to be completed in summer 2016. The results shall be compared to drilling results which have been obtained from laboratory testing, with lessons learned noted throughout. The UPCD project team are excited to share their findings with the 6th International Conference on Mars Polar Science and Exploration.

**References:**

[1] Y. Bar-Cohen et al, (2000), SPIE Smart Structures, 3992, 101. [2] P. Harkness et al, (2011), IEEE Ultrasonics Control, Vol 58, 11. [3] R. Timoney et al. (2015). AIAA Space. [4] R. Timoney et al. (2016) ASCE Earth and Space. [5] X. Li et al, (2015), AIAA Space 2015. [6] B. Glass and P. Lee (2013), Analog Sites for Mars Missions II. [7] B. Glass et al, (2014) Earth and Space 2014. [8] R.Timoney et al, (2016), IPPW13. [9] L. Gertsch, J. Rostami and R. Gustafson, (2008), International Conference on Case Histories in Geotechnical Engineering.