DEVELOPMENT OF A DEEP DRILL SYSTEM WITH INTEGRATED DEEP UV/RAMAN SPECTROMETER FOR MARS.

Joey Palmowski[1], Boleslaw Mellerowicz[1], Evan Eshelman[2], Kris Zacny[1], Gale Paulsen[1], Michael Malaska[2], John C Priscu[3], William Abbey[2], Ivria Doloboff[2], Arthur L Lane[2], Luther W Beegle[2], Lauren P DeFlores[2], Brandi L Carrier[2], Peter Ngo[1], Paul Chow[1], Robert Huddleston[1], Albert Ridilla[1], Alexander Wang[1], Jameil Bailey[1], Huey Nguyen[1], Rohit Bhartia[2]
[1]Honeybee Robotics, Altadena, CA, United States, [2]NASA Jet Propulsion Laboratory, Pasadena, CA, United States, [3]Montana State University, Land Resources and Environmental Science, Bozeman, MT, United States

Introduction: Planetary exploration has been limited to surface and near surface terrains. To learn about planets' histories and especially to find life, deep drilling is required. This paper presents the WATSON Planetary Deep Drill, designed for penetration to 100's of meters into Mars' ice caps and Europa's ice sheets, respectively. The drill uses a wireline approach where the drill system is suspended on an umbilical cable; to drill deeper, more cable is paid out from a drum.

This prototype drill weighs approximately 62 kg and is 2.6 m long (without the auger and WATSON instrument). The drill diameter is 102 mm and the drill creates a borehole diameter of 108 mm using its full-faced auger and bi-center bit. The umbilical cable weighs approximately 20 kg/100m and constitutes a Vectran™ braided strength member which envelopes the core components: fiber optics for communication and conductors for power transfer between the surface and the drill. The system will be tested in a gypsum quarry to approximately twice its length (i.e. < 10 m) before being deployed on to the Greenland ice sheet at Summit to drill to a depth of 100 m. The system requires less than 500 W of power to penetrate at approximately 2.4 m/hr in -20C ice.

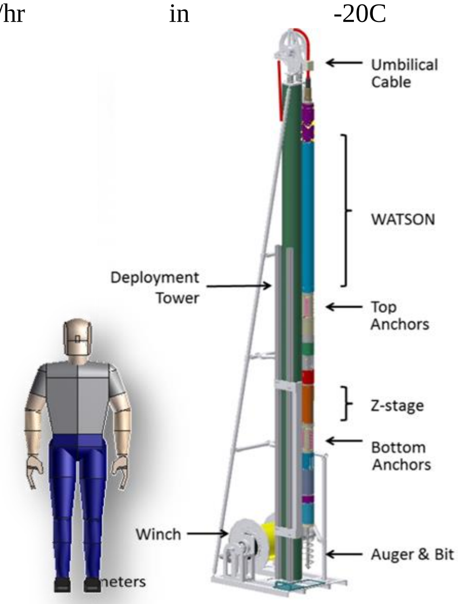

Figure 1 3D model showing the components of the wireline drill system

Motivation: Exploration of planetary bodies has been historically limited to 2D. The vast majority of instruments on planetary Flybys and Orbiters can only scan the surface and near surface of a planet or the Moon. Some instruments, such as Ground Penetrating Radars, could probe deeper, but the data very often has poor resolution (Orosei et al., 2010). Surface spacecrafts (landers and rovers) have also been limited to near surface exploration. The deepest humans have ever drilled off the surface of the Earth was on the Moon during the Apollo missions (Bar-Cohen and Zacny, 2009; Zacny et al., 2008). However, many believe that even the cores captured at the maximum depths reached of 3 m, were not deep enough. On Mars, all missions to date have been barely scratching the surface with scoops, grinders and arm-deployable drills.

Arguably the most important goal of planetary exploration is to determine if life exists, or ever existed, on another world. To understand the evolution of planetary bodies and to find definitive signs of present or past life, we need to go deep into planets or the Moon's subsurface. On Mars, Europa, and Enceladus, planetary objects with a high potential for life, one needs to penetrate deep below the surface that has been affected by damaging cosmic and solar radiation.

For this purpose, the prototype drill is designed to collect cuttings from up to a 100 m depth and bring them back to the surface for analysis. The drill will also perform in-situ analysis of the bore-hole with its integrated instrument called WATSON, designed by JPL. WATSON is a deep UV/Raman and fluorescence spectrometer that is based on Mars 2020 SHERLOC instrument and has the objective of determining the distribution of organics in glacial ice.

Approach: Technology enables space exploration. Smaller and faster computers, stronger and lighter materials, and more sensitive sensors all greatly increase the capabilities of future missions. For 3D exploration, a key enabling technology is a robust, low mass, low volume, and energy efficient drilling system.

Conventional drill systems deployed in the oil and gas industries screw drill pipes together to form a long drill string. To get deeper, more drill pipes are added. This is a very robust approach and solves many problems related to deep drilling. These drills require high power drives, weigh a lot, and occupy significant space. These are not major issues on Earth; however, they are show-stoppers in extra-planetary settings.

Currently we are limited to placing just one ton on the surface of Mars with a SkyCrane-type landing system. The one ton Mars Science Laboratory rover can carry only approximately 200 kg of payload; the rest is taken up by a mobility system, power system, communication system, and so on. Hence any near future planetary drill must weigh 200 kg or probably less, since the mission no doubt will also have a range of instruments needed to analyze a sample. The rover itself is 3 m long, and any drill system should fit within that envelope.

Figure 2 3D model of an MSL sized rover with the integrated Planetary Deep Drill in drilling position

Progress: During the summer of 2019, WATSON was deployed at a site located near Summit Station at an elevation of 3200 m.a.s.l. in the vast interior of Greenland. WATSON successfully demonstrated robotic drilling to 110.5 m and mapped the spatial distribution of organics and microbes in the borehole while acquiring 50 cm long cores used later for correlation of the acquired instrument data. Four days of science operations yielded 34 fluorescence maps, and 39 point cloud scans in both firn and glacial ice to a depth of 107 m. At least 5 types of distinct spectral features were identified in glacial ice and the spatial distribution was found to be in discrete locations which did not follow any apparent layering or fractures.

We saw no evidence of layering in the ice and features were distributed stochastically. The spectral signatures were consistent with organic matter fluorescence from microbes, lignins, fused-ring aromatic molecules, including polycyclic aromatic hydrocarbons, and biogenically derived materials such as fulvic acids. Detection of such organic matter hotspots, prevents loss of spatial information and signal dilution when compared to traditional bulk analysis on the ice core meltwaters, . We demonstrated a technique that will be useful for detecting and isolating microbial or organic carbon hotspots in terrestrial icy environments and on future missions to the icy environments of the Ocean Worlds of our Solar System.

Point clouds are opportunistic scans while raising and lowering drill (rastering not used) to identify Hot Spots or region of interests (ROI)!

Fluorescence maps are more detailed maps which use the instrument’s rotational and linear stage to create a raster of pulses and re-emitted spectra which approximately cover a 5 by 1 cm area and consists of an array of 89250 discrete laser pulses, half of which are used for background reference. This generates a “3D image” where the x and y coordinates represent the vertical and horizontal positions and the z coordinate represents the extracted wavelengths which span across 32 bands from approximately 280 to 440 nm. Note that wavelength calibration is in process at JPL.

Figure 3 3D model of an MSL sized rover with the integrated Planetary Deep Drill in drilling position