FIELD SIMULATION OF A DRILLING MISSION TO MARS TO SEARCH FOR SUBSURFACE LIFE

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Background: The discovery of near surface ground ice by the Mars Odyssey mission and the abundant evidence for recent Gulley features observed by the Mars Global Surveyor mission support longstanding theoretical arguments for subsurface liquid water on Mars. Thus, implementing the Mars program goal to search for life points to drilling on Mars to reach liquid water, collecting samples and analyzing them with instrumentation to detect *in situ* organisms and biomarker compounds. Searching for life in the subsurface of Mars will require drilling, sample extraction and handling, and new technologies to find and identify biomarker compounds and search for living organisms. In spite of its obvious advantages, robotic drilling for Mars exploration is in its technological infancy and has yet to be demonstrated in even a terrestrial field environment.

MARTE Project: MARTE (Mars Analog Rio Tinto Experiment) is developing drilling, sample handling, and instrument technologies relevant to searching for life in the Martian subsurface. MARTE is funded by the NASA ASTEP program and has the dual goals of (1) searching for a subsurface biosphere in an environment of unique relevance to life in the Martian subsurface, and (2) developing and demonstrating in a mission realistic field test the technical approach for drilling into the subsurface of Mars to search for life. The development of the robotic drill and instrument systems and the science approach of the simulated drilling mission draws heavily on lessons learned from a successful search for subsurface life at a site in Rio Tinto, Spain described in related abstracts by Stoker *et al.* and Fernandez *et al.* [1,2]. The drilling system is being developed by Honeybee robotics for future use on Mars. The drill brings to the surface 25 cm core segments at 2.5 cm diameter while operating on low power without the use of drilling fluids. The MARTE drill system is capable of achieving 10 m depth. An automated Core and Sample Handling facility will extract the cores from the drill and pass them to a suite of instruments on a lander platform. Cores are first examined by remote sensing instruments to determine best locations to select to search for life. Powdered samples of cores are then extracted and analyzed by life detection instruments. Each of the subsystems utilized in the robotic drilling system is described below.

Drill: The drilling mechanism utilizes dry rotary cutting techniques including both carbide drag cutters and mono-crystal diamonds. An auger-type chip removal system moves the cuttings away from the drill bit and into a chip reservoir located inside the lead drill tube, which is emptied upon removal from the borehole. A core hand-off sub-system removes the acquired core from the lead drill tube and delivers it to a core clamp for sample preparation and delivery to scientific instruments for analysis. The system is designed to operate at or below 150 Watts average power during drilling operations. Highly integrated sensor feedback control on all drilling axes allows for integration of sophisticated drilling algorithms and fully autonomous control.

The prototype 10 m, ~1cm coring drill proposed here is based directly on the drill built by Honeybee Robotics and tested for the Mars Technology Program from 2001-2003. This drill, the Mars Deep Drill was designed for deep drilling (~10 m) so multiple drill segments can be used. The actual MARTE system incorporates an automated core handoff mechanism that transfers the collected samples onto the Core Sample Handling System for scientific analysis while providing depth information and other important data.

CSHS: The core extracted by the drill, is then transferred to the Core and Sample Handling System (CSHS) an automated system capable of positioning a particular section of the core under a suite of remote sensing instruments for analysis with a position precision of about 0.01mm. During the transfer of the core from the drill handoff mechanism onto the CSHS, the core is pushed out of the drill; the exposed rock is pushed past the suite of instruments (described further below). The piston pushing the core is carefully calibrated with the instruments and their placement. At any time, it is well known which part of the core is under which instrument. A particular spot on the core that is observed by one instrument can later be correlated with readings from another instrument for the same portion of core. The CSHS includes a saw that faces the core (exposes a pristine and flat surface) prior to exposing the core to inspection instruments. After the core inspection has been accomplished, cores are stored in a core storage rack, allowing scientists time to examine core inspection data and decide whether core sampling for life detection is desired. Cores then can be retrieved from the rack for sampling. Up to 10 core segments can be stored in the rack. The final item in the series of instruments is the core sampling tool. This tool cuts a slice of the core at a location specified by the operators. The slice is deposited in a crusher to produce powdered samples.

Remote Sensing Instruments: Remote sensing instruments are used to examine the cores. After the core segment is placed in the CSHS, a sliding stage moves the core past a suite of remote sensing instruments. These include a core context imager (image of full 25 cm core in color at 125 micron/pixel resolution), a microscopic imager (images sections of the core at 6 micron/pixel resolution in color), a visible to near infrared point spectrometer (collecting spectra at the same locations where microscopic images are obtained), and a hyperspectral imager. This latter instrument acquires a hyperspectral image of each core with 100 micron/pixel spatial resolution and 256 spectral points in the wavelength interval 400 nm to 1000 nm. As each core passes under a specific location, it is brushed with a sterile swab that is examined using ATP luminometry for a quick-look indication of the presence of living organisms. Additional instruments are mounted on the Borehole Inspection System (BHIS), a device that is lowered down the borehole when the drill is removed to perform additional science analysis. BHIS instruments include a panoramic borehole imager, a Raman spectrometer and a magnetic susceptibility meter. Analysis of these data leads to decisions to perform *in situ* analysis with life detection instruments at specific locations on the cores.

Life Detection Instrument: Once core sample locations are chosen, a subsection of core is sliced out, crushed, and then placed into the Signs of Life Detector (SOLID) instrument for further processing. The SOLID is a portable automated instrument that uses DNA and protein microarray technology to detect microorganisms as well as their metabolic products. The instrument is capable of sensing many kinds of biochemical compounds (nucleic acids, proteins, polysaccharides, etc.) using microarrays printed with DNA, antibodies or any other protein or molecule able to recognize and bind specifically to them.

Mission Simulation: A Mars drilling mission simulation is planned for September 2005 that includes interpretation of drill mission results by a remote science team in a blind test. A science team located at a remote operations center will analyze the data from the logging instruments and select core locations to extract samples to analyze with life detection instruments located onboard the lander. Scientific participation in that mission simulation is solicited from the planetary geology and astrobiology community. Participants will be selected based on a brief "Participating Scientist" proposal. This abstract announces the opportunity to participate in the MARTE field test.

The MARTE mission simulation will be the first time a field test of a robotic drilling system including science payload has been performed. This is a unique opportunity for scientists to participate in a robotic drilling mission. A comparison of results from robotic drilling to those obtained using conventional drilling and laboratory analysis methods is a key goal of MARTE that will give evidence for the near term viability of drilling to search for life on Mars.

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References: [1] Stoker, C.R. *et al.* (2005) LPSC 36. [2] Fernandez-Remolar, D. *et al.* (2005) LPSC 36.