LIFE-DETECTION MARS ANALOG TESTING AT RIO TINTO. B. Glass[1], V. Parro[2], D. Bergman[1], C. Stoker[1], A. Wang[3], T. Stucky[1], M. García-Villadangos[2], J.M. Manchado[2], and S. Seitz[1]. [1]NASA Ames Research Center, Moffett Field, CA 94305, USA, Email: brian.glass@nasa.gov, [2]Centro de Astrobiologia, 28850 Torrejón de Ardoz, Spain, [3]Honeybee Robotics, Pasadena, CA 91103, USA.

Abstract: The ARADS/Resource Prospector 1m-class planetary prototype drill was tested in 2017 on a full-scale Mars lander mockup at the analog site at Rio Tinto, Spain, (with sample transfer robot arm and the Signs of Life Detector (SOLID) prototype life-detection instrument). Field tests successfully demonstrated fully-automated drilling, sample transfer, and biomarker analysis of drill sample (cuttings) with SOLID.

Introduction: The Life-detection Mars Analog Project (LMAP) over three years (2014-2017) created a field brassboard similar in some respects to the proposed "Icebreaker" mission lander [1], including a fullsize InSight-derived lander platform, the ARADS drill, a sample transfer arm/scoop and the SOLID immunoassay instrument [2].

Looking for organics, biomarkers and signs of past or extant life in the Mars arctic will require sample acquisition there below the desiccated and irradiated surface, and through the hard ice layers that Phoenix encountered. A decade of evolutionary development by NASA of integrated automated drilling and sample handling, at analog sites and in test chambers, has made it possible to go deeper through hard rocks and ice layers [3,4]. The latest ARADS drill (Fig. 2) was previously tested in February 2017 in the Atacama Desert in Chile, another high-fidelity analog site (with the same sample transfer arm, SOLID and a rover) [5].

Unlike terrestrial drills, Mars exploration drills must work dry (without drilling muds or lubricants), blind (no prior local or regional seismic or other surveys), and light (very low downward force or weight on bit, and perhaps 100W available from solar power). Given the lightspeed transmission delays to Mars, an exploratory planetary drill cannot be controlled directly from Earth. Drills that penetrate deeper than a few cm are likely to get stuck if operated open-loop (the MSL drill only goes 5cm, and the MER RATs 5mm by comparison), so some form of drill automation is required [4].

Approach: Biomarker acquisition, processing by SOLID and LMAP instrument operations are described separately by Sanchez [6]. The ARADS rotary-percussive drill, completed in November 2016, was 3x less massive than earlier Mars drill prototypes [3]. Power consumption was 30-40 W, 200W max during 5-10 min drilling sequences. Fig. 3 shows a typical drilling sequence that resulted in sample transfer to SOLID. Transfer was by a MDA field-class robot arm with a Phoenix-derived scoop design as an end-effector. Iterative drill and scoop cleaning (with multiple solvents) and masks and gloves were used in the field to reduce the risks of human-sourced or cross-contamination.

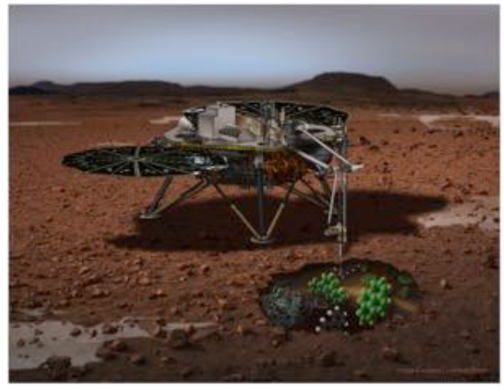

Fig. 1. Icebreaker mission concept would return to the northern Mars polar latitudes visited by Phoenix.

Testing: In June 2017 the LMAP platform and drill were deployed to the Rio Tinto, Spain Mars-analog site together with its robotic arm (for sample transfer), its full-scale lander deck and the operational Signs of Life Detector (SOLID) prototype instrument [2]. Fig. 2 shows the drill deployed over the deck alongside the integrated sample transfer arm with scoop. The functional SOLID instrument prototype is the black box mounted on the deck in Figure 2 behind the arm and drill.

Fig. 2. ARADS drill tested with SOLID instrument (black case) and sample transfer arm at Rio Tinto in June 2017.

A series of nine holes, cumulatively 7.4m, were drilled by LMAP adjacent to a low-Ph acidic stream at the "SOLID Planitia" area in Rio Tinto, characteristic of sites where extremophiles have been typically observed in the past. Five parallel ground-truthing holes were drilled using conventional equipment (also with extra cleaning and protocols) for laboratory analysis as a control.

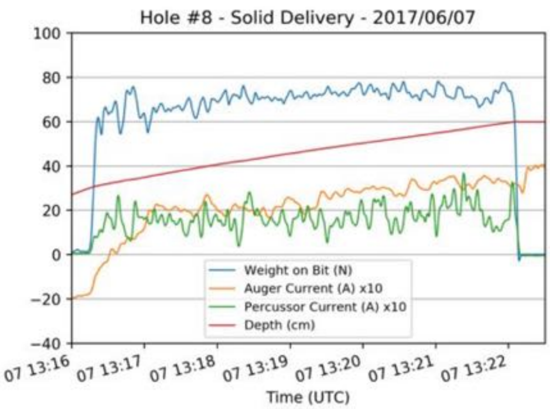

Fig. 3. Dirt-to-data: Robotic drilling leads to sample robotically provided to the SOLID instrument.

Results: Holes 1-4 were used to confirm parameters and to verify hardware and software functionality of the drill, robot arm, and delivery to the SOLID instrument. The ~2 hour cycle time for SOLID instrument processing, compared to the time needed for sample acquisition (5-10 min to drill 20cm and 10 min to deliver) meant that for holes 5-9, only 2-3 full SOLID-included cycles could be run per day. The onsite science operations team would designate these "SOLID runs" daily, and other samples taken were simply caught instead in sterile jars for offline analysis.

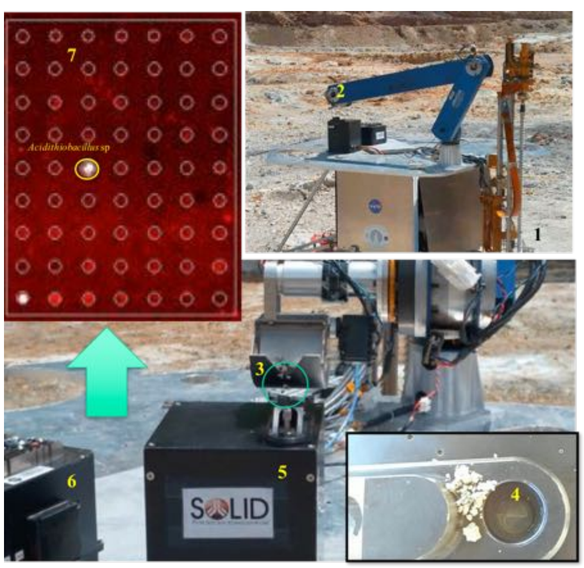

Fig. 4. LDMS Cycle: 1, Drilling; 2-3, loading SOLID SPU; 4, adding liquid extraction buffer; 5, extraction by ultrasonication; 6, analysis of the extract with LDChip; 7, image capturing and analysis. Highlighted spot corresponds to an antibody to an *Acidithiobacillus* strain.

For the former, the fully automated LMAP operations cycle (see Fig. 4) with the drill, sample transfer arm, and SOLID instrument on the lander deck repeatedly demonstrated sample (drill cuttings) handed-off from the drill to the arm/scoop and thence to the SOLID inlet port (so-called "dirt-to-data" from [7]) whereupon analysis of the sample was accomplished. Preliminary results in Sanchez [6] find results suggesting a variety of biosignatures of prokaryotic and eukaryotic origin. Fig. 4 shows a positive SOLID result for an *Acidithiobacillus* strain from a given LMAP sample.

Samples acquired robotically from the drill down to 90 cm depth were analyzed by SOLID. While drilling, the LMAP automation software managed drilling, sampling, curation and instrument operations. Fig. 5 shows the automated detection, adjustment (of weight on bit and auger rotation) recovery and continuance of drilling during 3 choking faults in Hole 4 around 90cm depth.

Conclusions: The automated LMAP lander system, tested at the Rio Tinto analog site in 2017, successfully demonstrated fully robotic and intelligent sample acquisition, transfer, and in-situ onboard biomarker analysis. This demonstrates a subsurface sample acquisition and bioanalysis capability that is significant for future Mars astrobiology missions.

Acknowledgements: The LMAP project thanks Sarah Noble (NASA MMAMA program), Mary Voytek (PSTAR program) and also the Spanish Ministry of Economy and Competitiveness (for funding CAB's work).

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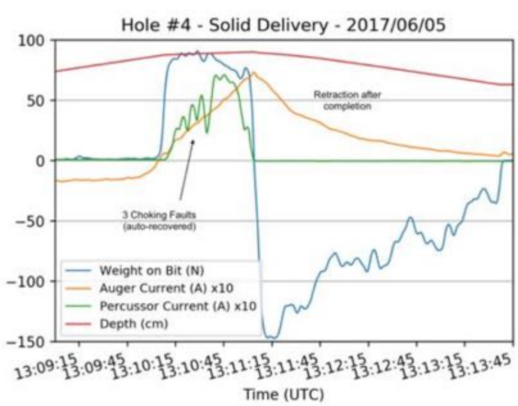

Fig. 5. LMAP system demonstrating fully-automated drilling, hands-off fault recovery (3 choking faults around 13:10) and retraction after completion.