Introduction: Missions to search for evidence of life on Mars, including Mars Science Laboratory (MSL) are using drilling systems to get beneath the high oxidized and radiated surface where biomolecules may be preserved. MSL drill holes show that even at shallow depth the subsurface is more reduced and therefore more likely to preserve biosignatures. Analysis of these reduced materials yielded the first detection of organic carbon compounds on Mars [1]. While MSL was capable of drilling only 10 cm, the ExoMars mission now planned for a 2022 launch will feature a rover carrying a 2 m drill, motivated by desire to penetrate beneath the irradiated surface. The Atacama Rover Astrobiology Drilling Studies (ARADS) was a PSTAR project that used flight prototype technologies in a highly relevant Mars analog site, together with related scientific studies, to better understand how to best search for life on Mars. ARADS field work was performed in Atacama Chile and featured a rover-mounted 1.2 m auguring drill to acquire subsurface samples that were analyzed with flight prototype instruments designed to search for chemical signatures of life.

Project description: In September 2019 ARADS performed an operational simulation of a life search mission, including direction and analysis performed by a remote science team. The core of the Atacama Desert was chosen for being extremely dry, and is a close analog to sites of interest on Mars [2]. The objective was to use the drill and instruments suite to search for and characterize biosignatures in a “new site”, i.e., one that remote operators had not previously studied. Requirements established prior to the mission were to drill in at least 3 locations and analyze samples from at least 2 depths to deduce an understanding of the area and search for biosignatures of life. The remote science team (RST) for this operation consisted of participants who had worked previously in the Atacama, but chose the site from a list of candidates based on satellite imagery. They performed the operation from their home locations; most of the team was located in California. Prior to the mission, a strategic plan for studying it was developed by the RST using Google Earth satellite images. The site is in the Atacama core, long considered to be the driest part of the Atacama Desert, which is the driest desert on Earth.

The equipment supporting the test included the NASA Ames KREX field rover (Figure 1) carrying a 1.2 m rotary percussive TRIDENT drill from Honeybee Robotics. A sampling arm with a scoop captured cuttings swept off the drill auger flights by a cog as the drill was withdrawn from the hole. The arm/scoop was used to deposit cuttings into funnels mounted on the deck surface of the rover, connected to instruments stored below the deck aided by a motorized plate at the back of the scoop that pushed sample out in controlled amounts. The instruments used included (1) the Signs of Life Detector (SOLID) [3] which searches for a wide range of biologically produced compounds using immunassay; (2) Microchip Electrophoresis LASAR Induced Fluorescence (MELIF) [4] which uses an electrophoresis based separation approach to identify amino acids extracted from soil; and (3) Wet Chemistry Laboratory (WCL) [5] which uses a suite of ion selective electrodes to perform an analysis of the soluble ions in the sample.

Figure 1. KREX rover carried drill, robotic arm, and instruments located below the deck.

The landing site selected (Figure 2) was a light-colored area hypothesized to be sediments deposited by small channels emanating from nearby hills. Immediately prior to mission start, imaging data were collected with a DJI Phantom drone and processed with “Maps Made Easy” software to create a digital elevation model (DEM) of the landing site. This plus associated images were used to plan the daily tactical operation.

The rover and instruments were operated semi-autonomously by software routines, commanded to
start by field engineers in Chile, based on command sequences sent from a Science Operations Center (SOC) in California. Each day, the SOC sent a command sequence to the field that included a target location to drive to and drill, a depth to acquire sample, and instruments to deliver to and operate. A full operation including drilling and sample analysis by all 3 instruments took 18 hours. The field team was connected to the internet via a satellite dish. At the end of the day’s operation, the resulting data was uploaded to a data base to be analyzed by the RST. All communication between the field and RST including uploading of commands and return of data was performed using Slack™. The mission operated for 6 days simulating 6 + sols of a Mars operation. All instructions sent to the rover/drill/arm and instruments were documented along with the time required to perform each operation. Drilling parameters of auger torque, rate of penetration, and weight on bit were logged during all drilling operations. These can be used to help diagnose the material properties drilled.

Results: Drill site 1 was in the deepest area (Fig. 2) and samples were collected from 20, 50 and 73 cm depths. Drill site 2 was near the center of the shallower basin, and samples were collected at 20 and 80 cm in that location. Drill site 3 was on the desert floor outside the basin and light-colored material and sample was collected at 20 cm. Rover imaging revealed small scale polygonal features (mud cracks) in area 1. Area 2 did not have these features and appeared more modified by wind. The desert floor outside of the basin had desert pavement texture. The material drilled in areas 1 and 2 was a fine sediment that posed low resistance to drilling, but at 70 cm depth in area 1 a hard layer was encountered and the drill became stuck. Several cycles of forward and reverse drilling were required to free it. SOLID and MELIF results were consistent when both instruments analyzed the same sample. Biosignatures were observed by both SOLID and MÉLIF at 20 cm in location 1. SOLID also saw biosignatures at 50 and 70 cm depth there but found the material had much lower signal at 70 cm. MELIF did not analyze the deeper samples in location 1. MÉLIF identified biosignatures at 20 and 80 cm depths in area 2, but SOLID experienced clogging and was unable to perform either analysis. SOLID and MILA both analyzed a sample from 20 cm depth in location 3 but neither detected biosignatures.

Taken together, the data lead to the following interpretation. The site is subject to episodic flooding during infrequent Atacama rains resulting in sediments deposited in a basin. When the basin is wet bacterial growth occurs. Afterwards the basin dries but the biosignatures are preserved. While the surface morphology suggested more recent flooding in area 1 than 2, the instruments were unable to distinguish a stronger biological signature between those 2 areas, but no signatures were observed in area 3 that has no evidence of flooding. At 70 cm depth in area 1 gravel or another hard material was encountered, but weak biological signals were still observed in the 10 cm interval above this resistant material.

Our results demonstrate that a drilling mission to Mars could successfully search for life and that the drilling, sample handling, and instruments are technically and scientifically ready for the task.

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References: