LIFE IN THE ATACAMA: SCIENCE AND TECHNOLOGY PATHWAYS TO THE ROBOTIC SEARCH FOR LIFE ON MARS. N. A. Cabrol[1], D. S. Wettergreen[2], and the Life in the Atacama Project Team, [1] SETI Carl Sagan Center/ NASA Ames Research Center. Space Science Division. MS 245-3, Moffett Field, CA 94035-0001. Email: Nathalie.A.Cabrol@nasa.gov; [2] Carnegie Mellon University Robotics Institute, 5000 Forbes Avenue, Pittsburgh, PA 15213. Email: dsw@ri.cmu.edu.

Introduction: Whether life ever existed on Mars or survived profound climate changes is unknown. However, all recent missions have returned evidence that thin films of liquid water or ground ice are present under current conditions [1]. Their presence supports the hypothesis that the martian subsurface could have provided a suitable refuge to life as surface conditions became hostile. Life might still be present, its habitat distribution possibly following residual water. Yet, despite large aquifers predicted at depth and surface ice in the polar regions, most of Mars remains extremely arid. The distribution of residual water/ice is likely to be heterogeneous, and to follow global to local factors, e.g., climate, geology, topography. Accessing deep aquifers can be performed by deep drilling [2] but requires significant infrastructure and may only have limited to no mobility, constraining the number of sites visited per mission.

As we are just embarking on the search for life on Mars and preparing the design of a 2020 rover mission, there are still many uncertainties about life's distribution in hyperarid environment, including on our own planet. Therefore, an exploration strategy that could both multiply the number of sites to be visited per mission through mobility and provide subsurface access may give us initially a greater statistical chance of success of finding life.

Project Overall Goal. The Life in the Atacama (LITA) project is funded by the NASA ASTEP program (2011-2014). Its overarching goal is to demonstrate, in realistic mission configurations, autonomous operations of a rover-mounted drill that could access and interrogate the martian subsurface using *in situ* and remote instrumentation, and could cover long distances to document a diversity of environments. This analog mission takes place in the Atacama desert of Chile along an arid-hyperarid-arid transect that runs from the Coastal Range to the Andes. It provides the background data to critically perform a quantitative assessment of such strategy. Over that transect, LITA seeks evidence of past and present life and habitats down to 1-m depth, in the process drilling through the three major boundaries identified from microbial life by previous Atacama soil studies [e.g., 3-5].

Further, the geological diversity of the traverse that includes desert pavement, volcanic, hydrothermal, playa, channel, gully, lag and aeolian deposits, and soils of varied cohesiveness and hardness provide a unique opportunity to test and quantify the response of the rover-drill system in each specific environment, and to accumulate critical operational data for future planetary missions (Fig. 1)

Figure *– Examples of areas to be explored by the rover for surface and subsurface life in the Atacama desert. (a) Impact crater; (b) layered aqueous sedimentary deposits (Valle de la Muerte); (c) altiplanic lake paleoterraces; (d) hydrothermal and geyser deposits; (e-f) dry lakebeds deposits; (g) Desert boulder field and pavement.*

Science & Technology Objectives. LITA's objectives for the three-year field campaign are to:

(1) Seek evidence and characterize past and present life and habitats through large-area surveys from the Pacific coast to the Andes in Chile and perform subsurface sampling in an environment presenting analogy to early Mars.

(2) Characterize and quantify the performance of the rover, drill, and instrument system on a variety of geologic terrains and, the nature of sample contamination associated with repeated drilling for subsurface exploration; and

(3) Identify and optimize science exploration strategies and validate technologies that maximize productivity in Mars survey missions.

While local and regional studies were performed in the past using standard field methods, a systematic, robotic, exploration of the Atacama's subsurface along a transect from the coast to the altiplano has never been conducted. Our investigation comprehensively documents unexplored habitats where life faces extreme environmental factors. In doing so, LITA bears tremendous potential for genuine discoveries about extreme terrestrial ecosystems, adaptation to desert environments, and their planetary relevance.

Rover Remote & Contact Science Instrument Payload. The payload is designed to address questions of critical significance about boundary conditions and factors governing subsurface and surface microbial life's presence, distribution, and adaption. In the process, LITA also documents poorly-known subsurface ecosystems that have adapted to Mars analog conditions, including increased aridity, oxidation, salinity, and the formation of perchlorates [6]. Ultimately, their exploration enables the quantification of their individual and combined role on subsurface habitability.

Remote and contact instruments have TRLs ranging from 4-8. They are proven in the laboratory and/or in the field, and include:

- The Stereo Panoramic Imager **(SPI)** is a high resolution (0.3 millradian/pxl) trinocular stereo, 3-CCD camera assembly mounted on a pan/tilt mechanism for investigating mega- to mesoscale geology, morphology, and topography [7]. *D.S. Wettergreen, PI.*

- The Microtextural Imager **(MTI)** produces close-up, high resolution (15 µm/pxl, 1.5 Mpxl FoV) images of soils, rocks, trenches, and exposures. It collects sedimentological and textural data at microscale on individual particles and soil mixings, as well as information on stratigraphic changes. *N. A. Cabrol, PI.*

- The Visible/Near Infrared **(VNIR)** spectrometer produces 350-2500 nm spectra with 10 nm spectral resolution. It is automated [8], including target acquisition, tracking, and data validation. *J. Moersch, PI.*

- The Mars Microbeam Raman **(MMRS)** spectrometer performs close-up analysis of rocks and soils for detecting and characterizing water and organic and inorganic forms of carbon. *A. Wang, PI.*

- The Fluorescence Imager **(FI)** detects life by applying fluorogenic dye probes that bind specifically to proteins, carbohydrates, nucleic acids, and lipids. It incorporates a cooled CCD camera with a 10-position emission filter-wheel in front of the lens [9], and acquires RGB and fluorescence channels in a 10x10 cm FoV. *A. Waggoner, PI.*

- The Neutron Detector **(ND)** detects hydrogen abundance 1-2 m in the subsurface. It is similar in design to the one carried by the rover Curiosity on Mars [10]. *J. Moersch, PI.*

- Environmental Sensors **(ENVIS)** continuously monitor air temperature, pressure, relative humidity, condensing moisture, wind speed and direction. A subsurface logger collects soil temperature, pH and Redox to survey soil oxidation. *E. A. Grin, PI.*

- The Geophysical Package **(GEOPACK)** is a pyranometer that continuously monitors UV. O_3 data is provided by the NASA Aura satellite (OMI instrument) on 0.25^o x 0.25^o grids. *N. A. Cabrol, PI.*

- The **Drill** penetrates one meter into soils and rocks, and remove core samples at specific depths. It is prototyped by Honeybee Robotics. *K. Zacky, PI.*

With this payload, LITA's goal is to reveal evidence of evolutionary pressure and adaptation strategies that extremophiles take against the Atacama's extreme environmental factors, and quantify their impact on subsurface habitability. Environmental analogy is selected to help us shed light on the survival potential of putative life on Mars, as it is generally accepted that Martian life (if any) retreated to the subsurface when surface conditions became inhospitable.

Science Autonomy. In addition to providing realistic simulations of a rover mission seeking subsurface life on Mars, LITA furthers science autonomy started with its predecessor project [8, 11-12] by using and developing technologies for science decision making onboard rovers. Over the course of three years, the project will integrate the next generation of science autonomy for: target detection using feature segmentation and classification techniques [13]; target tracking and validation [15]; information-optimal exploration for determining science-driven rover paths [14]; and intelligent data compression techniques that maximize science content [15]. New results from Science-on-the-Fly have demonstrated onboard techniques for using low-resolution satellite imagery (ASTER) to develop exploration and observation/sampling strategies that optimally cover a region. Our goal is to further develop this technology to enable the rover to explore areas observed only by satellite and select representative samples while recording sufficient observations for scientific interpretation of the region.

References:

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