SEARCHING FOR LIFE WITH ROVERS: EXPLORATION METHODS & SCIENCE RESULTS FROM THE 2004 FIELD CAMPAIGN OF THE "LIFE IN THE ATACAMA" PROJECT AND APPLICATIONS TO FUTURE MARS MISSIONS.

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Introduction: The *Life In The Atacama* (LITA) project develops and field tests a long-range, solar-powered, automated rover platform (Zoë) and a science payload assembled to search for microbial life in the Atacama desert. Life is barely detectable over most of the driest desert on Earth. Its unique geological, climatic, and biological evolution have created a unique training site for designing and testing exploration strategies and life detection methods for the robotic search for life on Mars.

The Mars Exploration Rover (MER) mission is currently documenting the early environment at Gusev crater and Meridiani planum [1]. As precursors to MER, previous rover field experiments focused on the methods and payloads to best characterize geology and climate. Neither these rover field tests [2-9] or MER [10] were designed to search for life. Meanwhile, during some of the terrestrial field trials, remote science teams stumbled into life in a few cases but the findings were essentially the result of a speculative process [4-5] and/or could not have been conclusive if they had occurred on Mars, where sample return is not (yet) available.

The findings at Meridiani and Gusev crater are establishing that Mars had conditions for habitability early [*Science* 305-306, MER special issues]. They give high relevance to the preparation of new missions to document Mars' biological potential. *Spirit* and *Opportunity* also demonstrate that rovers are critical science reconnaissance tools for planetary missions. Mobility will be essential for the search of microbial habitats on Mars, where spatially isolated, very localized, and likely sheltered oases, if any, might be the rule. As a result, it becomes critical at this stage of the Mars exploration to start developing and testing new investigation strategies and payloads to assess the feasibility and our ability to detect and characterize life signatures from rovers.

LITA's Overall Science Goal and Objectives: LITA's overarching goal is to understand if/how life can be detected *in situ* by a remote science team using a rover. The science objectives are to: (1) *Seek Life:* Seek and characterize biota surviving in the Atacama and analyze micro-habitats along traverses exploring the Coastal Range and the most arid parts of the desert. LITA questions the hypothesis that the most arid regions of the Atacama represent an absolute desert;_(2) *Understand Habitat*: Determine the physical and environmental conditions associated with habitats, including the search for structural fossils, the monitoring of current biological oases and microorganic communities, and learning how these organisms have contributed to the modification of their environment; (3) *Perform Relevant Science*: Design exploration strategies, integrate and field test a suite of instruments that are capable of detecting hyper arid desert life and characterizing habitats, and are relevant to the investigations and measurements that will facilitate the detection and exploration of life on Mars. We hope to establish whether unambiguous remote identification of life is realistic and achievable with the tested suite of instruments, or if not, to develop the methods and strategies that will increase the probability of detection.

Remote Operations: The 2004 field investigation included two phases: Phase 1 (09/04) at Site B exploring an area of the Atacama near the more humid (20-90%Rh) coast; Phase 2 (10/04) at Site C in the arid core of the desert (3-15%Rh). Each phase lasted one week. Before the beginning of the remote operations, the science team had access to visible and multispectral orbital data (ASTER, IKONOS, Hyperion) with MGS and MO equivalent resolution. Science operations were conducted and scheduled to simulate a real Mars mission, with relevant bandwidth, actual command sequencing, and a cycle of one data uplink and downlink per day.

Rover Payload: LITA opens the path to a new generation of rover missions that will transition from the current study of habitability (MER) to the upcoming search for, and study of, habitats and life on Mars. Zoë's science payload reflects this transition by combining complementary elements, some directed towards the remote sensing of the environment (geology, morphology, mineralogy, weather) for the detection of conditions favorable to oases and habitats along survey traverses, others directed toward the *in situ* detection of life' signatures (biological and physical, such as biological constructs and patterns). The payload is designed to detect microorganisms and chlorophyll-based life, and to characterize habitats. The existence of endoliths in extreme environments analog to early Mars makes the testing of detection methods for chlorophyll-based life a valid working hypothesis. Whether or not life on Mars (if any) used—or uses—photosynthesis, detecting its signature will likely involve accessing isolated oases scattered over large distances. LITA focuses on demonstrating such capability in a relevant terrestrial analog.

The rover payload consists of a Stereo Panoramic Imager (SPI) for geology, morphology, large-scale texture, topography at MER equivalent resolution; High-resolution Fluorescence Imager (FI) with 10 cm x 10 cm footprint, 180µm resolution, allowing 1 m x 1 m mosaics of low-resolution images in visible light control RGB images and B&W fluorescence; Vis/NIR Reflectance Spectrometer, 250-2500nm range, for iron-bearing silicates, carbonates, sulfates, clays and oxides, identification of secondary alteration minerals and other minerals formed in the presence of liquid water; IR spectrometer as Mini-TES analog (not integrated onboard) with emissivity spectra (8-12 µm thermal infrared region) to determine the mineralogical composition of geological targets; Stereo cameras for navigation and context imaging; Workspace cameras give context imaging under the rover for the FI; Environmental Sensors document weather, incident sunlight for possible correlation with biotic processes and habitat localization, temperature, pressure, wind, insolation, UVA and UVB; and a deployable Plow to access subsurface structure, and flip rocks.

2004 Field Campaign Summary of Results: The 2004 investigation achieved a total science traverse (Sites B & C) of 29.5 km in 14 sols. In the last four sols of operations at Site C, autonomy reached 83% with the longest autonomous traverse segment (1.2 km) accomplished on Sol 14. The same sol, the total science traverse reached 9.1 km. [After the end of the science experiment, Zoe traversed 56 km autonomously, with longest single traverse at 3.3km. To put this result into perspective, such mobility would bring the Columbia Hills less than one sol of the landing site in Gusev]. The effectiveness of combining (a) rover long-range reconnaissance mapping and (b) localized focused investigations (targeted sampling) to identify potential habitats was also demonstrated. The long-range mapping allowed a very rapid, regularly spaced (usually 100's of meters) environmental survey along one sol's traverse using the remote sensing instruments. With data compression, this survey took only a fraction of the daily bandwidth and provided critical data about the morphology, mineralogy, and geology of the traverse, allowing a better selection of targets for *in situ* measurements. Remote science and single uplink per sol emphasized one downside of this strategy: some potentially high-science payoff targets being located kilometers away from the location where the rover last stopped. On sol 14, the remote science team used the mobility and navigation capabilities of Zoë to mitigate this issue and demonstrate that the rover was capable of returning, first, to locale 040 (autonomously) some 1.2 km back on the previous sol's traverse, where the survey mapping had shown possible biological potential. Zoë came only within a few meters of the specific site and completed more science before departing again to finish the sol's sequence, which ended by a command to return to the "landing site" from locale 025, almost 9 km away. The rover ended up only 150 m short from its destination. The ability for a rover to return fast and accurately to sites of interest is likely to be a critical asset for future Mars long-range rover astrobiology missions and sample return. This new exploration method will become part of our 2005 search strategy and its results will be quantified.

During science operations, the science team inspected thoroughly 20 samples (targeted examination) and 16 more were partially surveyed within two main types of habitats (hypersaline and desert pavement). The plow was used on 4 soil samples to expose the subsurface for *in situ* measurements. To evaluate the presence of life within the samples, the science team used 4 converging types of evidence: visual, chlorophyll, DNA, and protein data. None of the targeted sampling areas (for Site B or C) met the all 4 criteria at once. However, several samples showed 2 or 3 out of the 4 criteria and were listed as possible positives. The samples were brought back to the lab after the field experiment, and analyzed for ground-truth. The first phase of laboratory analysis indicates that among those samples that were positive on DNA and protein dyes in the field, preliminary results suggest biological activity [Minkley et al., this LPSC].

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