Searching for life with rovers: exploration methods and 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 characterize 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 (Fl) 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,
classes, 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 Fl; Environmental
Sensors document weather, incident sunlight for
imaging under the rover for
geological targets;
determine the mineralogical composition of
TES analog (not integrated onboard) with emissivity
presence of liquid water; IR spectrometer as Mini-
examination
range rover
3.3km
the end of the science experiment, Zoe
sol, th
reached 83% with the longest autonomous traverse
last four sols of operations at Site C, autonomy
traverse (Sites B & C) of 29.5 km in 14 sols. In the
geological targets;
subsurface structure, and flip rocks.

2004 Field Campaign Summary of Results:
The 2004 investigation achieved a total science
trace (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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