DIAGNOSTIC CHARACTERISTICS OF MACROSCOPIC BIOPATTERNS DETECTED WITH NOVEL ROBOTIC PLATFORM. H. S. Kelly[1], P. J. Boston[1, 2], and A. J. Parness[3]. [1]New Mexico Institute of Mining and Technology, Socorro, NM 87801, [2] National Cave & Karst Research Institute, Carlsbad, NM 88222, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

Introduction: Biosignatures, i.e. the many different traces of life, are a prime objective for future missions to astrobiologically significant targets like Mars. Much of the thinking that goes into creating mission plans for life detection missions depends upon methods developed to detect and characterize one or more types of such biosignatures. Large knowledge gaps currently exist in the interpretation of possible origins of many mineral deposit textural biosignatures in challenging geological settings like caves, cliff faces, rock shelters, patterned terrains, etc. We have identified and characterized some highly distinctive biopatterns (known as *biovermiculations*) found on Earth in caves and other extreme environments (Figure 1; [1-19]) that should be detectable by landed missions using a variety of multispectral imaging techniques. One of the primary technological and operational challenges is to gain access to these currently rover-unfriendly sites. Advances in robotic capabilities are being developed at JPL (Figure 2) allowing first pass reconnaissance and testing of the detectability of these unique biopatterns in the field in caves and other rugged terrains. Field trials in 2015 showed that the robotic platform can navigate test sites where biopatterns under study are present.

Biovermiculations: We hypothesize that mineral deposit textures that are influenced by biological processes (like biovermiculations) are sufficiently distinctive that a suite of diagnostic characteristics (Table 1; [5]) can be developed which will enable us to distinguish them from non-biological textures in the field through use of our robot/instrument package.

Lithified macroscopic structures and microscopic textures that resemble living microbial mats, biofilms, algal fingers, layered endolithic desert communities, and stromatolites
Extant microorganisms found in association
Organic material and molecular fossils
Microscopically visible organisms
Microscopic mats and biofilms containing minerals forming in situ
Internal layered structure
Filamentous microstructure
Other evidence of current or previous biological activity

Table 1: Diagnostic Characteristics Indicating an Influence on Mineral Deposit Textures by Biological Processes [5].

Instrumentation: We are developing a suite of robot-mounted instruments to test the detectability of biopatterns. This initial, simple, proxy suite of instruments will serve as a proof-of-concept that such a macroscopic imaging approach works with real biopatterns in nature on complex, often high surface roughness, natural settings. The most apposite instrument suite was selected and measurements implemented using our latest robotics design. The robotic platform is based on the science requirements for an introductory exploratory and data collection mission into lava tubes as a wholly robotic mission, or where human investigation may be limited by accessibility and safety concerns. Size, weight, power draw, and cost were optimized as well. The suite of instruments selected for our environmental sensor package includes:10x hand lens, 100x micro-imaging device, white light illumination, UV illumination, multi-gas monitor (capable of measuring potential biological indicator gases: CO, H_2S, CH_4, NH_3, O_2, and NO_2), temperature and relative humidity (RH) sensor, and video camera with dual capability to produce stills.

LEMUR Robotic Platform: The LEMUR III robotic platform was selected for this project nominally for its rock climbing capability and mechanical adherence to vesicular basalt—the most common lithology present in lava tubes where many biovermiculations are located—through the use of microspines. Microspines are arrays of sharp hooks that contact rock, and lodge some proportion of the spines into pits and fractures of all sizes in the rock surface [20]. Additionally, the LEMUR robotic platform (Figure 2) has the ability to scale rock walls and overhangs utilizing four omni-directional anchors that can withstand over 100 N of force in all loading directions, and may be supported by a single anchor [21, 22].

Results & Conclusions: We believe that visual detection of distinctive biosignatures via a novel and highly capable robotic platform can provide access to terrains currently outside of our ability to navigate robotically. Visually distinctive biopatterning is within the capability of our melded robotic and instrument unit. Biosignature detection in these types of rugged terrains will further advance robotic capabilities for missions to astrobiologically significant targets like Mars.

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Figure 1: Microbial colonies in extreme environments as shown here (A-J) often exhibit more geometrically elaborate patterns as opposed to simple solid mat growth. These highly distinctive biopatterns, known as *biovermiculations*, are found on Earth in caves and other extreme environments. From Boston et al., unpublished results 2015.

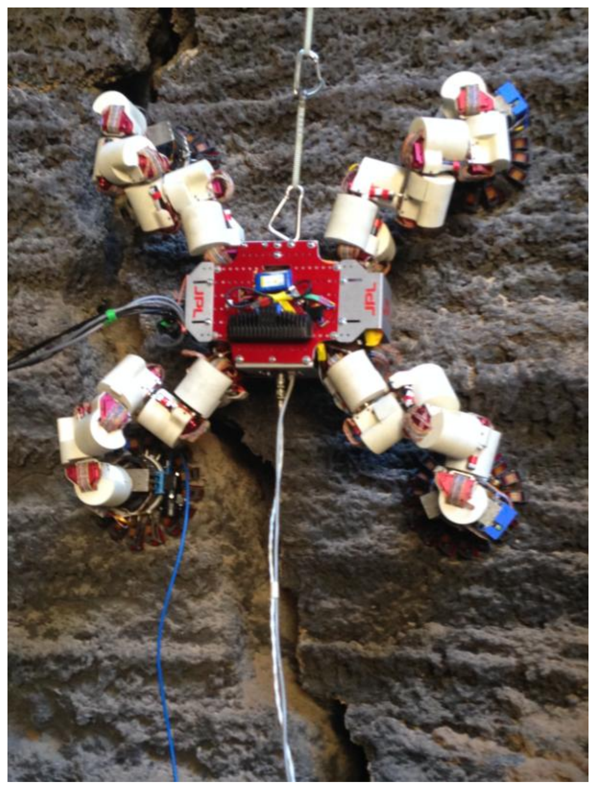

Figure 2: LEMUR III robotic platform demonstrates rock-climbing capabilities to better detect biopatterns in the field in caves and other rugged terrains.