NEAR-IR REFLECTANCE SPECTRA IN A LAVA TUBE CAVE FROM A ROBOTIC PLATFORM. N. J. Chanover[1], K. Uckert[1], D. G. Voelz[2], X. Xiao[2], R. Hull[2], P. J. Boston[3], A. Parness[4], N. Abcouwer[4], A. Willig[4], and C. Fuller[4] [1]Astronomy Department, New Mexico State University, Box 30001/MSC 4500, Las Cruces, NM 88003, [2]Klipsch School of Electrical and Computer Engineering, New Mexico State University, Box 30001/MSC 3-O, Las Cruces, NM 88003, [3]Earth and Environmental Sciences Department, New Mexico Institute of Mining and Technology, Socorro, NM 87801, [4]Extreme Environment Robotics Group, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109

Introduction: Lava tube caves on Earth serve as valuable analogs for similar structures on other solar system bodies such as the Moon and Mars. Due to the protection they offer from the constant bombardment of cosmic rays and energetic particles and radiation from the Sun, particularly on bodies that lack a protective magnetic field, these subsurface environments may offer refugia where the environments could remain habitable over a long time scale [1, 2]. Hence, planetary caves are desirable sites for future robotic exploration efforts aimed at the detection of biosignatures resulting from extinct or extant life [3-5].

The robotic exploration of planetary caves should include the abiliy to analyze sites that traditional rovers cannot access, *i.e.* the walls or overhangs, as these locations are often rich with interesting formations and deposits. A rock climbing robot equipped with a suite of remote sensing instruments designed to address habitability and biomarker detection is ideally suited for this task. Here we describe a pilot effort to integrate a near-infrared point spectrometer developed for operation on a robotic platform with the LEMUR rock climbing robot.

Field Site Description: We selected the Four Windows Cave in El Malpais National Monument in New Mexico for our first field tests because it offers a wide range of rock features and orientations for testing the LEMUR robot. This cave and the surrounding volcanic terrain has been frequently used as a planetary analog [4, 6, 7], and its microbially precipitated mineral deposits and biovermiculation patterns may contain unique NIR spectral signatures that could be identified as biomarkers. The field tests of LEMUR and PASA at Four Windows Cave were conducted from June to mid-September 2015.

Technology Description:

NIR Reflectance Spectrometer. We employed the Portable AOTF Spectrometer for Astrobiology (PASA), which is a point spectrometer that operates between 1.6-3.6 microns and uses an acousto-optic tunable filter (AOTF) as the wavelength selecting element [8]. This instrument has been used in several caves, including Fort Stanton Cave (Lincoln County, NM) and Four Windows Cave (El Malpais National Monument, Grants, NM) and Cueva de Villa Luz in Tabasco, Mexico, to acquire NIR reflectance spectra of various deposits, formations, microbial colonies, and biofilms [9-10]. PASA was modified for mounting on the LEMUR robot by making it more lightweight, operable through a 10 m cable bundle, and using a higher power lamp to improve the signal-to-noise ratio for the darker basaltic rock typical of a lava tube cave (Fig. 1).

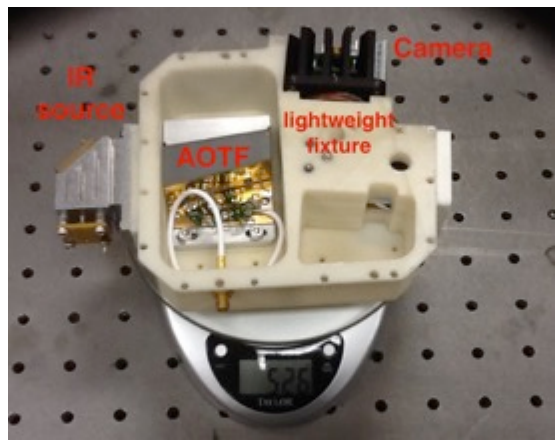

Figure 1. PASA-Lite on the benchtop

Rock climbing Robot. The LEMUR rock climbing robot is a limbed system with 7 degrees of freedom (joints) per limb and 4 limbs. Each joint within the limb is exactly the same and joints are arranged in a serial manner such that there are no collocated degrees of freedom. The robot uses microspine grippers as end effectors to anchor itself to the floor, walls, and ceilings of caves and cliff faces. Microspine grippers use hundreds of sharp hooks that catch small bumps, pits, and other rough spots on a rock surface. The robot grips the rock by squeezing all of these hooks towards the center of the gripper. Compliance in the independent microspines allows the hooks to conform to the arbitrary roughness of the rock and also distributes the load amongst the hooks that have found a grip. Typically only 10 percent of a grippers hooks need to engage to create a strong anchor. A previous version of the robot with much more limited mobility is described in [11].

Candidate Biosignatures: In Four Windows Cave (NM) and Cueva de Villa Luz (MX), distinctive mazelike microbial mats known as biovermiculations decorate rock surfaces and have been the subject of a number of studies [12-16]. These patterns occur both as living mats and as fossil examples and we have chosen them as a major focus for testing PASA because they present clear macromorphological evidence of life while also offering significant challenges in analysis of chemical and mineralogical composition.

Results: We will present preliminary results from our integrated field measurements at Four Windows, including NIR reflectance spectra of biovermiculation mats, other previously characterized microbial colonies (mineralized with calcite, thenardite, and other minerals, see Fig. 2), surfaces showing no macroscopic evidence of microbial colonization, and freshly fractured bedrock surfaces as controls.

Figure 2. Example of one of the types of surfaces in Four Windows Cave that will be sampled with PASA-Lite.

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