DEMONSTRATION OF AN INFRARED SPECTROMETER AS PART OF A GEOCHEMICAL/ASTROBIOLOGY INSTRUMENT PACKAGE ON A ROBOTIC PLATFORM. K. Uckert[1], N. Chanover[1], A. Parness[2], D. G. Voelz[3], X. Xiao[3], R. Hull[3], P. J. Boston[4], N. Abcouwer[2], A. Willig[2], and C. Fuller[2], [1]Astronomy Department, New Mexico State University, Box 30001/MSC 4500, Las Cruces, NM 88003, [2]Mobility and Robotics Systems Section, Jet Propulsion Laboratory, Pasadena, CA, [3]Klipsch School of Electrical and Computer Engineering, New Mexico State University, Las Cruces, NM, [4]NASA Astrobiology Institute, NASA Ames Research Center, Moffett Field, California

Introduction: Planetary caves are desirable sites for future robotic astrobiology exploration efforts due to the protection these sites offer to microorganisms from solar radiation and their thermal stability [1-5]. A rock climbing robot equipped with a suite of *in situ* instruments designed to identify biosignatures and characterize subsurface mineralogy is ideally suited for this task. We present an effort to integrate a near-infrared (NIR) point spectrometer developed for operation on a robotic platform with the LEMUR rock climbing robot. Our near-term goals include the additional integration of a Raman spectrometer and a micro X-Ray fluorescence instrument with LEMUR.

PASA-Lite: The Portable AOTF Spectrometer for Astrobiology (PASA), is a NIR (1.6 - 3.6 μm) point spectrometer using an acousto-optic tunable filter (AOTF) as the wavelength selecting element [6]. We operated PASA in several remote and extreme environments, including Fort Stanton Cave (Lincoln County, NM), El Malpais National Monument (ELMA) lava tubes (Grants, NM), and Cueva de Villa Luz (Tabasco, Mexico), to acquire NIR reflectance spectra of speleothem formations, microbial colonies, and biofilms [7]. PASA-Lite was modified from previous PASA prototypes for mounting on the LEMUR robot by reducing its mass, increasing its focus length, and using a higher power lamp to improve the signal-to-noise ratio for the darker basaltic rock typical of a lava tube cave.

LEMUR: 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 technical overview of the robot is described in [8]. A photograph of PASA-Lite mounted on the body of LEMUR in the field is presented in Figure 1.

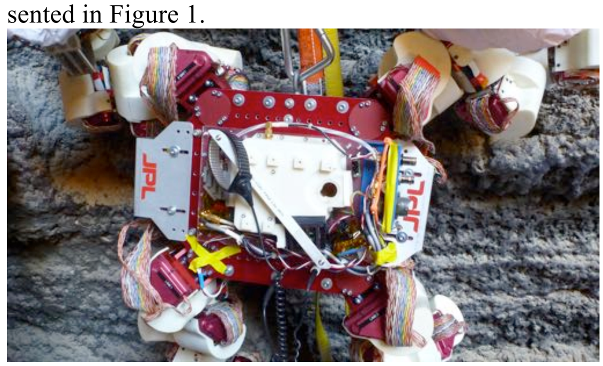

Figure 1: PASA-Lite mounted to LEMUR in Big Skylight Cave.

Big Skylight Cave Field Campaign: We conducted field tests of LEMUR and PASA-Lite at the ELMA lava tubes from September 10-18, 2015. Big Skylight Cave in ELMA offers a wide range of rock features and orientations for testing the LEMUR robot, and has been frequently used as a planetary analog field site [4, 9-10]. We show that the microbially precipitated mineral deposits and biovermiculation patterns present in these lava tubes contain unique NIR spectral signatures that may be identified by PASA-Lite. Furthermore, we demonstrated successful vertical traverse of LEMUR on a basalt wall in the cave while simultaneously acquiring NIR spectra with PASA-Lite.

References: [1] Boston, P. J. (2010) J. Cosmol., 12, 3957–3979. [2] Pavlov, A. A. et al. (2012), GRL, 39, L13202. [3] Boston et al. (1992) Icarus, 95, 300-308. [4] Boston et al. (2001) Astrobiology, 1, 25-55. [5] Leveille, R. J. and Datta, S. (2010) Planet. Space Sci., 58, 592-598. [6] Tawalbeh et al. (2013), Opt. Eng., 52, 063604. [7] Uckert et al. (2015), 46th LPSC #1832, 2694. [8] Parness et al. (2017) *IEEE Int. Conf. Robot Autom.*, *Accepted*. [9] Northup, D. E. et al. (2004) AMCS Bull., 19, 119-125. [10] Northup, D. E. et al. (2011), Astrobiology, 11, 1-18.

Acknowledgements: This work was supported by a NASA Space Technology Research Fellowship (NNX13AL49H). This work was also supported by NASA's Moon and Mars Analog Missions Activities program and Planetary Science and Technology Through Analog Research program.