GEOLAB RESULTS FROM THREE YEARS OF ANALOG MISSION TESTS. C.A. Evans[1], M.S. Bell[2], and M. J. Calaway[2], [1]Astromaterials Acquisition and Curation Office, Mail Code KT, NASA Johnson Space Center, 2101 NASA Pkway, Houston TX 77058, cindy.evans-1@nasa.gov, [2]Jacobs Technology (ESCG), NASA Johnson Space Center, Houston TX 77058.

Introduction: GeoLab is a prototype glovebox for geological sample examination that was, until November 2012, fully integrated into NASA's Deep Space Habitat Analog Testbed [1,2]. GeoLab allowed us to test science operations related to contained sample examination during simulated exploration missions. The facility, shown in Figure 1 and described elsewhere [1-4], was designed for fostering the development of both instrument technology and operational concepts for sample handling and examination during future missions [3-5]. Even though we recently de-integrated the glovebox from the Deep Space Habitat (Fig. 2), it continues to provide a high-fidelity workspace for testing instruments that could be used for sample characterization. As a testbed, GeoLab supports the development of future science operations that will enhance the early scientific returns from exploration missions, and will help ensure selection of the best samples for Earth return.

Figure 1: GeoLab glovebox integrated in to NASA's Deep Space Habitat Demonstration Unit.

The conceptual design for GeoLab came from several sources, including ongoing spaceflight research and instruments used on International Space Station (e.g. Microgravity Science Glovebox), other terrestrial analog studies, existing Astromaterials Curation Laboratory hardware and clean room procedures, and mission scenarios developed for the former Constellation program.

Figure 2. NASA's Deep Space Habitat, 2011

GeoLab Operations: Over the past three years of GeoLab operations we reconfigured the GeoLab hardware and software interfaces, and evolved our test objectives. Our tests were constructed to address the following goals: 1) definition of requirements for analytical instrumentation, sample handling, and prioritization strategies based on realistic concepts for geological operations on other planetary surfaces; 2) assessment of the scientific contribution of selective in-situ sample characterization for mission planning, operations, and sample prioritization; 3) evaluation of analytical instruments and tools for providing efficient and meaningful data in advance of sample return; 4) determination of activities that are best done by astronauts, and identification of science operations that leverage human presence with robotic tools.

In year 1 (2010), we tested basic glovebox operations with one and two crewmembers, and science operations with a remote science team. We also tested the efficacy of basic sample characterization (descriptions, microscopic imagery, XRF analyses) and feedback to the science team [1,3,5,6]. In year 2 (2011), we tested enhanced software and interfaces for the crew and science team (including web–based and mobile device displays) and demonstrated lab configurability with new diagnostic instruments (JPL/ASU Multispectral Microscopic Imager) [2]. In year 3 (2012), we installed and tested a robotic sample manipulator [7] and evaluated robotic-human interfaces for science operations. We also tested science operations with significant (50 sec) one-way time delays.

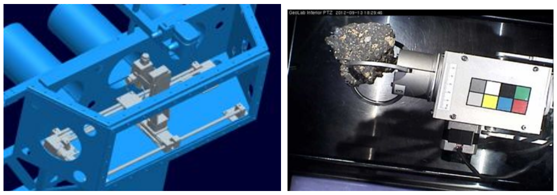

Figure 3. CAD rendering of robotic arm inside glovebox, viewed from above (left); robotic arm end effector positioning sample (right).

Results: During the three years that GeoLab was physically integrated into the Deep Space Habitat Test Facility, we participated in 19 days of simulated mission testing in full analog settings, and monitored operations with 18 different test subjects. We also conducted stand-alone tests with nearly 20 other operators. We continue to compile our test results, but we can confidently report the following:

1. The GeoLab design supports autonomous crew operations of the basic glovebox functions. In many ways GeoLab operations are similar to experiment operations on the International Space Station, including both independent crew operations and operations with PI involvement. The trained crew enhances science returns by providing real time and spontaneous observations; this is especially important when time delays preclude real-time science team involvement.

2. Good sample imagery is key for preliminary characterization. Imagery collected at a range of scales forms the basis for additional characterization and aids sample handling operations. Our earliest tests indicated that basic microscopy was, perhaps, the most valuable data for rapid assessment of samples.

3. Robotic assists for sample handling are critical in microgravity. Robotics aid crew and enable precision sample handling for operations and data collection. Our 2012 tests validated the quantity and quality of microscopy that could be achieved with a robotic sample holder. The sample holder made possible one-person operations (crew efficiency), flexibility in sample positioning (six degrees of freedom allow positioning in complete X-Y-Z space, see Fig. 4), systematic and repeatable sample positioning, allowing for registration and mapping of the sample in Cartesian space for future analyses. Finally, proper robotic sample handling can result in less sample handling, and therefore present less risk of damaging or compromising a sample.

4. A combination of imaging tools and robotic tools provides significant flexibility for designing facilities and operations related to sample characterization and sample handling. Progressive tests using robotic interfaces will help develop requirements, instruments and procedures for different exploration scenarios.

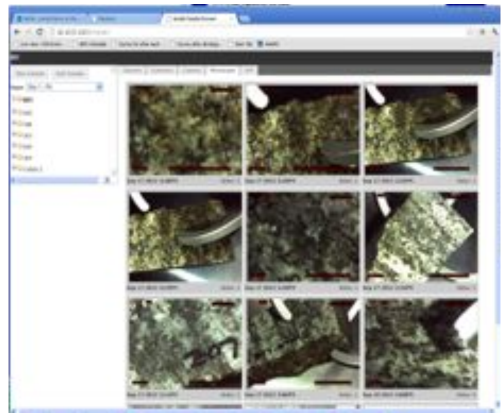

Figure 4. Suite of images taken at a variety of magnifications and orientations, made possible by sample manipulator.

5. Preliminary sample characterization provides data that supports smart decisions during mission operations. It provides data for sample handling and prioritization, enables a better understanding of the regional geology being explored [6], highlights details such as alteration surfaces on samples (see Fig. 5), and is useful for future exploration plans. The types of data we collected in the GeoLab during our analog tests allow for wide dissemination and broad participation by scientists and students on Earth.

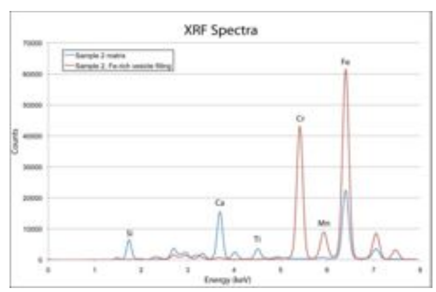

Figure 5. Example XRF spectra taken during 2011 analog tests that show compositional differences between rock matrix and vesicle filling material.

References: [1] Evans, C.A., et al. (2012) Acta Astronautica, doi:10.1016/j.actaastro.2011.12.008; [2] Evans, C.A., et al. (2012) LPS XLIII, Abstract #1186; [3] Calaway, M.J., et al. (2011) LPS XLII, Abstract #1473; [4] Calaway et al. (2010) LPSC XLI, Abst. #1908; [5] Evans et al. (2010) LPSC XLI, Abst. #1480; [6] Young, K.E. et al. (2012) Am.Geophys. Union Fall meeting, V33B-2867; [7] Bell, M.S., et al. (2013) LPS XLIV, this meeting.