THE NASA REFLECTANCE EXPERIMENT LABORATORY (RELAB) FACILITY: PAST, PRESENT, AND FUTURE. R.E. Milliken[1], T. Hiroi[1], & W. Patterson[1], [1]Dept. Earth, Environmental & Planetary Sciences, Brown University, Providence, RI 02912 (ralph_milliken@brown.edu) (http://www.planetary.brown.edu/relab/)

Overview: The Reflectance Experiment LABoratory (RELAB) is a NASA-supported multi-user spectroscopy facility that has been housed and operated at Brown University for over 30 years. The goal of RELAB is to provide services to acquire and distribute high quality spectral data to members of the NASA, planetary science, and remote sensing communities. The two major components of RELAB are 1) instrumentation to acquire reflectance and transmission spectra and 2) a publicly available database of all spectral data acuiqred over the history of the lab. Instrumentation for acquisition of new spectral data is available to all NASA-funded researchers on a no-charge basis.

Interested investigators, including students, may submit samples to RELAB for measurement. Specific research objectives are funded by individual NASA R&A programs, and investigators that utilize RELAB have been funded by a diversity of programs including (but not limited to) Planetary Geology & Geophysics, Cosmochemistry, Astronomy, Mars Data Analysis, Mars Fundamental Research, Lunar Advanced Science and Exploration Research, Solar Sytstem Workings, Exobiology, and NASA graduate student fellowships. RELAB also supports measurements related to planetary missions, including spectral characterization of flight hardware components.

All spectral data are made publicly available within three years of their acquisition date, allowing investigators and graduate students appropriate time to publish their results. The open database continues to be used by numerous members of the planetary science and remote sensing communities both within the U.S. and abroad as a reference for the spectral properties of (primarily geologic) materials.

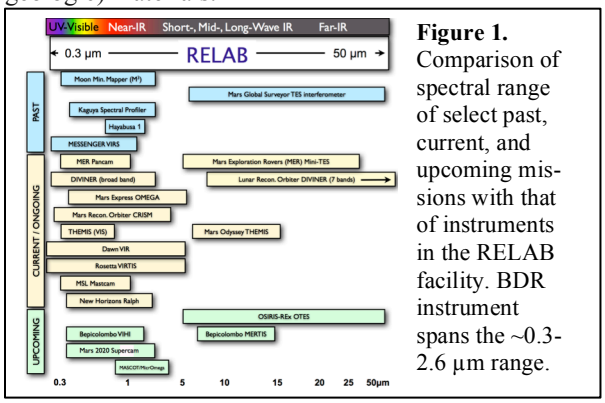

Figure 1. Comparison of spectral range of select past, current, and upcoming missions with that of instruments in the RELAB facility. BDR instrument spans the ~0.3-2.6 µm range.

Measurement Capabilities: The RELAB facility's primary capabilities are focused on acquiring reflectance spectra of materials over visible, near-infrared, and infrared wavelengths, spanning a range that is complementary to numerous past, current, and future planetary missions (Figure 1). This is accomplished through the integration of three main instruments. The primary instrument is a custom bi-directional reflectance (BDR) spectrometer that measures reflected light from 0.3 – 2.6 µm. This system uses a monochromator in combination with various light sources and detectors (Table 1) to progressively step through narrow bands of light to provide high-resolution, high-precision reflectance spectra of samples relative to one of several standards.

The BDR is also capable of measuring samples under different illumination conditions by varying the incident and emergent angles of light, allowing users to simulate spacecraft viewing geometries and assess phase function and scattering properties of materials. Incidence and emergence angles can range from 0-70° independently and a minimum phase angle of ~12° can be achieved. Samples can be in a variety of forms, including powders, rock chips, small hand specimens, gels, etc, and sample holders can be spun during measurement if desired.

Table 1. Specifications for BDR spectrometer. Minimum sampling interval is 1 nm, though 5-10 nm is standard.

Range (µm)	Resolution (nm)	Detector	Light Source
0.30-0.42	<1.7	Photomultiplier	Xenon
0.40-0.85	<1.7	Photomultiplier	Halogen
0.60-1.80	<3.4	InSb	Halogen
1.70-2.60	<6.8	InSb	Halogen

In addition to its high sensitivity and level of calibration, the BDR system is also capable of measuring small samples (~10 mg) and spot sizes (~1 mm). Therefore, this system provides a robust and non-destructive method for the spectral characterization of small, precious materials, and as such it has been used to measure the VIS-NIR reflectance spectrum of many lunar and meteorite samples. Details of the instrument are provided by *Pieters* (1983) [1] and the RELAB User's Manual [2], and results from early years of operation are presented in [1] and [3].

Other RELAB instruments include an FTIR spectrometer equipped with a diffuse reflectance attachment and an FTIR microscope. The bench FTIR spectrometer (Nicolet Nexus 870) can measure transmission, emission, and reflection of materials using the main sample compartment or external ports. Current combinations of beamsplitters and detectors allow measurement over the ~1-50 µm wavelength range. Samples are typically measured in the FTIR using a diffuse reflectance attachment with a bi-conical geometry that can hold up to

60 samples and a reflectance standard; this is in an enclosed environment that is purged to remove CO_2 and H_2O. Samples measured in this system can be transferred to and from the BDR system without additional sample preparation, thus FTIR measurements can be directly compared to corresponding BDR measurements for a given sample.

The FTIR microscope is a Thermo Nicolet Continuμm microscope with a spot size as small as ~50 μm and is often used in transmission mode as well as reflectance. This instrument is ideal for examining spectral properties of thin or thick sections.

RELAB Spectral Database: The RELAB database currently contains >24,000 spectra that represent >12,000 unique samples, including a wide variety of terrestrial and extraterrestrial (e.g., lunar and meteorite) materials. Spectra from the database have been used in over 325 peer-reviewed journals in the past 10 years alone, with the use of these data continually increasing as new missions acquire ever more spectral data. Advantages of the RELAB spectral database include:

- Long history (30+ years) of acquiring high precision and well-calibrated absolute reflectance spectra.
- Two technical operators over its entire history, ensuring continuity and homogeneity in sample preparation, measurement, data processing and thus data quality.
- Contains many reflectance spectra over the full 0.3 – 50 μm wavelength range.
- Provides a single source for spectra of lunar and meteorite samples that were prepared and measured in a consistent manner using the same instrument.

The result is that spectra in the RELAB database are highly reliable and provide absolute reflectance measurements of samples, thus allowing for direct *quantitative* comparison between and modeling of spectra in the database. In other words, the spectrum of an Apollo 16 soil measured in 1984 can be compared directly to the spectrum of an Apollo 17 soil measured this year, with the assurance that any observed differences are likely due to true sample differences and not caused by the use of different instruments, differences in sample preparation, or different data acquisition processes (e.g., use of different reflectance standards).

A key goal of RELAB is to provide a way for members of the broader science community to easily access this unique database and download data for their own use. All data are currently available through an FTP server hosted at Brown University (http://www.planetary.brown.edu/relabdata/), but recent funding through the NASA PDART program will allow the database to be overhauled to meet the current and future needs of the community. This includes migrating the data to a searchable database, archiving all past and future data in the PDS Geosciences node, and developing an easy-to-use web-based search tool. The latter will allow users to rapidly search the database, preview spectra and auxiliary information, and download data using a shopping-cart style interface. An example of what a sample "quicklook" product might look like in the new search tool is shown in Figure 2.

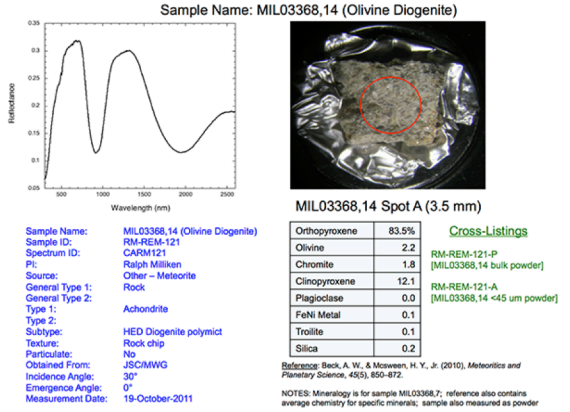

Figure 2. Example of what potential sample "quicklook" product may look like in new online searchable database, which will be hosted through the PDS Geosciences node.

Conclusions: The NASA RELAB facility provides a consistent, centralized, and easy way for experts and non-experts alike to acquire spectral data for a wide range of sample types over a wide wavelength range. Routine instrument calibration, significant experience in sample preparation and spectroscopy, and consistency in data acquisition and processing make RELAB a valuable facility for acquisition of spectral data relevant to a wide array of planetary studies. The facility also includes a designated sample prep room and is thus particularly useful for measurement of precious lunar and meteorite samples.

RELAB measurements are acquired at no cost to individual users and the lab is an ideal choice for those investigators who lack easy access to such equipment. Though not required, users are always welcome to visit the facility to learn more about operating procedures, and RELAB personnel are dedicated to helping users of the equipment and database with their measurements and data interpretation. An ongoing overhaul of the database, including improved accessibility, will allow the products of this facility to continue to meet the needs of the science community over the coming years.

Personnel: R.E. Milliken is Science Manager, T. Hiroi is Operations Manager, W. Patterson is RELAB Engineer

References: [1] Pieters, C.M. (1983) *JGR*, 88, 9534-9544; [2] RELAB User Manual: http://www.planetary.brown.edu/relabdocs/RELAB_UserManual_2015.pdf ;[3] Mustard, J. & C.M. Pieters (1987) *JGR*, 92, E617-E626.