STUDYING DUST AS A STEP TO SAFELY SENDING HUMANS BACK TO THE MOON: FINE-PARTICLE TERRESTRIAL MINERAL SPECTRA IN THE UV-VNIR-MIR ACQUIRED BY THE TREX SSERVI TEAM.

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Introduction: A primary objective of the TREX SSERVI team (trex.psi.edu) is to study dust in distributed laboratories and apply the knowledge gained to interpreting surface characteristics of the Moon, asteroids, martian moons, and other airless bodies to ultimately increase the safety of crewed missions to these surfaces. The focus of this abstract is spectroscopy of fine particulate (<10 μm) samples measured over the broad spectral range of ultraviolet (UV) to visible/near infrared (VNIR) to mid-infrared (MIR) (~0.22 to 25 μm) using reflectance and emission spectroscopy. Throughout the course of our grant we will be studying 3 general sample groups: terrestrial minerals, meteorites (request approved), and ultimately lunar materials (request pending).

Although not presented here, we are also conducting other relevant experiments with our dust samples that include: shock/impact studies, sample irradiation, dust/ice mixtures with spectroscopic study, plus measurements of our samples using Raman and Mössbauer spectroscopies.

Here we present the work we are doing with the terrestrial mineral samples using reflectance and emission spectroscopy.

Mineral Samples:

We have obtained and measured (UV-VNIR-MIR) 28 terrestrial mineral samples (Table 1).

Table 1. Terrestrial mineral samples.†

Forsterite Globe*	Pyrite
Forsterite SC*	Palygorskite (PFI-1)
Bytownite CB*	CaS (oldhamite)
Labradorite Chihuahua*	Hectorite (SHCa-1)
Labradorite ARSAA	Nontronite (NAu-2)
Diopside Herschel*	Na-montmorillonite (SWy-3)
Augite Harcourt*	Ca-montmorillonite (STx-1b)
Albite (AL-I)	Kaolinite (KGa-1b)
Anorthite (AN-G)	Serpentine, lizardite (UB-N)
Spinel ARSAA	Serpentine, antigorite (SMS-16)
Phlogopite Mica-Mg	Ilmenite
Enstatite (Zen 1)	Zinnwaldite (ZW-C)
Hematite AA-30	Fe metal <10 um
Hematite SA-500g	Graphite 7-11 um

* Samples being used by several SSERVI teams for cross-SSERVI collaborations & science linkages [1,2].
† We are acquiring amorphous C for terrestrial sample suite. If we can obtain enough bulk fayalite and/or pigeonite, we will add those to the suite, as well.

Particle Sizes: Our focus is on samples whose particle diameters are <10 μm, as supported by the returned samples from the asteroid Itokawa obtained by the Hayabusa mission. The Itokawa sample particles ranged in diameter from 3 to 40 μm, with the majority being <10 μm [3].

To verify that our bulk samples are fine enough, we analyzed each one using a particle size analyzer (either an Elzone or a Mastersizer). Our sample particles are typically closer to <2 μm diameter (Figure 1).

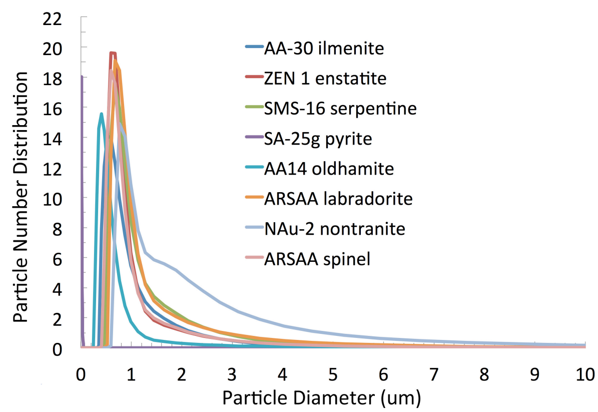

Figure 1. Determination of the particle size distribution of several bulk mineral samples. All samples were analyzed; only 8 are shown for clarity.

Participating Labs: The data to be presented in this work include spectra acquired at the Planetary Spectroscopy Lab (PSL) at Deutsches Zentrum für Luft- und Raumfahrt (DLR, Berlin, Germany), at the Planetary Science Institute (Tucson, Arizona), and at HoserLab at the University of Winnipeg (Canada).

Reflectance Measurements: Our team is continuing to upgrade and improve the various labs' capabilities in order to fine-tune and increase the vacuum capabilities, wavelength ranges (especially into the far-UV and far-IR where we are hoping to achieve great data short-ward to ~0.12 mm and long-ward to ~300 mm), calibration, and overall data quality.

When several labs are measuring the same samples with different hardware, some differences that are not due to the sample become clear. For dark minerals such as enstatite, our cross-lab comparisons are quite good (Figure 2). However, for light-toned, more transparent minerals, the cross-lab comparison can emphasize lab variability (Figure 3).

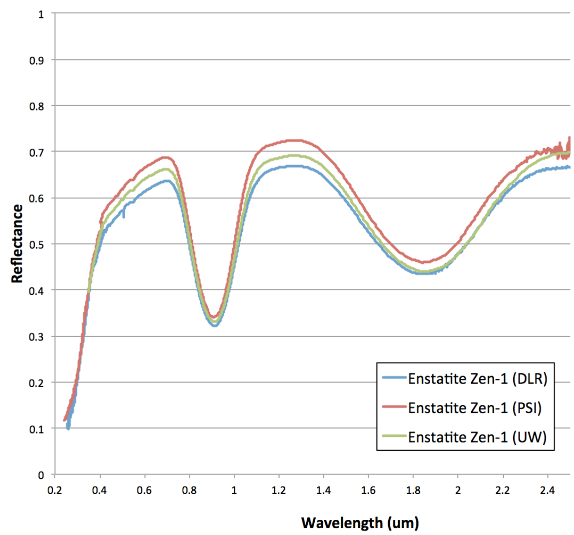

Figure 2. Reflectance spectra of enstatite from 3 of our participating labs. These spectra are remarkably similar.

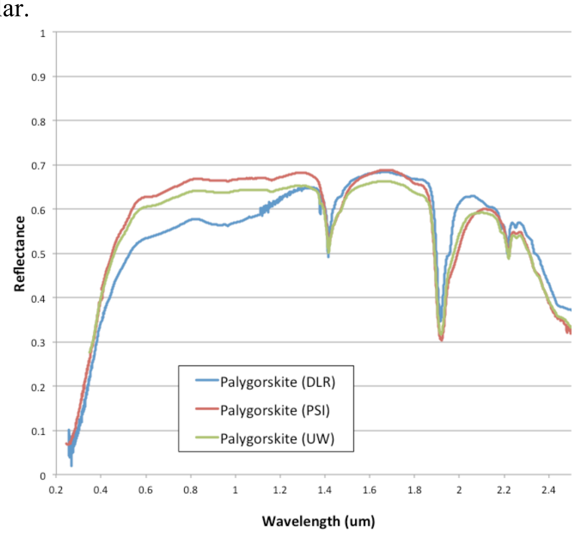

Figure 3. Reflectance spectra of palygorskite from 3 of our participating labs. These spectra show differences among the labs.

The differences in the reflectance spectra and potential causes will be addressed, including deuterium versus tungsten lamps, vacuum versus ambient chambers, sample cup depth, calibration target, etc.

We are actively making and assessing new UV calibration targets (both aluminum discs and glass discs are to be coated in platinum) that will introduce uniformity among the labs.

Emission Measurements: For direct application to airless bodies, mid-infrared emissivity spectra (unlike UV-VNIR spectra) must be obtained under vacuum conditions over a range of representative surface temperatures because atmospheric pressure and surface temperature affect spectral characteristics, especially for fine-particulate samples wherein thermal gradients are enhanced [4-6]. Emission measurements were made at DLR. Figure 4 shows an example mineral (forsterite).

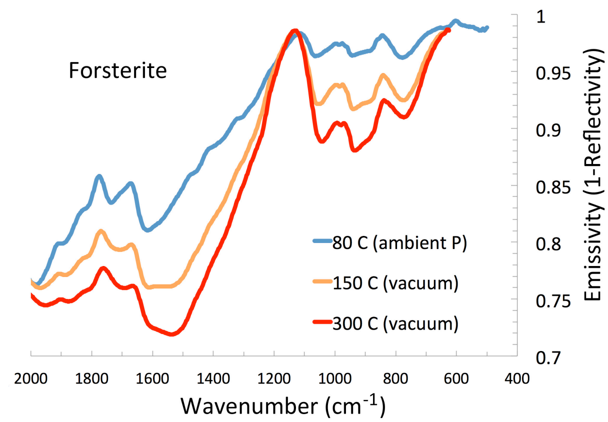

Figure 4. Spectra of fine-particulate forsterite olivine acquired at 80 ºC under ambient P (blue), at 150 ºC under vacuum P (orange), and at 300 ºC under vacuum P (red). Note: 1000 cm^{-1} is equivalent to 10 µm.

We will present the emissivity spectra we obtained and discuss the spectral behavioral changes resulting from temperature and vacuum conditions.

Data Availability: Ultimately the spectra from this research grant will be available through the Planetary Data System (PDS) for use by all researchers.

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References: [1] Byrne S. A. et al. (2015) *LPS XLVI,* Abstract #1499. [2] Dyar M. D. (2016) *SSERVI Expl. Sci. Forum*, nesf2016-043. [3] Nakamura T. et al. (2011) *Science, 333,* 1113-1116. [4] Hinrichs J. L. and Lucey P. G. (2002) *Icar., 155,* 169-180. [5] Logan L. M. and Hunt G. R. (1970) *JGR, 75,* 6539-6548. [6] Donaldson Hanna K. L. et al. (2012) *JGR, 117,* doi:10.1029/2012JE04184.