PLANETARY SURFACE TEXTURE LAB: INITIAL COMMISSIONING. David T. Blewett[1,*], Goran Basic[2], Jordan Wiker[3], Anna C. Martin[1], Adam Sniderman[4], Janine Newhook[4], Brett W. Denevi[1], Parvathy Prem[1], and Hiroyuki Sato[5]. [1]Planetary Exploration Group, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [2]RobotWorks Corp., Toronto, ON M6J 2J2, Canada. [3]Electronic Systems Engineering Group, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [4]Canadensys Aerospace Corp., Bolton, ON L7E 4G9, Canada. [5]Japan Aerospace Exploration Agency (JAXA), Institute of Space and Astronautical Science, Kanagawa, Japan. (*david.blewett@jhuapl.edu).

Introduction: Phase-ratio analysis is becoming a widely used technique to obtain sub-resolution information on the scattering behavior and particle size of the surfaces of airless bodies. Recently published examples have employed spacecraft images from the Moon [1–3], Mercury [4], Eros [5], and Vesta [6]. Phase-ratio images can reveal anomalous photometric behavior. An anomalous feature can be interpreted in terms of the roughness or particle size, which are important for understanding the geologic processes that have affected the surface. However, conclusions to date have largely been limited to qualitative inferences. The lack of a comprehensive laboratory framework for interpretation precludes the derivation of more quantitative information from the data.

There is also growing interest in imaging polarimetry as a planetary remote-sensing technique. *Hayabusa* carried a camera (AMICA, [7]) designed to obtain polarization images of asteroid Itokawa, although spacecraft control problems prevented the collection of the planned polarization image datasets. The payload of the forthcoming *Korea Pathfinder Lunar Orbiter* (KPLO) includes an instrument called PolCam [8] that will collect multispectral/multi-polarization images of the Moon. Compared with techniques like reflectance and emittance spectroscopy, there has been relatively little laboratory work aimed at exploring the polarization behavior of planetary surface materials. Such foundational work is necessary for the PolCam and other future datasets to yield their greatest scientific return.

Planetary Surface Texture Laboratory: We are in the process of establishing a Planetary Surface Texture Laboratory (PSTL) to explore the phase and polarization response of planetary regolith analogs as a function of illumination (i), viewing (emergence, e), and phase (g) angles (Fig. 1). Measurements are done in the principal scattering plane. PSTL obtains data with an imaging polarimeter (FluxData 1665-P, Fig. 2), that simultaneously collects co-registered images of a scene in three polarization states. For photometric studies, the three polarization images (at 0°, 45°, and 90°) will be combined into a single image of the Stokes intensity parameter. The polarimeter's CCD focal plane arrays are sensitive to wavelengths ~400–1000 nm, and specific wavelengths can be selected using bandpass filters. A goniometer permits the collimated light source and the polarimeter to be moved through a range of i, e, g geometries. Soil analogs will be placed on a sample stage in trays that are large enough to permit different samples or preparations to be viewed together. Thus, a key innovative aspect of PSTL is the use of imaging, going beyond the spot measurements of most current facilities. The regolith analogs that we study will be characterized in terms of particle size-frequency distribution, and crucially, they will also be characterized in terms of shape. The size and shape analysis will be done with an instrument (Camsizer from Retsch Technology) that measures parameters including average particle diameter, sphericity, and convexity, as well as the standard deviations and size-frequency distributions of these parameters.

The data obtained with PSTL will be important for comparative analysis of surface texture, and also provides the basis for modeling studies. The comprehensive data in i, e, g space will be used for photometric modeling, e.g., fitting of Hapke parameters that can be linked to the known particle properties such as albedo, size, and shape. We plan to perform modeling to test empirical relations that connect particle size to polarization, and also develop rigorous radiative-transfer code that includes the four Stokes polarization parameters and allows for incorporation of particle size, packing, and shape.

PSTL represents a unique capability for imaging studies of the photometric and polarization behavior of regolith analogs. By carrying out systematic investigation of well-characterized samples, we will provide the foundation for interpretation of phase-ratio image data from past and future planetary missions and for future polarization image data from missions like KPLO, as well as for astronomical polarization observations. The research will thus open new windows to aid in the understanding of the geological processes that have operated on surfaces throughout the Solar System. Remote assessment of particle shapes and sizes could also benefit site selection for in situ resource utilization.

The PSTL Goniometer: The Planetary Surface Texture Laboratory goniometer (Fig. 1) has design heritage from a smaller apparatus [9] that was developed by RobotWorks Corp. [10] for the laboratory of Prof. Michael Daly at York University (Toronto, Canada). The PSTL machine was designed and built by Canadensys Aerospace under license from RobotWorks. It consists of an arc-shaped track of ~1.5 m radius. Motorized, computer-controlled caddies carry a light source and the imaging polarimeter.

The LabVIEW software interface running on the system's desktop computer for the motor controllers (Fig. 3) enables the light source and camera caddies to be moved through a programmed set of positions. Motor control will be integrated with the LabView program that operates the camera (collection of images and transfer of data from the camera to the system computer).

The minimum phase angle of the system is governed by the physical sizes of the polarimeter and the light source and the radius of the arc, and is estimated to be ~8°. For the polarimetric and phase investigations that are the initial focus of PSTL, most of the interesting phenomenology is at larger phase angles. Examples include the inversion angle (the phase angle at which the polarization changes from positive to negative, ~30°), and the phase angle that produces maximum polarization (~100°) [e.g., 11]. In the future, we could adapt the system to mount both the camera and light source on the same caddy, or use a laser source and a spot detector for work at small phase angles (<~8°).

Construction, delivery, assembly, and testing of the goniometer were considerably delayed by COVID-19. It was delivered to the Johns Hopkins University Applied Physics Laboratory in August 2021. The instrument was assembled and is undergoing testing and evaluation of the LabVIEW control software. Also at present, characterization and calibration of the polarimeter cameras are underway. This includes evaluation of dark current, flat-fields, and linearity.

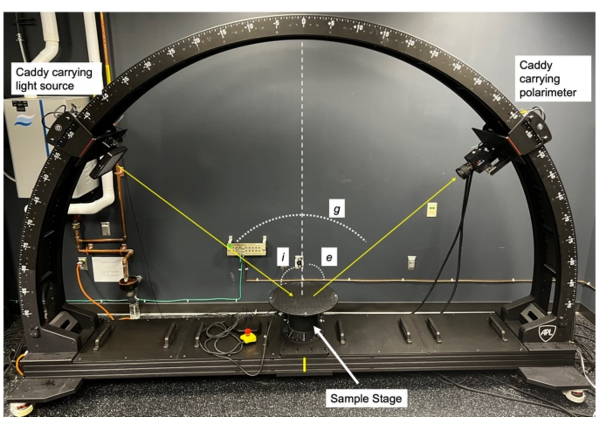

Fig. 1. Photograph of the goniometer. The three photometric angles *i*, *e*, *g* are illustrated.

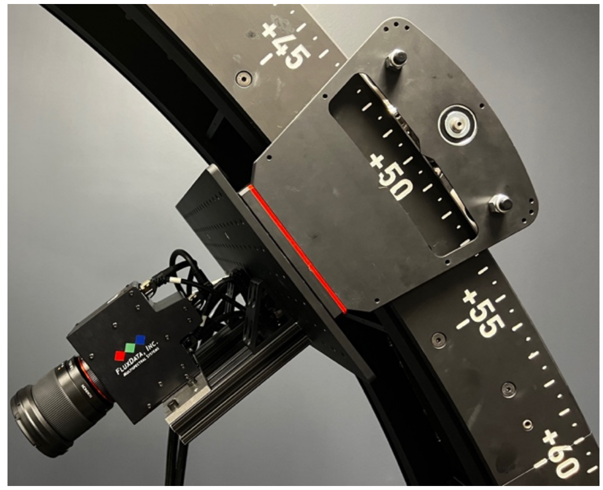

Fig. 2. Close-up of the polarimeter mounted on the goniometer caddy.

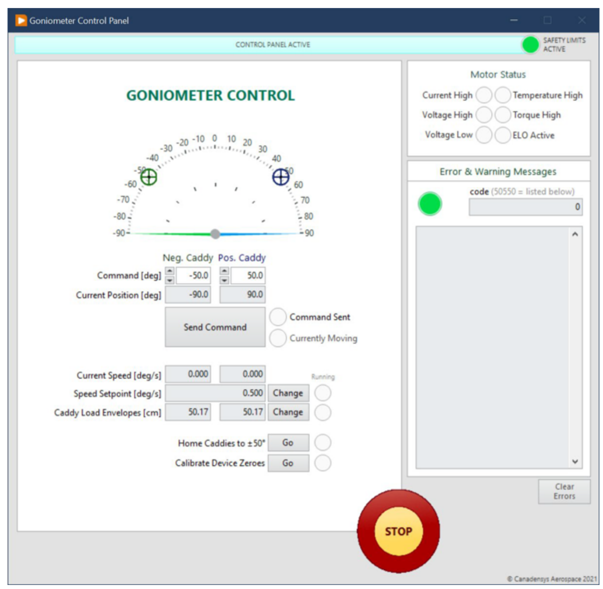

Fig. 3. Graphical user interface for the goniometer control, implemented in LabVIEW.

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