A PROBE FOR EXPLORING REGOLITH AND ICE BY SUBSURFACE CLASSIFICATION OF ORGANICS, PAHS, AND ELEMENTS (PERISCOPE). E. Eshelman[1], K. Simon[1], M. Willis[1], D. Van Hoesen[1], A. Yanchilina[1], and P. Sobron[1]. [1]Impossible Sensing, St. Louis, MO (eeshelman@impossiblesensing.com).

Searching for organics in the near subsurface: In the past few years there has been a change in strategy in planetary exploration. The earlier mandate to "follow the water" (search for habitable environments) is now shifting to "follow the carbon" (search for evidence of life). This is true for missions to Mars [1] and to icy moons like Europa, Enceladus, and Titan [2,3]. The new mandate to "follow the carbon" requires the development of instruments that can detect trace amounts of organic material, including potential organic biosignatures and even microbial cells. We are developing the Probe for Exploring Regolith and Ice by Subsurface Classification of Organics, PAHs, and Elements (PERISCOPE). PERISCOPE addresses these challenges by enabling in situ subsurface measurements in a compact package with no moving parts, amenable to small spacecraft. Here we present the PERISCOPE instrument concept, shown in Figure 1, and discuss preliminary results characterizing the instrument's ability to detect trace organic compounds.

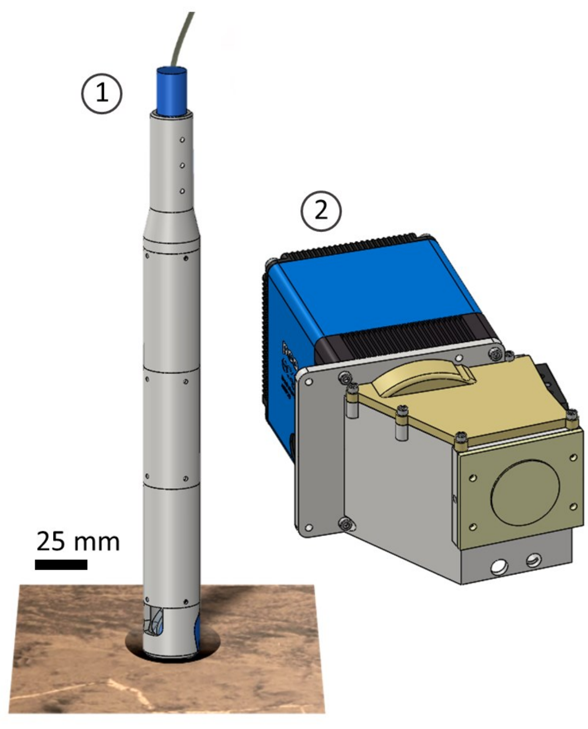

Figure 1: Rendering of PERISCOPE showing (1) the optical probe for scanning surfaces to search for organic compounds; (2) the hyperspectral imaging spectrometer. The probe is tethered to the spectrometer, allowing the electrical components (detector, laser) to be housed within a spacecraft body.

PERISCOPE Innovation: PERISCOPE focuses its illumination laser into a narrow push broom line at the sample. This narrow line allows the instrument to record high spatial and spectral resolution spectra across a cm-scale swath of a sample. The illumination line can be swept across a sample surface to generate high resolution spatial/spectral maps of organic content. This measurement approach provides fluorescence maps that determine the spatial distribution of organic targets on unprepared natural surfaces.

PERISCOPE is composed of three subsystems: 1) an ultraviolet optical probe that provides push broom hyperspectral mapping. The optical probe is passive, with no electronics or mechanisms, and therefore can be resized to fit the desired borehole diameter by changing the diameter of the optical lenses; 2) an optical relay with laser injection. This intermediate subsystem positioned between the optical probe and the spectrometer allows a laser to be injected into the optical path and directed via a fiber tether to the sample surface; and 3) a compact hyperspectral UV imaging spectrometer which records spatial and spectral information from the target surface. Multiple images are processed to obtain spectral information and reconstruct false-color images providing the spatial distribution of the observed signal.

PERISCOPE responds to the 2013-2022 Decadal Survey observational priorities, which emphasize the need for developing instruments for accessing and characterizing the subsurface and for trace organic detection. Measurements of the interior of a borehole can be correlated to measurements of a cored sample. Therefore, PERISCOPE provides analyses that can inform downstream measurements and sample caching. Outside of a borehole, cm-scale fluorescence imaging fills a gap in measurement capability that would inform the microscopic pointing of laser point-mapping techniques and site selection for sample acquisition.

PERISCOPE Performance: Ultraviolet (UV) fluorescence instruments are one of the preferred solutions for in situ organic detection of aromatic organics [e.g. 4, 5]. State-of-the-art UV fluorescence instruments are sensitive to trace concentrations of many organics, including PAHs, aromatic amino acids, and microorganisms [6]. With UV illumination typically no staining, dying, or manipulation of the sample is required, and therefore the technique is rapid and non-invasive [7]. Preliminary data obtained using the breadboard PERISCOPE spectrometer is shown in Figure 3 on a selection of organic compounds. Ongoing work centers on experiments with the end-to-end system to determine limits of detection to a range of relevant samples. The PERISCOPE TRL 4 instrument is shown in Figure 2.

Significance: The PERISCOPE concept proposed here addresses the need recognized in the Vision and Voyages Decadal Survey, and NASA Strategic Plan Goal 1 Objective 1: to detect ultra-low concentrations of organics. The compact nature of the optical probe may enable trace organic detection in SIMPLEx/Discovery scale missions, meeting the anticipated future need for small, low-mass, and low power consumption instruments. The tube-geometry of optical concept provides a proof-of-concept for future subsurface or arm mounted compact PERISCOPE-based instruments, particularly for Mars, icy moons and small bodies. PERISCOPE is relevant for any missions whose priority goal is to search for organic matter and potential biosignatures on the surface or in the near subsurface. These mission categories may grow in importance in the next decade with increased emphasis on astrobiology.

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References: [1] Mustard, J. F. et al. (2013). Report of the Mars 2020 Science Definition Team.

[2] Hand, K. P. et al. (2017). Report of the Europa Lander Science Definition Team. Retrieved from http://solarsystem.nasa.gov/docs/Europa_Lander_SDT_Report_2016.pdf

[3] Turtle, E. P et al. (2018). Dragonfly: in Situ Exploration of Titan'S Organic Chemistry and Habitability. 49th Lunar and Planetary Science Conference.

[4] E. Eshelman et al. WATSON: In situ organic detection on subsurface ice using deep-UV fluorescence spectroscopy. Astrobiology. Jun 2019.771-784. http://doi.org/10.1089/ast.2018.1925

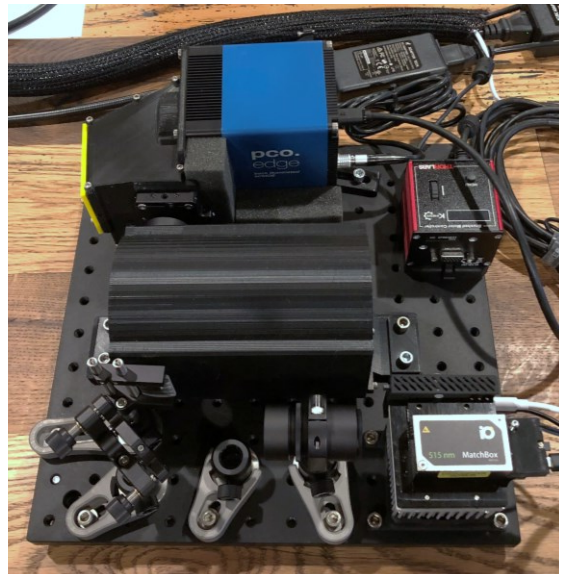

Figure 2: PERISCOPE TRL 4 instrument (excepting optical probe). Ongoing work centers around determining sensitivity and limits of detection to relevant organic compounds.

[5] E. Eshelman, et al. Detecting aromatic compounds on planetary surfaces using ultraviolet time-resolved fluorescence spectroscopy. Planetary and Space Science, 151:1-10, 2018.

[6] L. Beegle et al., "SHERLOC: Scanning habitable environments with Raman & luminescence for organics & chemicals," in 2015 IEEE Aerospace Conference, 2015.

[7] R. Bhartia et al., "Label-Free Bacterial Imaging with Deep-UV-Laser-Induced Native Fluorescence," Applied and Environmental Microbiology, vol. 76, no. 21, pp. 7231–7237, Sep. 2010.

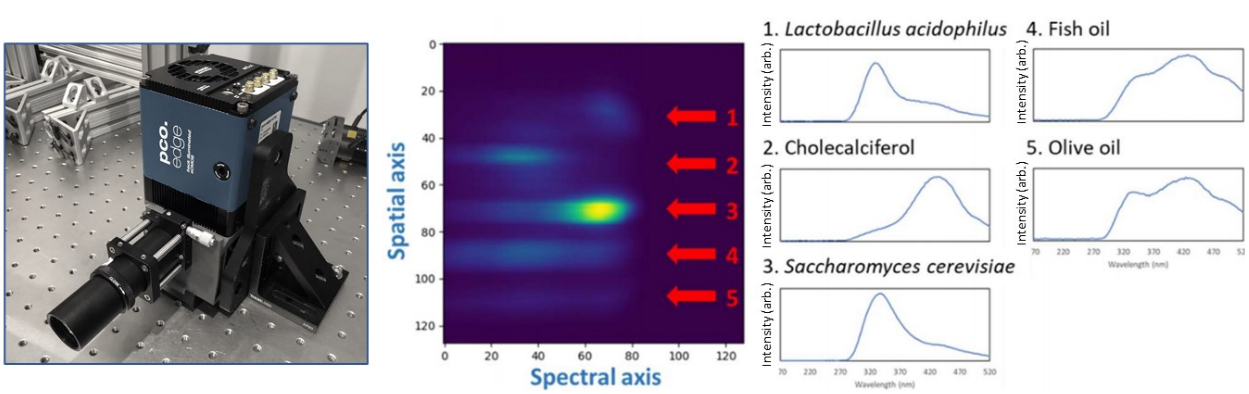

Figure 3: Testing performed with a breadboard of the PERISCOPE ultraviolet hyperspectral imaging spectrometer and probe (coupled in the breadboard configuration), observing fluorescence emission between 280 and 520 nm following excitation with ultraviolet light. Left: Image of breadboard spectrometer; middle: example raw image obtained from detector showing spatial and spectral axes observing mm-scale deposits of several organic compounds. Extracted spectra are shown (right).