**ROBOTIC DECISION-MAKING IN A FINE-GRAINED ENVIRONMENT.**

E. Z. Noe Dobrea[1], M. Banks[2], A.R. Hendrix[1], M.D. Lane[3], M. Osterloo[4], T. Prettyman[1], R. Watkins[1], D. Wettergreen[5], S.P. Wright[1], and the TREX Team [1]Planetary Science Institute, 1700 East Fort Lowell suite 106, Tucson, AZ 85719 – eldar@psi.edu, [2]NASA Goddard Space Flight Center, Greenbelt, MD, [3]Fibernetics LLC, Lilitz, PA, [4]Laboratory for Atmospheric and Space Physics, U. Colorado, Boulder, CO, [5]Carnegie Mellon University, Pittsburgh, PA.

**Introduction:** Today's robotic exploration centers around a tight operator/robot iterative process in which a team of operators carefully instructs the robot on navigation and target selection. Data rates are limited and hence a complete assessment of the study site is rare. Activities are therefore decided upon based on limited knowledge of the site.

The robotic explorers of the future should be able to make decisions regarding which observations to perform in order to address the driving hypotheses with little to no additional input. Periodically, or when the robotic explorer encounters something that falls outside the realm of expected observables, the explorer transmits updates or request revised hypotheses.

The goal of this SERVI investigation is to develop and test algorithms and instrumentation that will improve the efficiency of robotic systems supporting exploration of the surfaces of Solar System bodies.

The algorithms enabling this work are the hypothesis mapping method [1,2] and Tetracorder [3]. These algorithms aim to provide the rover scientific autonomy, improving operations efficiency and science yield.

The **hypothesis map** represents the basis for modeling and decision-making undertaken by the robot. It describes a set of hypotheses to be explored, and observables to be measured. As the rover observes and samples the terrain, certain hypotheses that classify terrain become more likely as others are eliminated. In conjunction, the rover populates an n-dimensional parameter space of observables, allowing it to identify the spatial distribution of terrain (spectral) endmembers, which can subsequently be targeted for in-depth analysis. Communication with an operator is performed at points in which the rover has a) a summary of observations of the mapping area, b) identified sample collection sites, or c) performed an observation that is inconsistent (unlikely) with the hypothesis map. If the latter occurs, the hypothesis map is updated via Baysian inference, leading to an iterative process between observation and inference during field exploration.

Hypothesis maps improve operations efficiency by encoding scientist's beliefs and objectives simply and intuitively, and thereby enabling selection of appropriate behaviors. Science yield is improved as data acquisition, analysis, and decision-making is no longer bandwidth or communication bandwitdth-limited.

**Tetracorder:** A Tetracorder module operating in real-time onboard the rover's computer allows itto constrain mineralogy and address the hypotheses it is tasked to test. The Tetracorder software analyzes spectra using multiple algorithms commanded by an expert system. The expert system can make identifications and classifications, and based on those results, apply new algorithms to make additional interpretations of the observations.

**Field Work:** We, the TREX SSERVI team, will visit two field sites characterized by fine-grained surfaces: the Palouse Loess and the Hopi Volcanic Buttes (Fig. 1). The Palouse Loess consists of thick beds of fine-grained material deposited during the last ice age, 15,000 years ago. The Hopi Buttes Volcanic Field consists of ~300 late Miocene volcanic centers. Fine grained sediment derived from these has been deposited within and around the buttes. The rover, equipped with UV – NIR spectrometers, a neutron and gamma ray spectrometer, and an FTIR, will be used to quantify improvements in science yield compared with present exploration techniques.

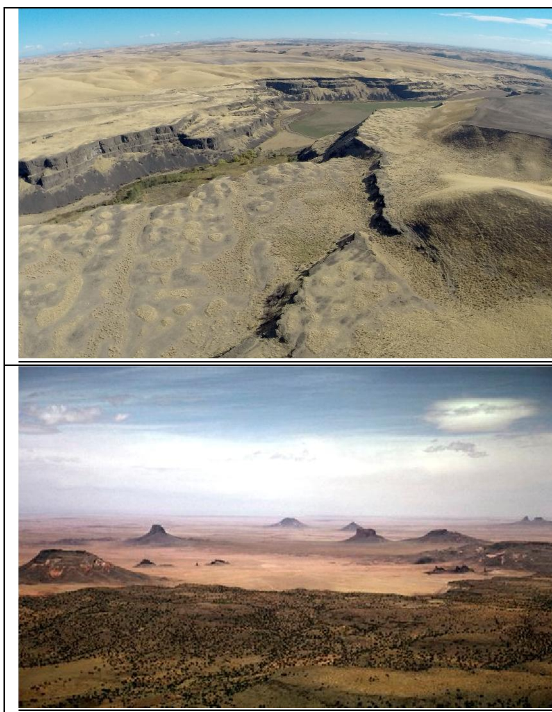

**Figure 1.** Top: The Palouse Loess (Image credit: The Reach Museum). Bottom: The Hopi Buttes Volcanic Field (Image Credit: Ron Payne).

**References: [1]** Candela, et al. (2017). *IEEE IROS*. Vancouver. **[2]** Thompson et al. (2018) *Astrobiology* 18, Issue 8. Clark et al. (2003) *J. Geophys. Res.* 108 E12 pp. 5131.