Utilizing a Hyperspectral Camera for Field Surveys during the TREX Field Mission.

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Introduction: The rapid development of machine learning, artificial intelligence, and increasingly capable electronics is leading to new classes of astro-biological and planetary exploration. The Toolbox for Research and Exploration (TREX) team aims to develop these methods. Our project aim is to develop the decision-making software and tools for robotic, human, and/or symbiotic human and robotic exploration of planetary bodies.

During October 2022, the TREX team engaged in a two-week field campaign in Yellow Cat, Utah to explore a simulated planetary landscape. The study was initialized with 18m/pixel areal images from the AVIRIS hyperspectral dataset to map mineralogy with Tetracorder [1] and create an initial geologic origins map of the field site. This instrument is analogous to the Compact Reconnaissance Imaging Spectrometer (CRISM) instrument on the Mars Reconnaissance Orbiter, which has a maximum resolution of 18m/pixel. With this map, the Carnegie Mellon rover, Zoë, explored the surface and communicated the results to a remote mission control science team. The rover included tools for remote observations and contact measurements, including real-time science analysis and several spectrometers: Gamma Ray, Ultraviolet, Visible-Near-Infrared, Fourier Transform Infrared, and X-Ray Diffraction. In addition to the in-situ data collection, field samples were collected for more thorough analysis and validation.

In addition to the measurement suite available on Zoë, a high-resolution hyperspectral imager was brought to the field to simulate the effects of drone assisted exploration. This imager could also be mounted to the rover for airless body or future TREX exploration. For this preliminary exploratory study, a tripod-mounted hyperspectral camera was used for instrument evaluation. This is analogous to the Ingenuity helicopter which has been repurposed to "scout" sites for the perseverance rover, but with an expanded spectral window and more limited mobility.

Hyperspectral Camera: The imager is a PIKA IR 900-1700nm camera provided by Resonon. This camera has 164 spectral channels with a resolution of 8.8 nm at full width half maximum. The camera automatically scanned from right to left at a rate of .2038 degrees per second and 4.993 frames per second. Each scan included a dark current image taken with the lens cap on. A white reference was included in each scan which is shown as a white canvas in the background of Figure 1.

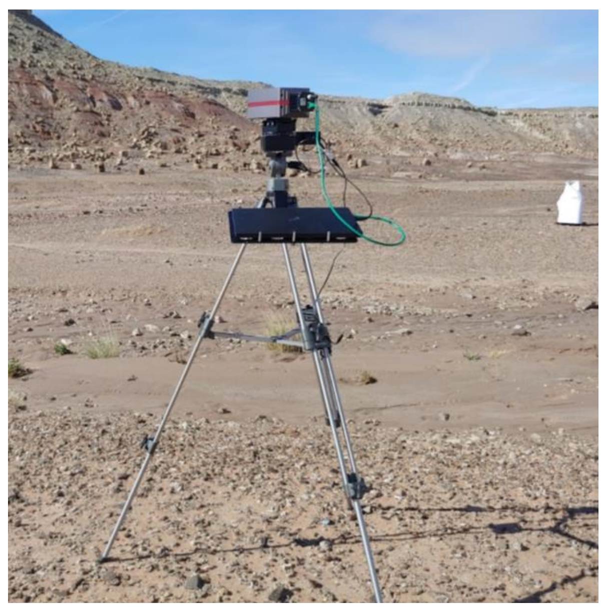


Figure 1: The hyperspectral imager at the Yellow Cat field site with white calibration target.

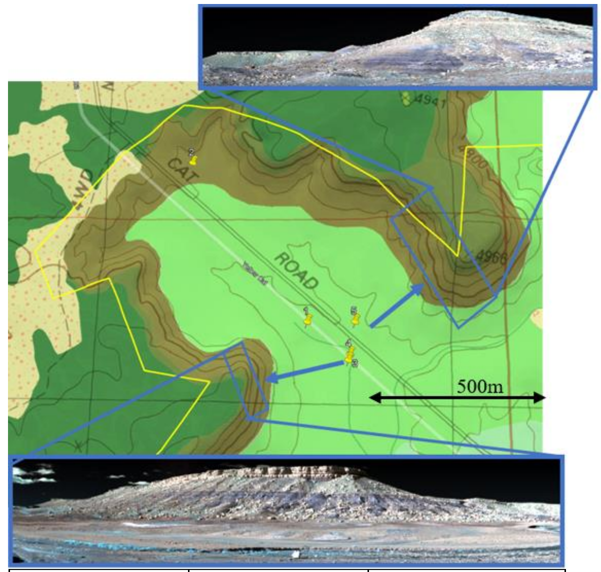
Field Site: The TREX site location, Yellow Cat, Utah, is situated on the Morrison formation, which is a well mapped area containing abundant iron oxides, carbonates, clay minerals, and a variety of geologic units (Figure 2). This site was selected for its lack of vegetation and distinct layering, making it an acceptable planetary analogue for the science goals of the TREX mission.

The Yellow Cat site contains diverse geologic units, primarily exposed in the cliffs. While driving, the rover can acquire a line spectrum with a narrow field of view and during the stops a panoramic visual image is collected along with contact measurements of a ground sample approximately 3cm in diameter. These in-situ measurements are added to the 18m/pixel AVIRIS overhead data to produce a detailed analysis of the environment.

There is a resolution gap between the rover and AVRIS data that is highlighted in this field site, which will be applicable to any planetary mission. For instance, the cliff faces surrounding the valley explored by the rover contain diverse geologic layers, namely a 15m thick mudstone unit containing red and white / grey layers which are impossible to resolve with the areal AVIRIS data. The rover may occasionally see this material washed into the valley floor, and the science team relied on image panoramas and astronaut teams to collect this material for identification, since the cliff was too steep for the rover. The additional hyperspectral imager was able to acquire images of these cliffs with roughly 5cm/pixel resolution, which is a powerful tool for mineral identification for the geologic map.

The study area is contained within the yellow line in Figure 2. Superimposed on Figure 2 are hyperspectral images of the cliff faces to the north-east and the south-east of the valley explored by the rover. Each pixel from these images contains full spectral information and will be further analyzed to assist in mineral identification of the surrounding area. The cliffs in the figure show both the diversity of the land surrounding the valley and the difficulty of the terrain for the rover. Identification of these minerals will serve as an aid for interpreting the spectra the rover collects with its local contact measurements.

Future Work: The mineral identification from the hyperspectral imager will be utilized as an additional input to the AVIRIS survey data to determine if there would be changes to the exploration program with a higher resolution initial data set. In future projects this imager will be incorporated onto a drone or rover. If a drone is available, the data will be collected prior to the arrival of the rover team. This will more accurately simulate operations on the other planetary bodies.



Formation	Member	Map Symbol
Cedar Mountain	Ruby Ranch	Kcmr
	Poison Strip	Kcmp
	Yellow Cat	Kcmy
Morrison	Brushy Basin	Jmb

Figure 2: This map shows the overlay of the field site (yellow line) on the geologic map of Yellow Cat Utah [2]. The contour interval is 40 ft (12.2m). Yellow pins show locations of hyperspectral camera. At two example sites, the blue arrows indicate the orientation of the camera for data collection, and the blue squares show the area images. Pictures of the hyperspectral data cube are overlaid for both locations.

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