

**SCIENTIFIC PHYSICAL AND OPERATIONS CHARACTERIZATION (SPOC) – CAPTURING TERRESTRIAL FIELDWORK IN CONTEXT.** M. J. Miller<sup>1</sup>, C. P. Pittman<sup>1</sup>, T. G. Graff<sup>1</sup>, M. J. Miller<sup>2</sup>, A. Abercromby<sup>3</sup>, J. Norcross<sup>4</sup>, E. Benson<sup>4</sup>, H. Kim<sup>4</sup>, A. Garbino<sup>4</sup>, J. Dunn<sup>4</sup>, S. P. Chappell<sup>4</sup>, K. H. Beaton<sup>4</sup>, K. J. Kim<sup>5</sup>, M. Schubert<sup>6</sup>, L. A. Stirling<sup>7</sup>, T. McGrath<sup>7</sup>, G. Nguyen<sup>7</sup>, D. Coan<sup>8</sup>, J. S. Cupples<sup>3</sup>, <sup>1</sup>Jacobs, NASA JSC; <sup>2</sup>NASA KSC; <sup>3</sup>NASA JSC; <sup>4</sup>KBRwyle, NASA JSC; <sup>5</sup>University of Miami; <sup>6</sup>Johns Hopkins University; <sup>7</sup>Massachusetts Institute of Technology; <sup>8</sup>Aerospace Corporation, NASA JSC; corresponding author email: [matthew.j.miller-1@nasa.gov](mailto:matthew.j.miller-1@nasa.gov)

**Introduction:** While future human spaceflight missions on planetary surfaces will necessarily impose engineering and operational limitations on extravehicular activities (EVAs), many of these limitations at present are speculative and difficult to accurately represent in analog field environments. The perceived limitations often stem from engineering and operations perspectives that lack the flight experience of ensuring productive scientific fieldwork. As a result, there is still a lack of understanding regarding the intrinsic operational challenges, success criteria, cadence, and behaviors that field scientists must overcome and exhibit to achieve their fieldwork objectives in present-day terrestrial settings, let alone hypothesized future spaceflight missions. Therefore, the SPOC (Scientific Physical and Operations Characterization) project aims to refine the relationship between the scientific process and future planetary EVAs. SPOC will do so by deconstructing the speculative scientific frameworks applied in analog EVAs and drawing lessons for future planetary fieldwork from unobtrusive studies of the rudimentary components of the scientific process as performed within traditional terrestrial frameworks.

The SPOC program aims to examine terrestrial scientific field campaigns to inform future human spaceflight missions by accomplishing two program goals: 1) capture and examine the moment to moment relationships between the *cognitive challenges* and *physical behaviors* demonstrated throughout planetary science relevant field campaigns and 2) provide an unobtrusive and extensible data collection capability to study a multitude of field scientists performing a variety of field campaigns.

These goals are achieved by integrating applied cognitive systems engineering methodologies [1-3] using unobtrusive qualitative data analyses combined with inertial measurement unit (IMU) system physical characterizations [4-7] to deconstruct terrestrial fieldwork practices. A cognitive task analysis of each observed field campaign will model the cognitive demands (e.g. goals, decision making, problems, etc.) and constraints associated with the fieldwork. Additionally, the types of physical tasks and actions being performed (e.g., standing, walking, kneeling, hammering, etc.), the functions of those tasks, and the frequency with which each task is performed will be quantified using a combination of observational techniques with unobtrusive

body-worn IMUs along with algorithms for body motion classification. A key component of SPOC is the complementary nature of these various data products. The intent is to not only describe the bulk physical activities of scientists (e.g. what scientists did in the field) but this data can be combined with the cognitive analyses to understand *why* scientists exhibited these behaviors. In doing so across many different science field campaigns, SPOC will establish a representative baseline of realistic fieldwork expectations associated with scientific exploration that can inform the planetary benchmarking efforts of future NASA spacesuit designs, concept of operations and technology development.

**Data Collection in the Field:** The SPOC program aims to capture both the physical and cognitive aspects of terrestrial field work by embedding an unobtrusive sensor suite of instruments and personnel within a scientific field team. Figure 1 shows the concept of operations with relevant data collection devices. Currently, SPOC is in the preliminary design and integration stages of development. Pilot testing has included collecting data from two field scientists simultaneously and requires three additional SPOC personnel to perform the cognitive systems engineering and IMU data collection activities. Each scientist wears a wireless microphone, a global positioning system (GPS) and IMUs. Each scientist has a companion SPOC scientist who is responsible for capturing video and still photography. All data is synchronized and stored in a SPOC database for post-processing activities and archiving.

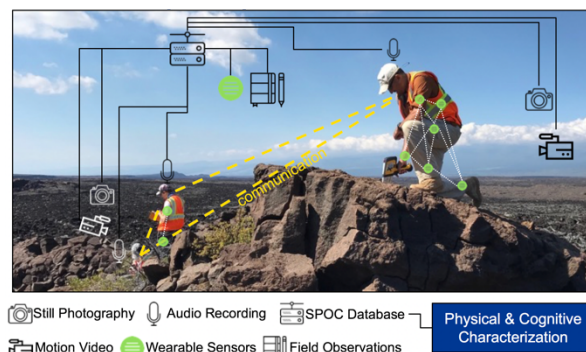


Figure 1. SPOC concept of operation schematic with field deployed sensors and data collective devices.

**SPOC Physical Data Capture:** IMU data is collected continuously in the field. Data is stored at the end of each field day. During post-processing analyses, the IMU data are processed to estimate body postures, coordinated movements, and levels of activity. These data are then aggregated into bulk physical representations of body postures and motions across specific tasks, field days, and entire campaigns. Combined with the cognitive data, the physical measures can be further parsed to explicitly examine performance in physically similar, but cognitively different tasks.

**SPOC Cognitive Data Capture:** A multifaced data collection approach is implemented to capture observational data required for cognitive systems engineering data analysis. These data consist of a continuous full day of audio communication recorded for each scientist, and an observer collection of still photography, field notes, and video clips of scientists working. These data products are temporally synchronized for each day and stored in a SPOC database for post-processing after each field campaign.

**SPOC Sensor Suite Integration Progress To-Date:** The SPOC sensor suite consists of various commercially available devices that have been tested and integrated in an integrative build and test environment. Figures 2 shows the current sensors suite configuration for a field scientist and field observer, respectively.

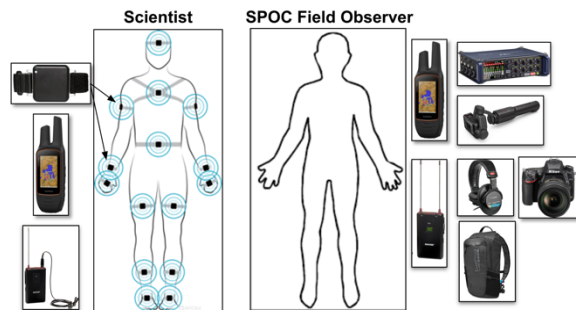


Figure 2. SPOC scientist sensor suite package with IMU locations.

We use COTS IMUs from APDM (Portland, OR), a Garmin GPS, and Shure wireless headsets. Each body-worn IMU (x15) is approximately the size of an Apple Watch and can be easily strapped on to the body without the need for high precision placement. These sensors enable a high-level understanding of the tasks being performed, which permits the automation of task timeline decomposition, as well as a detailed-level understanding of task technique. Each device can provide data collection continuously for an entire field day without adding significant weight to the scientist.

The SPOC field observer carries and operates professional grade audio/video/photography devices to

provide a 3<sup>rd</sup> person perspective of the scientist working in the field setting. Additionally, this person ensures the collection of multichannel audio data from the scientists. Note that the audio system does not provide a walkie-talkie system for the scientists to communicate with each other. Rather, the audio devices only record their individual communications.

Testing to date has focused on the configuration and attachment of devices to each person and the data collection and storage processes required for each data stream. Some devices store data locally to be saved after a data collection session (e.g. GPS) while other devices such as the audio devices can stream data real-time for remote data collection (if a local internet connection is available). One major challenge currently being addressed is time synchronization across these various devices and systems. Additional time syncing devices and software solutions are currently being evaluated.

**SPOC Relevance and Future Work:** Continued sensor suite integration is planned as well as the development of data post-processing procedures and data outputs. Development efforts also include the ability to scale the number of scientists that can be included in the sensor suite up to 5-10 personnel. Another program aim is to transition from laboratory settings to actual scientific field settings embedded within actual scientific field research campaigns. This goal would entail unobtrusively studying multiple high-fidelity science terrestrial field campaigns that are planetary science relevant (e.g. map to Lunar Exploration Analysis Group roadmap goals) [8]. The aggregate data collection and analysis of these field campaigns would provide the opportunity to characterize “Earth-normal” scientific fieldwork to be integrated with ongoing exploration development and testing efforts at NASA JSC that incorporate high-fidelity spaceflight constraints based on reduced gravity testing in pressurized spacesuits. By contributing a more complete representation of fieldwork physical and cognitive workload and scientific productivity, these spaceflight testing efforts will assess capabilities and operations that more appropriately promote scientific planetary exploration.

**References:** [1] Miller, M. J. et al. (2017) *J. of Cog. Eng. and Dec. Making*, 11(2): 136–165; [2] Hollnagel, E. and Woods, D. D. (1983) *Inter. J. of Man-Machine Studies*, 18:583–600; [3] Elm, W. C. et al. (2008) *J. of Cog. Eng. and Dec. Making*, 2(3): 249–273; [4] Kim KJ, et al. (2018), *Nature npj Microgravity*, 4:1-8; [5] Kim K.J. et al. (2018), *Journal of Biomech*, 11(71):151-158; [6] McGrath, T., et al. (2018). *Sensors*, 18(6), 1882–17; [7] Stirling, L. et al, (2016) *PLoS ONE*, 13(6); [8] LEAG V1.3 (2016)