A SYSTEM FOR SUPPORTING DISTRIBUTED FIELD SCIENCE OPERATIONS DURING ASTRONAUT TRAINING AND PLANETARY EXPLORATION: THE ELECTRONIC FIELDBOOK.

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Introduction: Future human missions to the Moon and Mars will involve Extra-Vehicular Activities (EVA) focused on scientific exploration. Much like during the Apollo missions [1], astronauts participating in these EVAs will investigate scientifically interesting areas, gather a variety of information, including pictures, videos, audio recordings, scientific data, and collect samples. However, unlike Apollo, they will be supported by a host of new technologies for managing operations and data collection [2]. The storage and distribution method employed to share this data between mission support teams is vitally important for enabling timely and useful feedback to be provided to the astronauts from ground during an EVA, for example when selecting the best samples for return to Earth [3]. Maintaining situational awareness for all personnel involved in the EVA will be a key asset in this task, but requires all relevant information and reference knowledge is retrieved, collected, indexed, stored in a structured way and made available rapidly for fast decision making support and archiving.

To prepare astronauts for these future planetary science exploration activities, astronauts are being trained in specific campaigns to gain field science experience. In this context, the Electronic FieldBook (EFB) was developed as key supporting tool for the ESA PANGAEA/PANGAEA-X 2018 and PANGAEA 2019 campaigns, which offer planetary geology training integrated with operations and technology testing [4]. From this, the EFB has developed into a promising system for supporting future lunar and Martian exploration.

The Electronic FieldBook: Traditionally, in planetary geology analogue campaigns, data is separately captured through a multitude of devices and stored locally. Rarely is it integrated into an overall data collection and distribution system [5, 6]. In order to improve the effectiveness of operations, scientists located in a support centre control room should ideally receive, in near-real time, a relevant portion of the data acquired in the field. This allows them to provide scientific and operational guidance to the astronauts whilst they are in the field. In addition, astronauts require information pertaining to navigation, decision support tools and other reference information to augment their effectiveness and autonomy.

The Electronic FieldBook (EFB) is a deployable system being developed to meet these needs. It is designed to support field mission operations, scientific data gathering and direct interaction with mission control and science support teams through automatic data transmission. The system provides a structured way to collect data during geological traverses, where astronauts can interact with several sensors, collect data and/or samples, and take notes (Fig. 1). This is all then automatically associated to specific sites or samples.

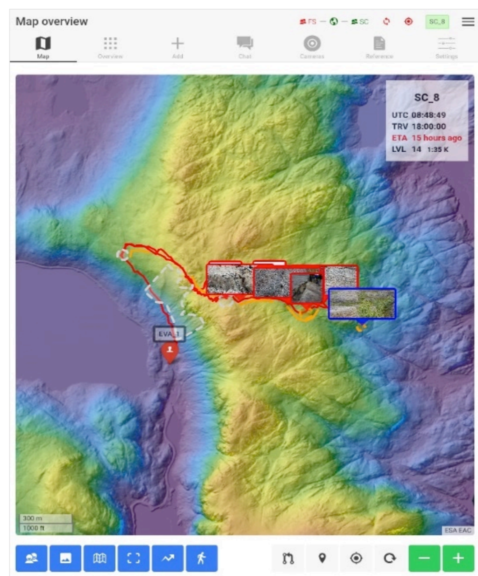

Fig. 1. The EFB interface for traverse overview display.

The project is being designed to provide real-time situation awareness to the following primary entities:

- A “Field Segment” (Astronauts on EVA), who require a portable tool (Fig. 2) to retrieve reference geological and navigational information, document locations, sites, samples, collect notes and drawings, capture scientific data from analytical tools and communicate with other users during a traverse.
- “Support Centres” (Sci&Ops ground teams or support astronauts in IV), who require a real-time overview of the scientific data/samples collected by the EV team in order to provide relevant and informed scientific or operational advice (Fig. 3).

Fig. 2. The tablet is used to document sampling site and to transfer observations to the ground support team for evaluation.

The current version of EFB is developed for laptops and tablets (with ergonomic modifications to be usable with EVA gloves), and provides the following functionalities:

- Display of pre-defined traverses, geological stops and sampling sites, with retrieval of associated reference and real time information
- Marking of geological stops, sampling sites, and interesting areas on the map
- Positioning of all field elements in 2D and 3D maps
- Collection and storage of geo-located relevant geological/scientific information and data analysis
- Simultaneous crew data acquisition
- Interface with external scientific instruments like microscopes or analytical tools
- In-site decision support thanks to embed of custom machine learning models for mineral recognition
- Information exchange in near real-time amongst field and ground segment
- Access to reference and support material (e.g. scientific databases, manuals)

The types of information that can be retrieved, collected and exchanged includes, but is not limited to: geolocation, rich text, photos, 360 photos, audio, videos, maps, surveys, reference files, support databases.

One of the main functionalities of the EFB is the continuous and automatic data flow amongst field and ground. The system is designed to cope with provisional loss of connection and/or extended offline sessions, ensuring data availability from local database-replicas. The EFB uses a dedicated wireless mesh network to ensure the replication of data across multiple nodes, allowing two distant nodes to share a database without direct connection, and relying on a series of inter-nodes to transfer replicated data.

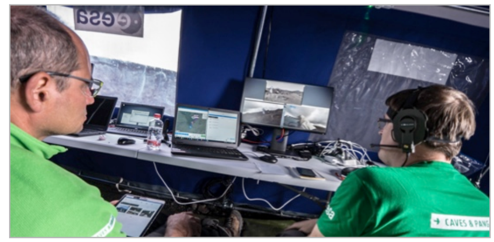

Fig. 3. Using the EFB, ground teams can maintain situational awareness over a traverse, each geological stop and sampling site, down to individual samples.

Future implementations: The project is looking to add additional functionalities in the future. These include the integration of specific panoramic-bifocal cameras for quick environmental inspection and assessment, the wireless integration of additional analytical tools for examining geological materials (e.g. VNIR, RAMAN, XRF, LIBS), the integration of additional Machine Learning (ML) autonomous classifiers in support of field decision making processes, integrating the system into enhanced data displays such as Augmented Reality (AR) and Virtual Reality (VR) visors, and linking to other planetary geology databases like the PLANMAP program of Horizon2020.

Conclusions: For future interplanetary missions, scientific data collection and sampling will be primary objectives of astronaut and rover traverses on the surface of the Moon and Mars. The EFB project offers promise for a structured way to collect data during geological traverses and to make them available to the crew and ground control during these missions. The variety of interfaces provided by the EFB also promises to strongly enhance the efficiency of using portable analytical instruments as real-time decision-support tools.

References: [1] Goddard E. N. et al. (1965) *Project Apollo Field Geology Planning Team*. [2] Coan, D., (2020) *Exploration EVA Concept of Operations*. [3] Hodges K. V. and Schmitt H. (1997) *Geological Society of America Special Paper 483,* 17–31. [4] ISECG (2020) *The Global Exploration Roadmap Supplement - Lunar Surface Exploration Scenario Update*. [5] Hurtado J.M et al. (2011) *Acta Astronaut. 90(2),* 344-355. [6] Young. et al. (2017) *Planetary Science Vision 2050 Workshop* (Contrib. No. 1989).