The Electronic FieldBook: a tool for supporting science data collection and mission operations during lunar EVA activities:

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Introduction: During the Apollo EVA traverses, astronauts gathered a variety of data, including pictures, videos, audio recordings, geographic positions and scientific data [1]. Post-mission, this information was integrated together in order to provide geological context for the scienfic research. Compared to the Apollo missions, future EVA's on the surface of the Moon will be supported by a host of new technologies used to collect scientific data and select the best samples for return to Earth [2]. How this data is stored and shared amongst all the mission support elements in real time will make a significant difference to the feedback that can be given to the EVA teams. Maintaining situational awareness for all personnel involved in the EVA will be a key asset, but requires that 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.

As one of the main goals of a future planetary exploration activities will be perform geological science, astronauts are being trained in specific campaigns to gain field geology experience. The Electronic FieldBook (EFB) has been the 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.

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 [3, 4]. 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 and 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 a number of sensors, collect data and/or samples, and take notes. This is all then automatically associated to specific sites or samples.

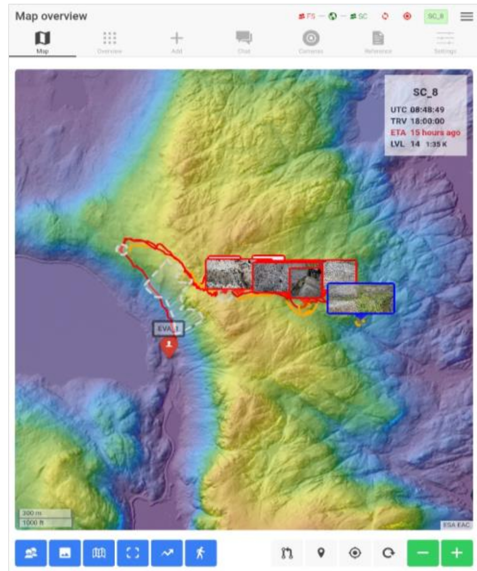

Fig. 1. The EFB interface for traverse overview display.

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

- A "Field Segment" (Astronauts on EVA), which requires a portable tool 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 geological traverse.

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

- A “Support Centre” (Sci&Ops ground teams or support astronauts in IV), which requires a real-time overview of the EV team’s progression through a traverse, and observations and data collected, in order to direct or support the operations but also to provide relevant and informed scientific advice.

Fig. 4. Using the EFB, ground teams can maintain situational awareness over a traverse, each geological stop and sampling site, down to individual samples.

The EFB is currently being developed for laptops and tablets (with ergonomic modifications to be usable with EVA gloves), and will provide 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.
- Collection and storage of geo-located relevant geological/scientific information and data analysis.
- Simultaneous crew data acquisition.
- Exchange of information 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.

The system comes as a fully integrated package including:

- Wireless mesh data transmission
- Fault resistant data communication between each system node
- Data forwarding for long range applications
- Data acquisition from every point on the deployed network
- Portable, lightweight, waterproof devices with long battery lives

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 analytical tools for examining geoligcal materials (e.g. VNIR, RAMAN, XRF, LIBS), the integration of 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, science 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 making support tools.

References: [1] Goddard E. N. et al. (1965) *Project Apollo Field Geology Planning Team*. [2] Hodges K. V. and Schmitt H. (1997) *Geological Society of America Special Paper 483*, 17–31. [3] Hurtado J.M et al. (2011) *Acta Astronaut. 90(2),* 344-355. [4] Young. et al. (2017) *Planetary Science Vision 2050 Workshop* (Contrib. No. 1989).