THE ELECTRONIC FIELDBOOK: A FIELD SCIENCE SUPPORT SYSTEM FOR ASTRONAUT TRAINING AND PLANETARY EXPLORATION. L. Turchi[1,5], S.J. Payler[1,2], F. Sauro[3], R. Pozzobon[4], M. Massironi[4], L. Bessone[1]. [1] Directorate of Human and Robotics Exploration, European Astronaut Centre - European Space Agency, [2]Agenzia Spaziale Italiana, Rome, Italy, [3] Department of Biological, Geological and Environmental Sciences, Italian Institute of Speleology - Bologna University, [4] University of Padua, Dipartimento di Geoscienze – Padova, [5]Spaceclick Srl, Milan, Italy

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].

To prepare astronauts for future planetary science exploration activities, astronauts are being trained in specific campaigns to gain field science experience. In this context, the Electronic FieldBook (EFB) [4] was developed as key supporting tool for the ESA CAVES & PANGAEA campaigns, which offer planetary geology training integrated with operations and technology testing in analogue environments. From this, the EFB has developed into a promising system for supporting field science, including 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 to provide scientific and operational guidance to the astronauts. In addition, astronauts require information pertaining to navigation, decision support tools and other reference information to augment their effectiveness and autonomy.

The 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. This is all then automatically associated to specific sites or samples (Fig. 1) and distributed to other EFB users using the EFB's dedicated wireless mesh network.

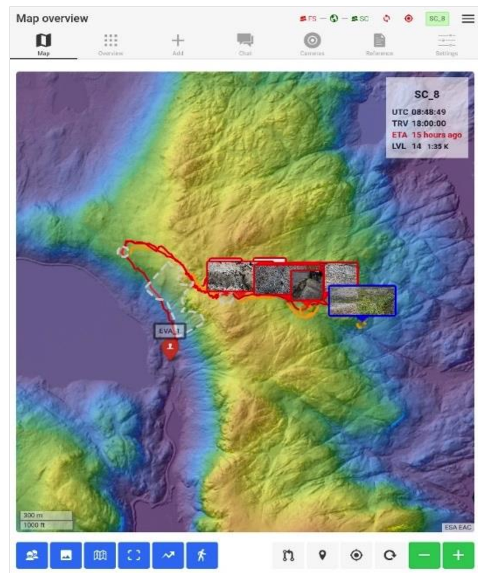

Fig. 1. The EFB interface for traverse overview display.

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).

The current version of EFB is developed for laptops and tablets, and provides: the display of pre-defined or real-time traverses, stops, samples and other zones, retrieval of associated references, positioning of all field elements (in 2D and 3D maps), collection and storage of geo-located relevant geological or scientific information, concurrent crew data acquisition and merging, interface with external scientific instruments, on-site decision support with embedded custom machine learning models for mineral recognition [7], and information exchange in near real-time with all the supporting teams (also, can cope with provisional loss of connection and/or extended offline sessions). The types of information that can be retrieved, collected and exchanged includes, but is not limited to: geolocation, rich-text, photos, audio, videos, maps (digital terrain models surveys), reference files and support databases.

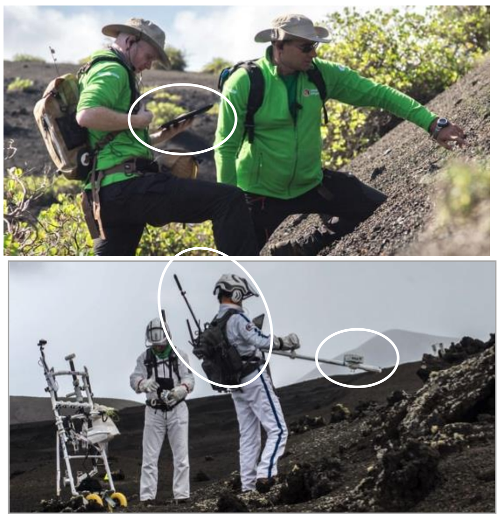

Fig. 2. The tablet is used to document sampling site and to transfer observations to the ground support team for evaluation.

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 core of the EFB is built on standard web stack technologies. For data acquisition and display, the EFB employs user interfaces tailored to needs of specific campaigns. Additional modules include databases for data persistency, networking, data management supervision and synchronisation, and APIs for providing interfaces to external devices or systems. The EFB's approach to data management is "offline-first", meaning a portion of data is stored locally on each device. In such way, any device becomes a data replication node in the network. Users can therefore interact with a local copy of the distributed database, resulting in zero-latency when manipulating data, even when connectivity is not available. Automatic processes for conflict resolution and data merging ensure no data is lost when connectivity is reestablished and synchronisation restarts. The local database also supports the storage of mapping and metadata for the 2D and 3D map-viewers, including Tile Map Service compatibility (both for 2D tiles and 2.5D digital terrain models). The map database is also capable of seamless updates distributed from other nodes in the network, which result in the possibility to remotely update, add, remove, and refresh old and new custom mapping layers at runtime in field operated devices.

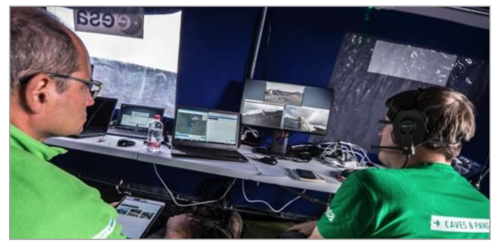

Fig. 3. Using the EFB, ground teams can maintain situational awareness over a traverse, each geological stop and sampling site, down to individual samples.

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.

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 a structured way to collect data during geological traverses and to make them available rapidly to the crew and ground control. 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*. [4] Turchi L. et al. (2021) *Planetary Space Science*. [5] Hurtado J.M et al. (2011) *Acta Astronaut. 90(2),* 344-355. [6] Young. et al. (2017) *Planetary Science Vision 2050 Workshop*. [7] Jahoda, P. et al. (2020), *The Analyst*.