# → THE ELECTRONIC FIELDBOOK TOOL SUITE

## SCIENCE AND DECISION SUPPORT TOOLS FOR STRUCTURED INFORMATION COLLECTION AND DISTRIBUTION DURING ASTRONAUT TRAINING AND HUMAN PLANETARY EXPLORATION


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*www.esa.int/pangaea*

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# → PANGAEA TRAINING AND TESTING

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**PANGAEA: P**lanetary **A**nalog **G**eological and **A**strobiological **E**xercise for **A**stronauts

Geological field training: traverses w/ real scientific objectives in real Planetary Analogue geologic environments

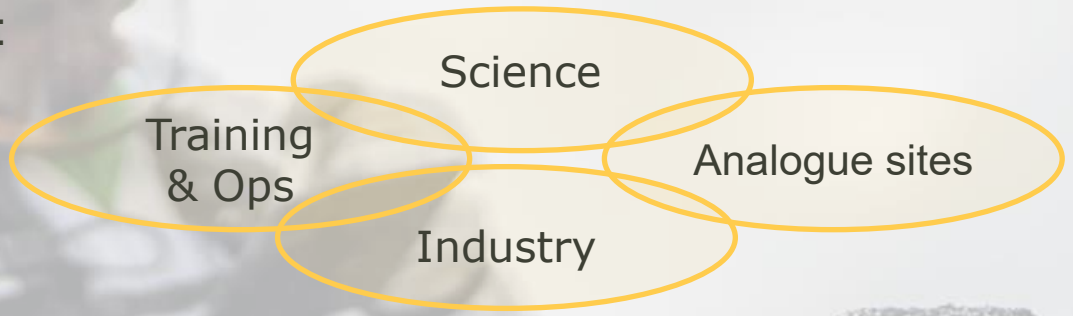
**PANGAEA**-e**X**tension

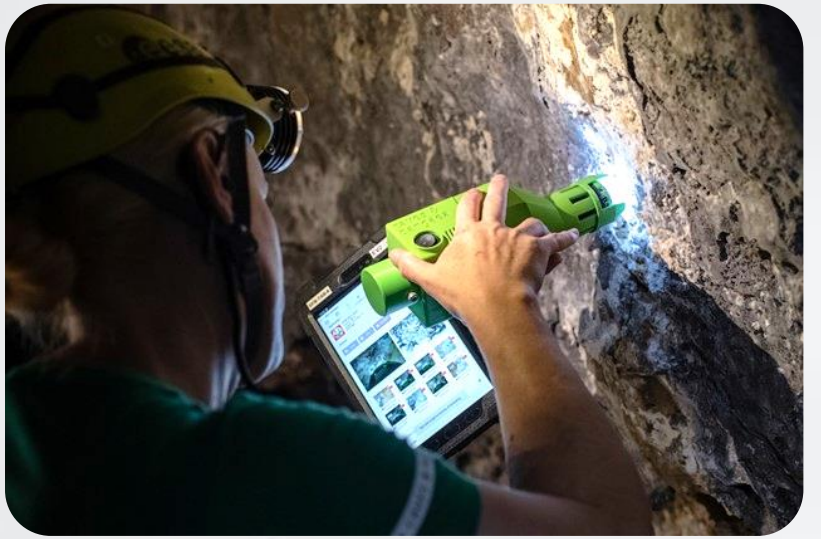
Space analogue test campaigns, following a session of PANGAEA training, involving astronauts, planetary scientists, trainers, operations personnel and space engineers in a real planetary analogue setting, testing:

- Science
- Technology
- Operations

# ESA PANGAEA: Astronaut Training for Planetary Geology

- ✓ Not a simulation: real science traverses
- ✓ Multiple space-related partners simultaneously involved in field training
- ✓ Cooperation between:



**NASA ARTEMIS III Science Definition Team Report**

- ***6.1.4-1*** Astronauts should participate in an Apollo-style **course in geology and planetary science.**
- ***6.1.4-2*** Astronauts should be trained and equipped to **collect a variety of surface/sub-surface samples.**
- ***6.1.4-3*** We recommend a mission capability of **real-time transmission of data from in situ science instrumentation** that provides **documentation for site characteristics** and enables a science support team (backroom, operations center, etc.) to **support EVA operations with (near) real-time feedback** to the crew when necessary on science decision-making, as well as **provide processed data when necessary** (i.e. helping convert raw data into tactical decision-making).

# → EFB Tool Suite

*The Electronic Field Book Tool Suite*

*situational awareness & science decision support during field science operations*

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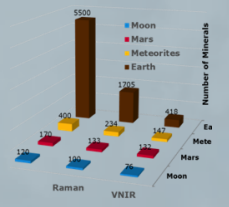
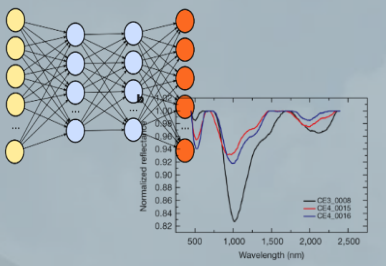
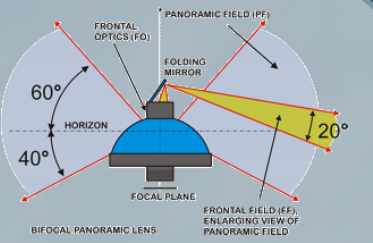
Handheld Spectrometers
**Mineral identification**




Planetary Minerals Libraries
**Knowledge retrieval**




Machine Learning
**Autonomous classification**




External Img devices
**Situational Awareness**

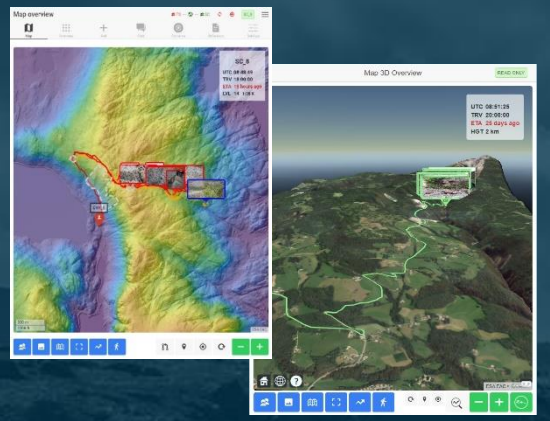
Science & Mission Support

- Geolocated **Data collection**
- **Data Harmonization**
- **UI** for Science Operations
- Disruption Tolerant **Information Exchange**
- **Concurrent** data acquisition
- External **Tools Integration**

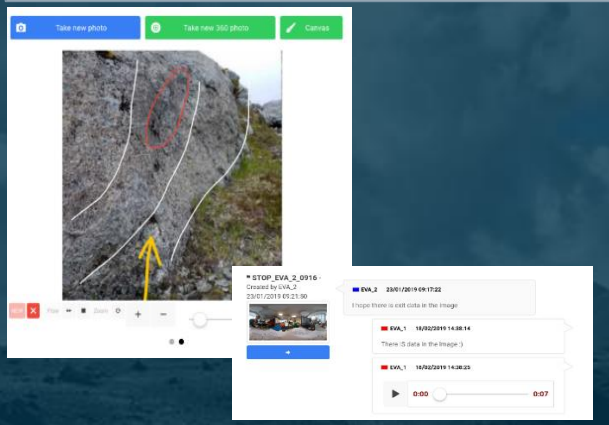
Field Ops (Crew & Rovers)

# → SCIENCE SUPPORT DURING FIELD TRAVERSES

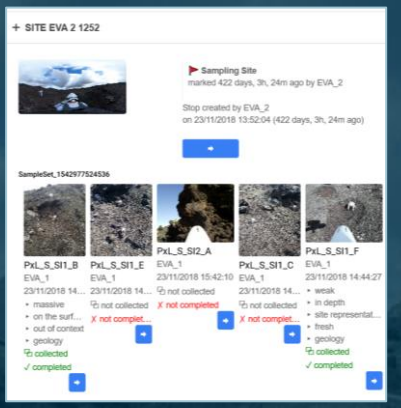
TRAVERSE PLANNING



SITES DOCUMENTATION



GROUND MONITORING




# → DISTRIBUTED SCIENCE OPERATIONS

**Situational awareness** and data sharing amongst **crew members** in the field and the extended **support teams** is crucially important for successful planetary exploration [1].

[1] NASA ARTEMIS III Science Definition Team Report (link)

- → All relevant information must be retrieved, collected and stored in real time in a structured way
- → Interaction with portable instruments must be easy, enabling cooperative science operations
- → Multimedia information sharing is bidirectional, field to ground to field

**EFB – Planetary Space Science** https://doi.org/10.1016/j.pss.2021.105164

L. Turchi[1,5], S.J. Payler[1,2], F. Sauro[3], R. Pozzobon[4], M. Massironi[4], L. Bessone[1]
[1]European Astronaut Centre (EAC) - European Space Agency, Cologne, Germany, [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 S.r.l. - Milan

## FIELD SEGMENT

PANGAEA
PANGAEA-X

CAVES

EV Team

Eurocom
-IV Team

SciCom/Science Backroom

## SUPPORT CENTRE

# → Analytical Tools Real Time Data Integration

## SPECIFIC SPECTROMETERS INTEGRATION

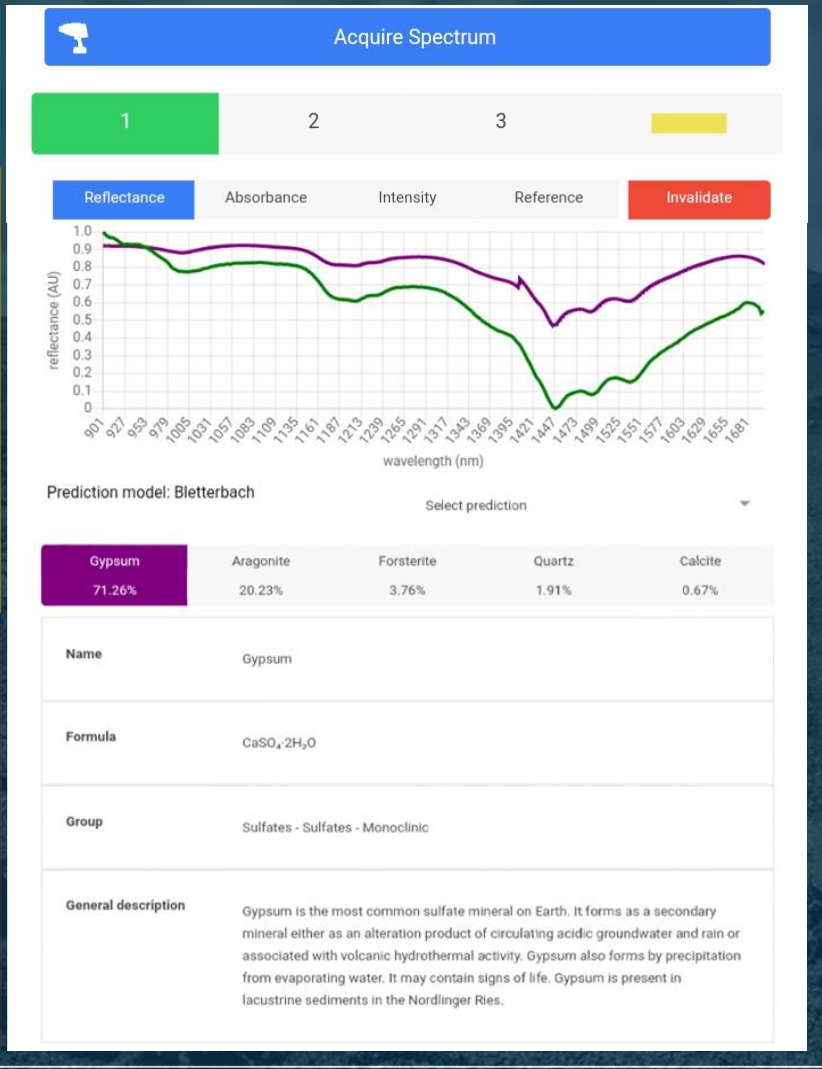
WIRELESS ANALYTICAL DATA ACQUISITION

↓

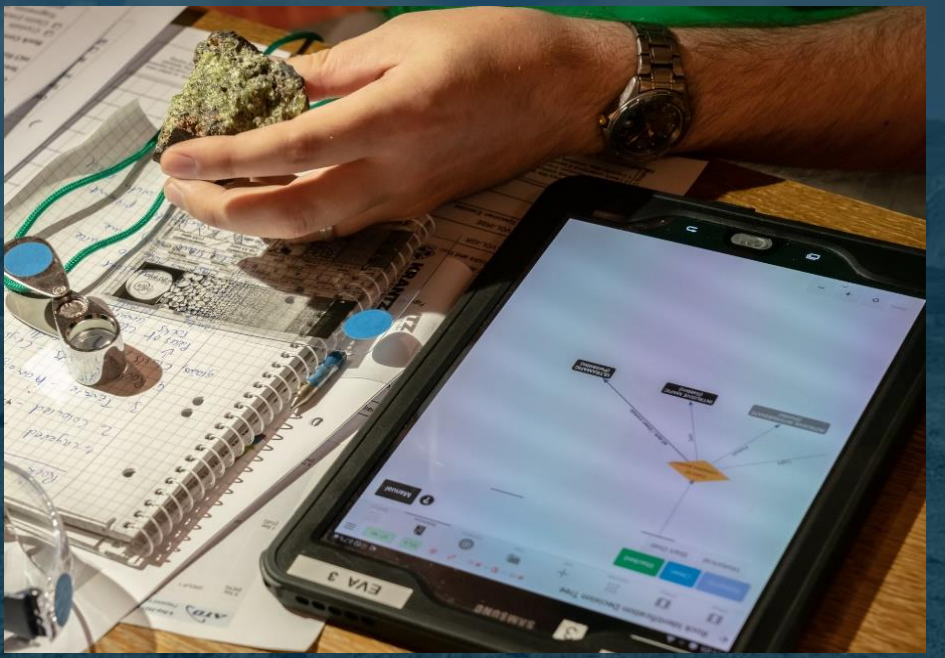
MACHINE LEARNING MINERAL CLASSIFICATION

↓

QUICK INSIGHT FROM MINERALOGICAL DATABASE




## REFERENCE & GUIDED CLASSIFICATION PROCESSES



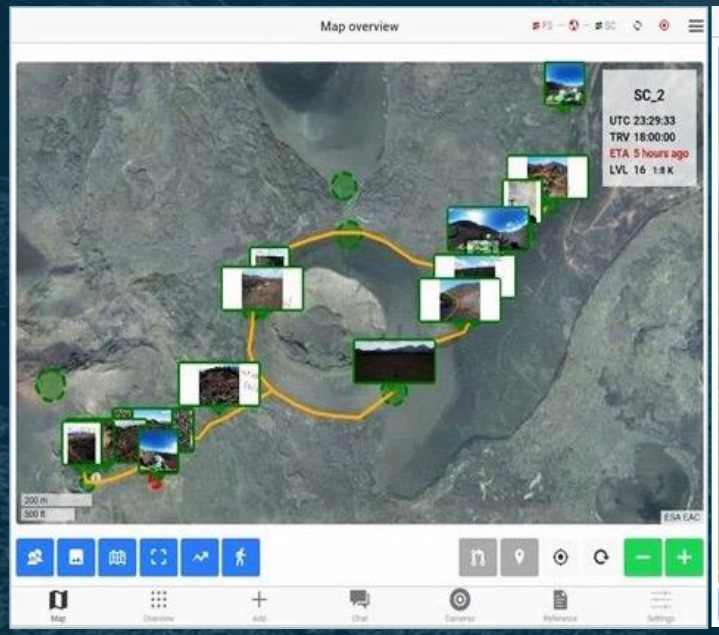
# → Ground monitoring and remote support

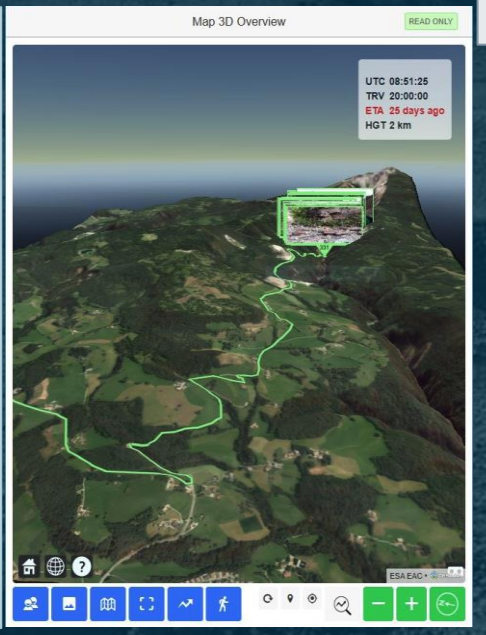
**Ground Sci/Ops rooms can**

- receive data in near real time
- give feedback on operations
- manipulate data and add details

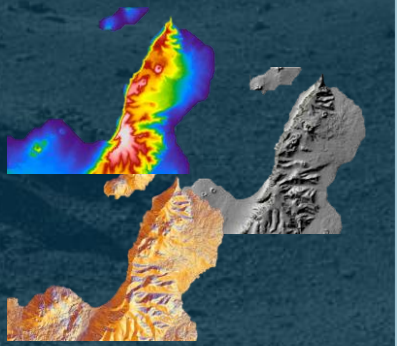
→ Information is then **synced back to the crew**

## PINPOINTED INFORMATION (2D & 3D)

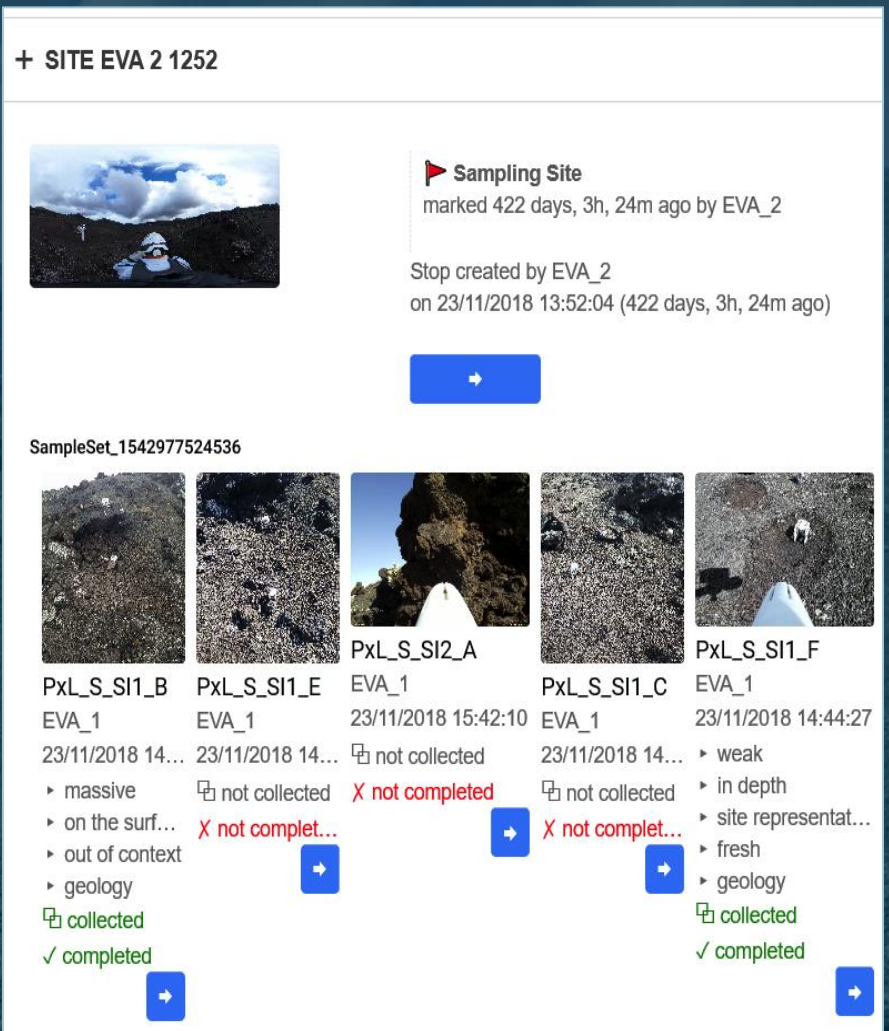



## MULTISPECTRAL MAP OVERLAYS



## STRUCTURED INFORMATION

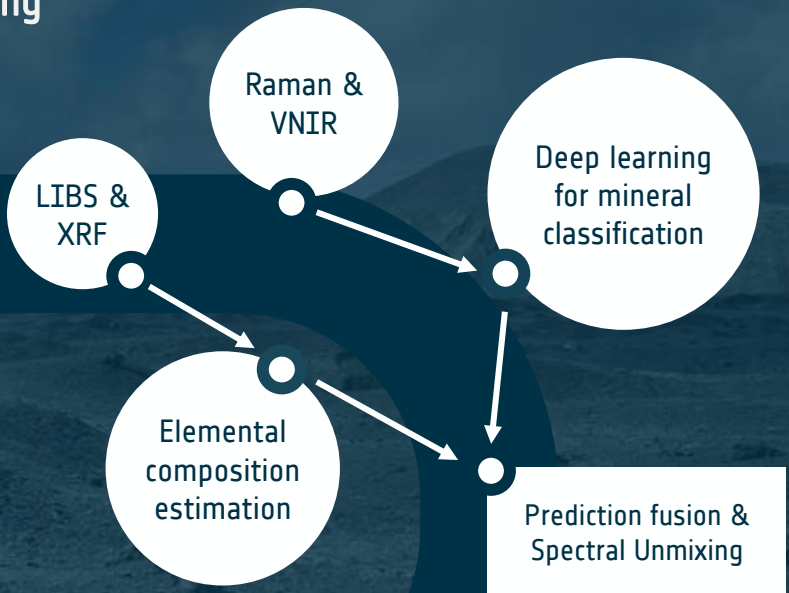


# → RECOGNIZING PLANETARY ROCKS AND MINERALS

## Combining a Custom Mineralogical Database with Deep Learning based Multispectral Unmixing

**577 minerals**

Petrographic catalogue & Custom archive of reference spectra




### Spectral coverage by method

64.12% Raman

41.59% VNIR

**~$10^4$ spectra**

Developed and tested together in the context of ESA's astronaut field science training using analogue environments, PANGAEA, the mineral library and recognition software are a real-time decision support tool for future planetary surface exploration missions.

### Spectral coverage by prominence

69.84% Meteorites

33.62% Mars

24.09% Moon

Metrics are stored in the database for continuous improvement

### Prediction accuracy per method

92.76% Raman & VNIR

83.21% Raman & LIBS

79.34% VNIR & LIBS


S. Hill[4], F. Venegas[4], A. Angellotti[4], I. Drozdovskiy[1], F. Sauro[2], S.J. Payler[1,3], P. Jahoda[4], K. Jaruskova[4], M. Franke[4], P. Lennert[4], G. Ligeza[4], P. Vodnik[4], L. Turchi[1], L. Bessone[1]

[1]European Astronaut Centre (EAC) - European Space Agency, Cologne, Germany; [2]Geological and Environmental Sciences, Italian Institute of Speleology - Bologna University, [3]Agenzia Spaziale Italiana, Rome, Italy, [4]ESA-EAC, CAVES & PANGAEA intern



- Mineralogical DataBase – Data in Brief https://doi.org/10.1016/j.dib.2020.105985
- Machine Learning – The Analyst https://doi.org/10.1039/D0AN01483D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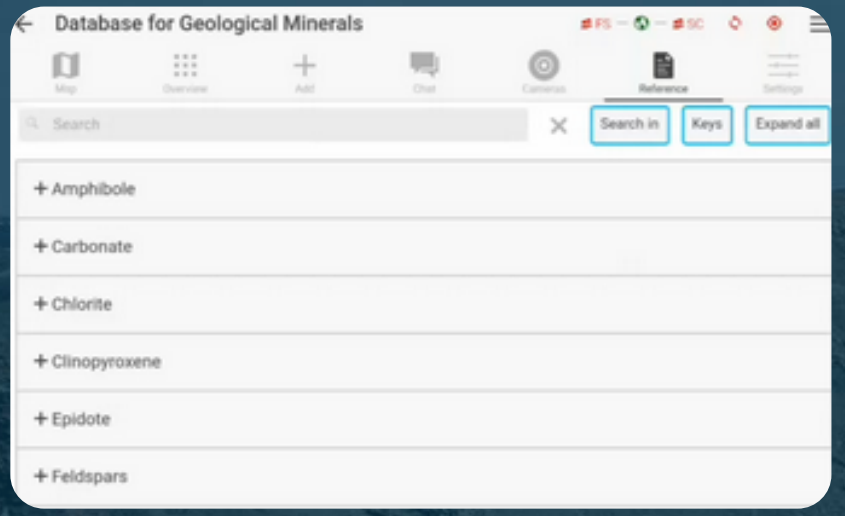
# →MINERALOGICAL DATABASE & GEOLOGICAL BACKGROUND




Physical properties

Geological formation

Synonyms

Location & surface abundances

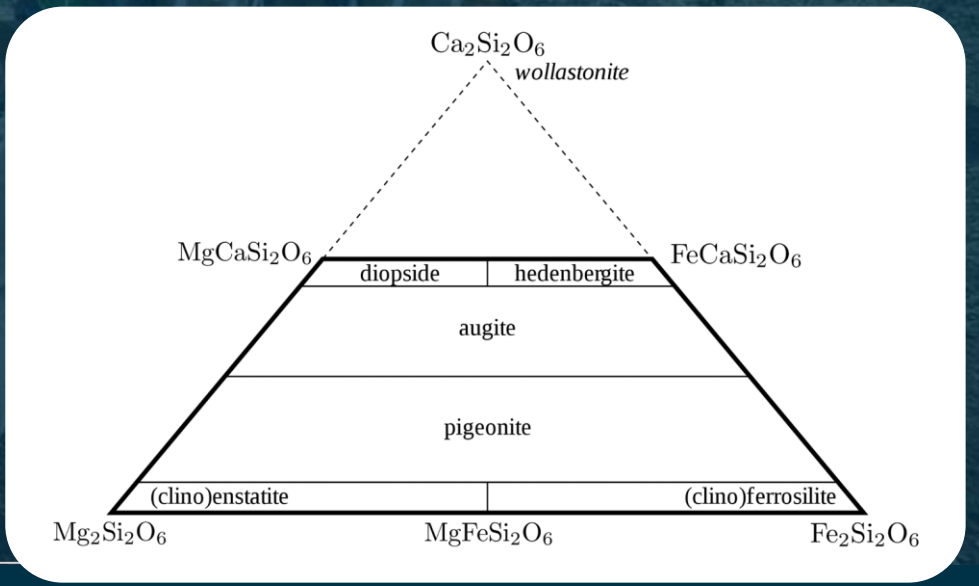
Chemical composition

Systematics

- ✓ The catalogue consists of petrographic information on all currently known minerals identified on Moon, Mars, and associated with meteorites.
- ✓ The catalogue is envisioned to provide essential analytical in-field information for each mineral to assist in rapid identification and understanding of significance in real time geological exploration.

Challenges during identification

- Spectroscopy is surface sensitive
- Rock-Mixture of minerals
- Alteration in the samples

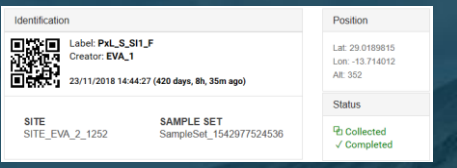


# → EFB TOOLSUITE DEPLOYMENT AND USE DURING FIELD SCIENCE OPERATIONS

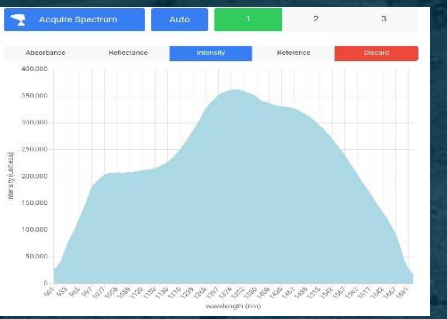
## SCIENTIFIC DATA COLLECTION

### INTERACTION WITH MICROSCOPES

### METADATA & TAGGING



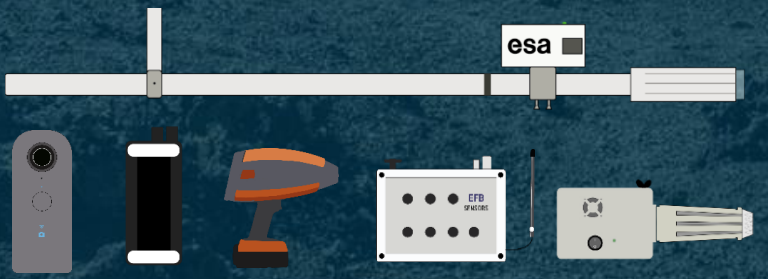

### ANALYTICAL TOOLS




### INTERACTIVE DRAWINGS

## U/M INTERACTION DEVICES

## SENSORS & TOOLS




## NETWORKING

# THANK YOU FOR YOUR ATTENTION

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## → SUMMARY

**The ESA Electronic Field Book Tool Suite for Geological Planetary Operations will allow to:**

- ✓ Maximize **sampling efficiency** through real-time in-situ characterization and selection of the most promising sample, reducing duplicates and **identifying** out of context cases (Analytical Tools, MDB, ML)
- ✓ **Document** the operations and science objectives with a **multi-scale** and multi-spectral approach (imaging devices, pan-cam)
- ✓ Keep a **continuous flow of data** and a simultaneous data acquisition and interpretation between crew and science backroom (EFB)