
we
europlanet 2024
Research Infrastructure

Geology & Planetary Mapping
Winter School

The PANGAEA geologic field training for astronauts

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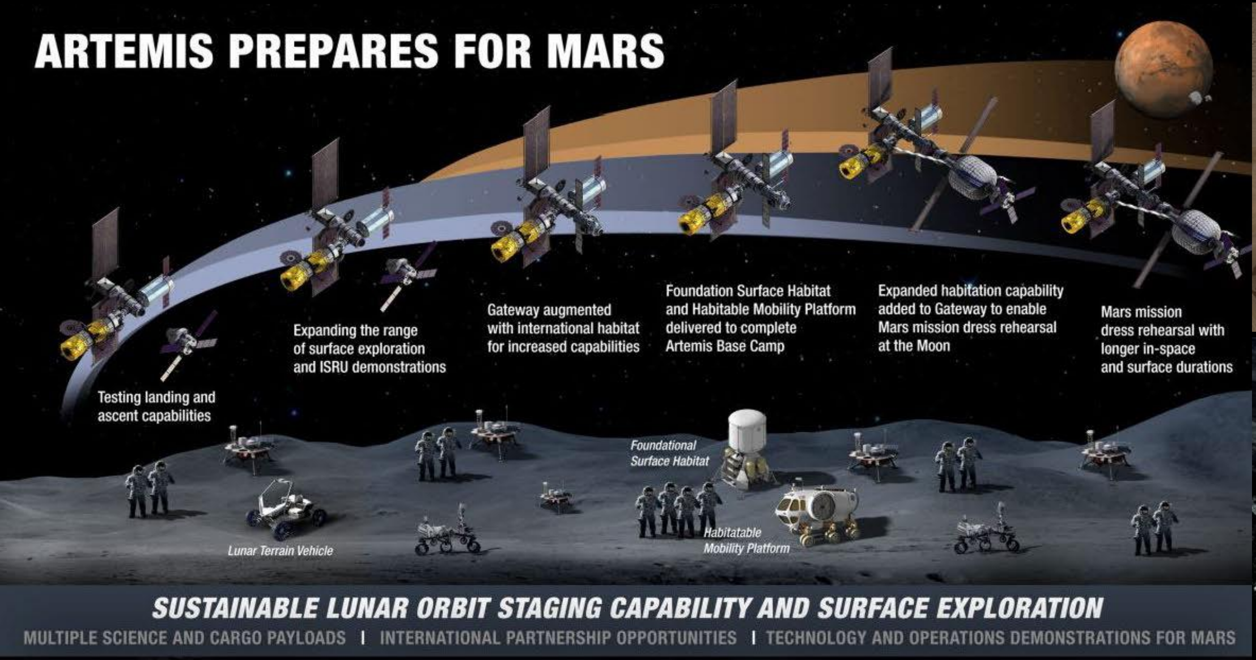
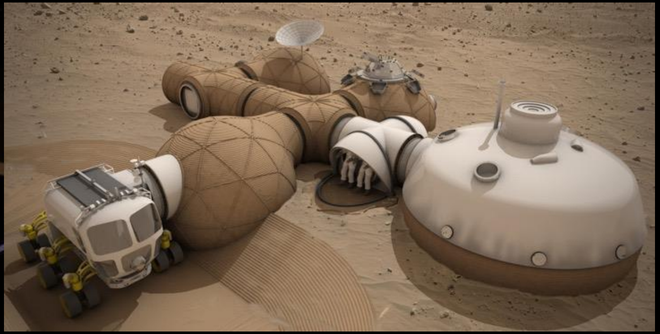
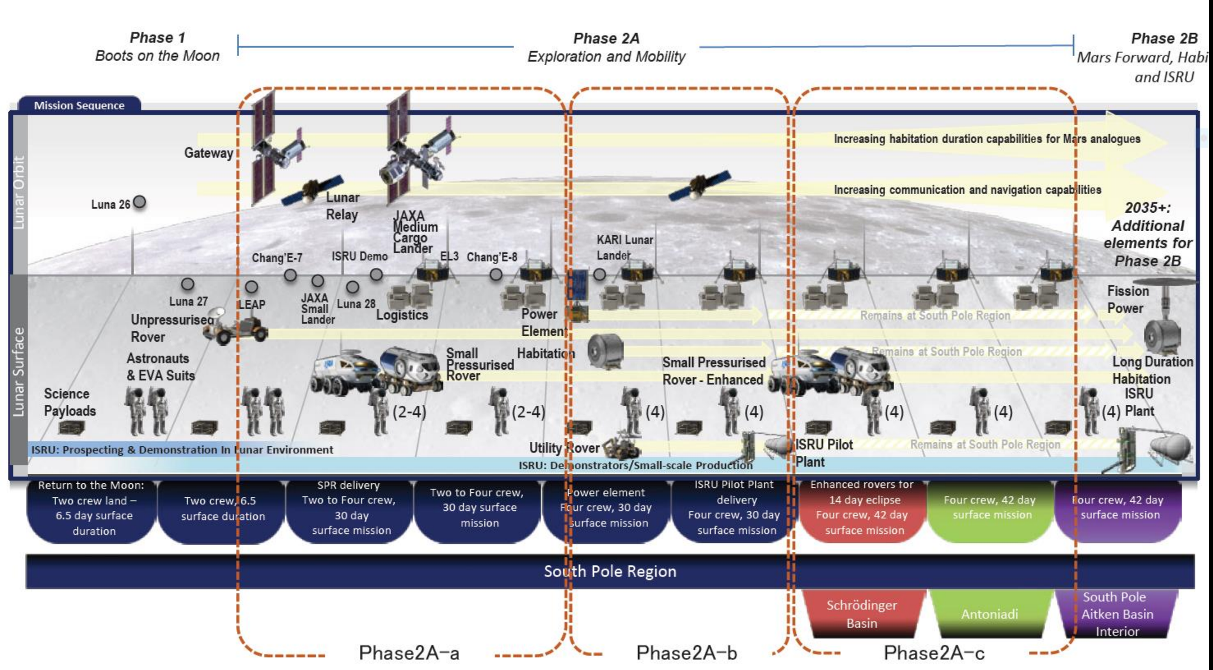
Future in situ Exploration: From the Moon to Mars



Artemis Plan 2020



Future in situ explorations: Next Moon



Global Exploration Roadmap 2022

esa caves & pangaea

Of the Moon	On the Moon	From the Moon
Bombardment	Habitability of the Earth through time	Radio astronomy
Structure from core to crust	Life in the Universe	Optical and infrared astronomy
Rock diversity and distribution	Survivability in space	Cosmic ray astronomy
Polar volatiles (e.g. ice)	Physiology and medicine	
Volcanism	Fundamental physics	
Impact processes	Space physics	
Regolith	History of the Sun and Solar System	
Atmosphere, plasma and dust	Impact rate	
Tectonics	Earth-Moon formation	

ESA strategy for sience at the Moon

AREA	DETAILS
1. Explore the origin and evolution of the solar system.	a. The Moon retains the bombardment history of the inner solar system and informs early solar system formation and dynamics. b. Volcanic processes over billions of years preserved on the Moon can inform planetary evolution and interior composition of a differentiated planetary body. c. The lunar poles host cold traps, or PSRs, that entrain lunar volatiles sourced from the lunar interior, implanted by the solar wind, or delivered to the surface via primitive material left over from the solar system's formation. d. Sample return may yield new insights into how the Moon and the Earth are chemically linked, helping to constrain Earth-Moon formation models and test formation hypotheses. e. Geophysical investigations of the deep and shallow structure and composition of the interior will lead to data and new theories on planetary formation, evolution and the current state of the Moon.
2. Define processes that shape planetary bodies.	a. Lunar crustal rocks and regolith are preserved and inform impact processes on both a macro and micro scale. b. Space weathering effects on airless, anhydrous bodies are investigated at the lunar surface due to the lack of atmosphere. c. Investigations into space plasma physics and electrodynamical interactions with regolith/dust.
3. Use the Moon as a platform for novel and unique measurements.	a. Unique solar observations and measurements can be acquired on and around the Moon, including solar coronal imaging, solar x-ray and gamma-ray spectroscopy, radio imaging of physical processes in the inner heliosphere, magnetospheric imaging, and in-situ plasma and solar wind measurements. b. Dark Ages observations and other cosmological studies of the early Universe are enabled by utilising the radio-quiet far side of the Moon. c. Observations of climate change and Earth as a life-bearing exoplanet are enabled from the lunar surface through full-disk Earth viewing.
4. Characterisation of the Moon's environment and resources to enable more efficient and sustainable exploration of our solar system.	a. Scientific knowledge of lunar resource reservoirs and their associated sinks/sources will allow for a more complete understanding of the Moon's evolution and environment as well as the quantity and accessibility of those resources for ISRU considerations. b. Additional resources available for sustainable exploration include illumination/lighting at the poles, lava tubes that may be a resource for habitation or protection, etc. c. Research into the physical and chemical processes underlying ISRU
5. Utilise the Moon as a testbed for life sciences investigations that enable human exploration.	a. Exposure and measurement of biological (varied complexity of non-metabolic and metabolic samples) sensitivity and responses to the integrated lunar surface environment, optimized by combination of in situ and return sample analyses. b. Optimisation of countermeasures against the debilitating effects of deep space and reduced gravity environments. c. The Moon retains the impact history of the Earth-Moon system as well as reservoirs of primordial organic material delivered by comets/asteroids that may inform important astrobiological questions such as: Where did the Earth get the building blocks of life? What was the role of impacts and mass extinctions in the evolution of life?

Global Exploration Roadmap 2022

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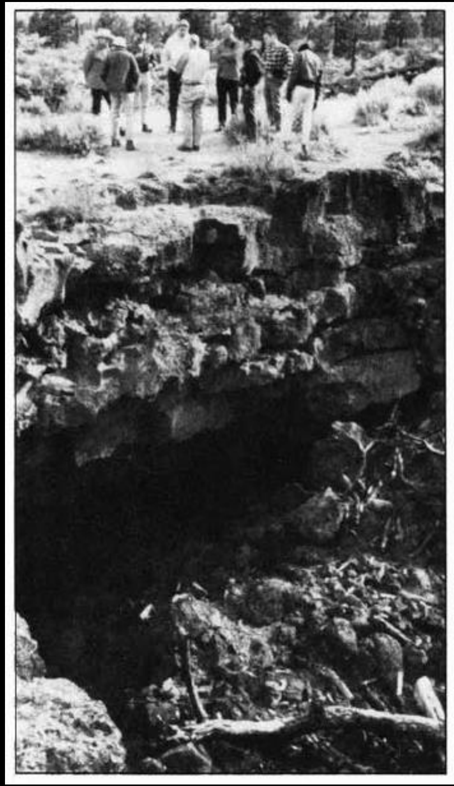
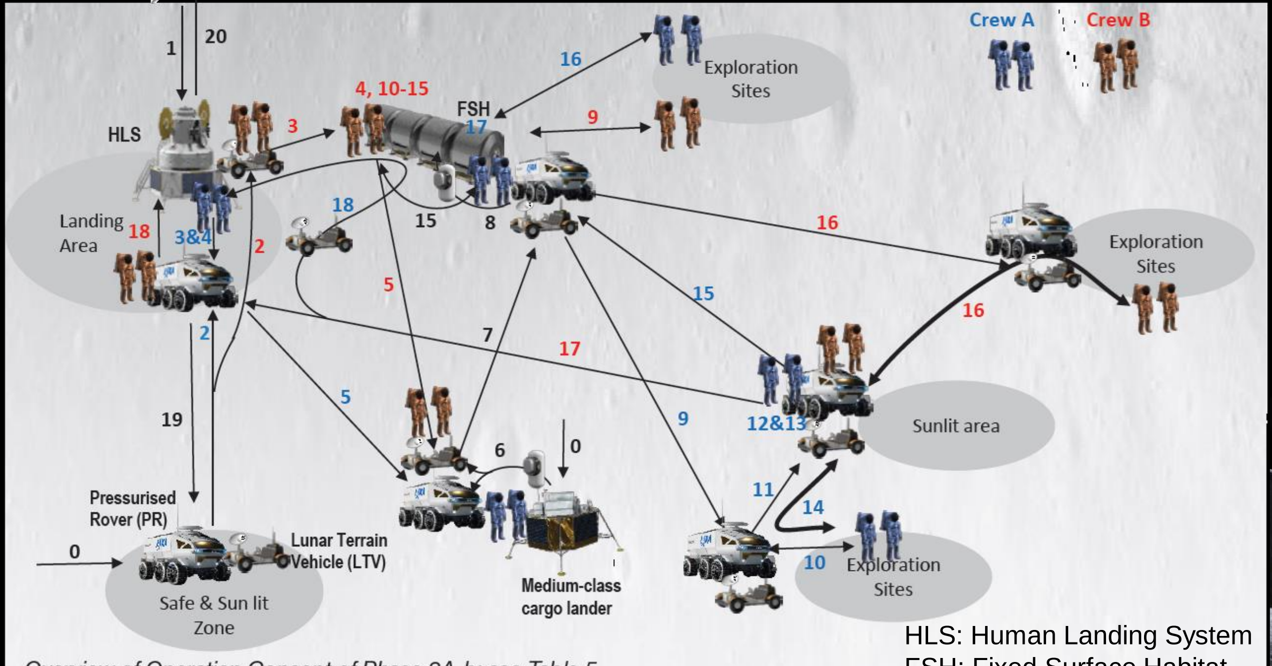
“No substitute exists for working in the field to learn the principle of geologic field observation and sampling”



Lunar in situ Exploration

Global Exploration Roadmap 2022

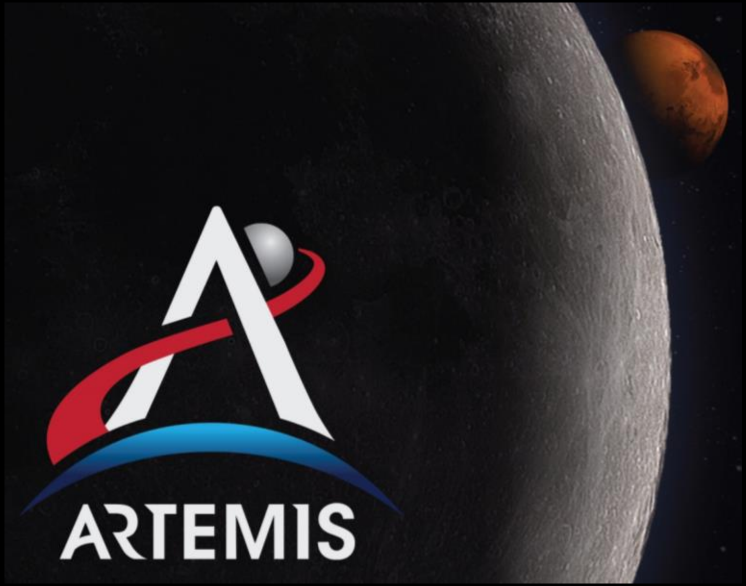


Overview of Operation Concept of Phase 2A-b; see Table 5.

HLS: Human Landing System
FSH: Fixed Surface Habitat

PANGAEA - WHY

- Human missions to the Moon and Mars will require astronauts required to function as field scientists exploring unknown planetary surface environments



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 and sub-surface samples.

PANGAEA - Planetary Analogue Geological & Astrobiological Exercise for Astronauts

Field science training in real planetary analogue geological environments

Provides the knowledge and skills required for effective mission/site specific training

PANGAEA Topics of Learning

- Fundamentals of geologic processes on Earth, Moon, Mars and asteroids
- Observational skills to:
  - identify prominent geological features on field
  - identify most plausible geologic environments that could host life
  - conduct efficient sampling
  - to report correctly to the "ground" (scientists)
- Operational constrains, strategies and analytical tools assisting planetary explorations

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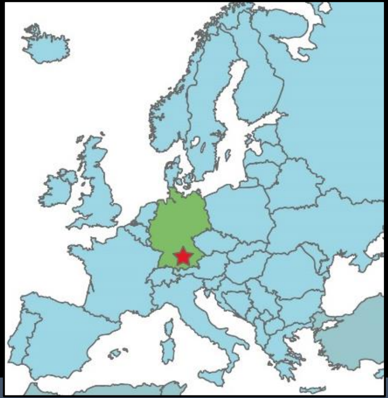
WHERE– Planetary Analogues

GEOPARC Bletterbach
Aldino & Redagno
Dolomiti Patrimonio
dell'Umanità UNESCO

Dolomites:
Panetary Geology
Sedimentary environment
Earth and Mars

GEOPARK RIES
Europas Riesiger Meteoritenkrater

Ries Crater:
Impact cratering
Lunar Geology
Meteorites-Small Bodies



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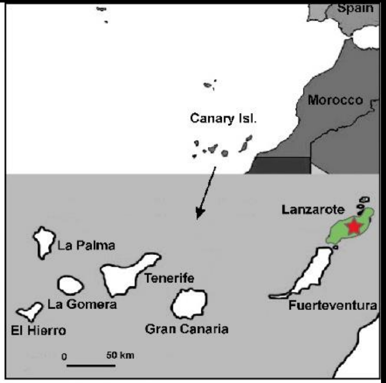
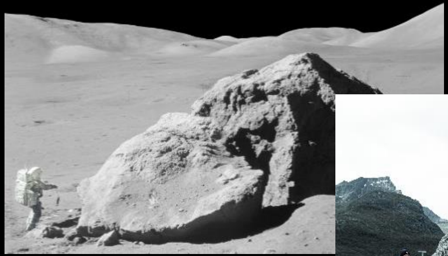
WHERE– Planetary Analogues

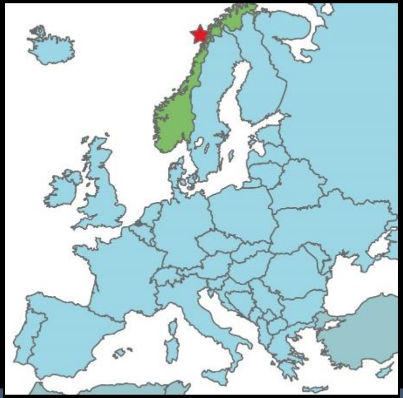
Lanzarote Geoparque y Archipiélago Chinijo

Lanzarote:
Volcanism on
Mars and Moon
Geomicrobiology

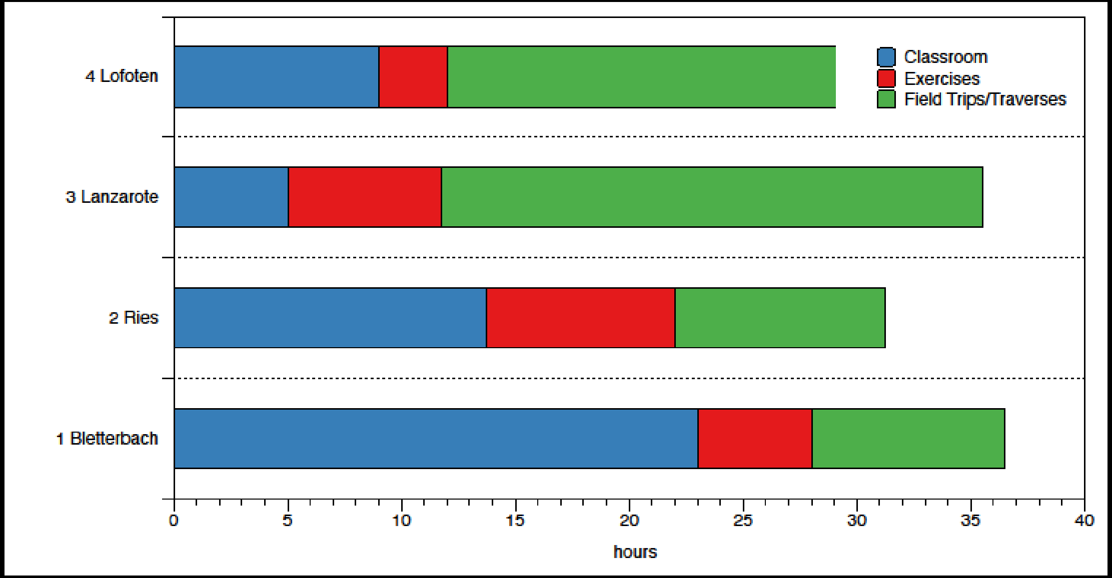


Lofoten:
Intrusive suites
Lunar Highlands





PANGAEA Activities



Classroom

Exercises

Field Work

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Observational Skills

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Rock recognition

Description

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Use of analytical tools

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Sampling

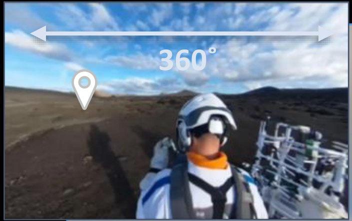
Documentation and communication

The EFB Toolsuite

Eurocom/IV Team

SUPPORT CENTRES

SciCom/Science Backroom

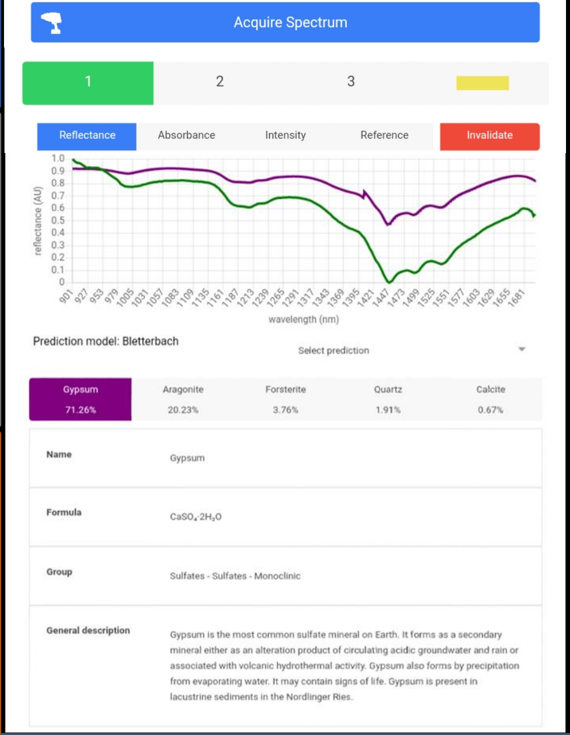


EV Team

FIELD SEGMENT

The EFB Toolsuite

SPECIFIC SPECTROMETERS INTEGRATION



WIRELESS ANALYTICAL DATA ACQUISITION

↓

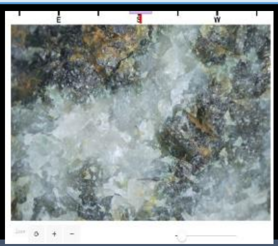
MACHINE LEARNING MINERAL CLASSIFICATION

↓

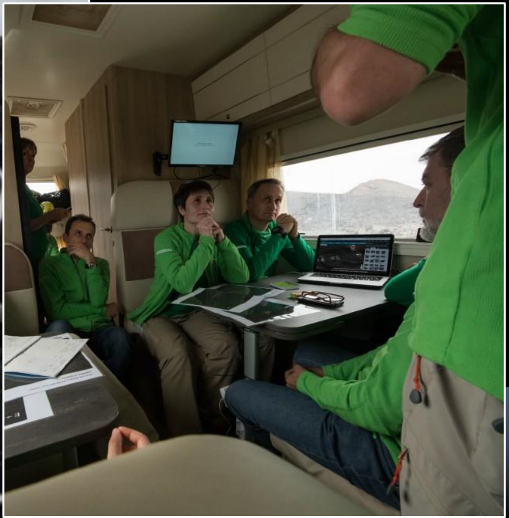
QUICK INSIGHT FROM MINERALOGICAL DATABASE

REFERENCE & GUIDED CLASSIFICATION PROCESSES

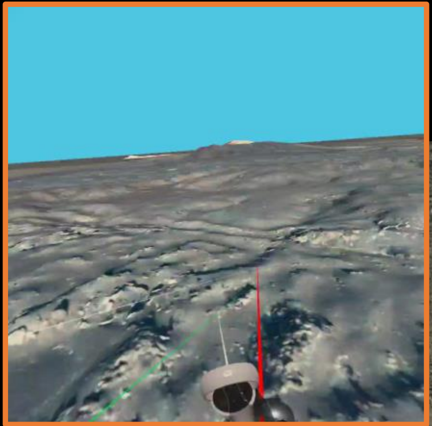
MICROSCOPE INTEGRATION



Traverse planning

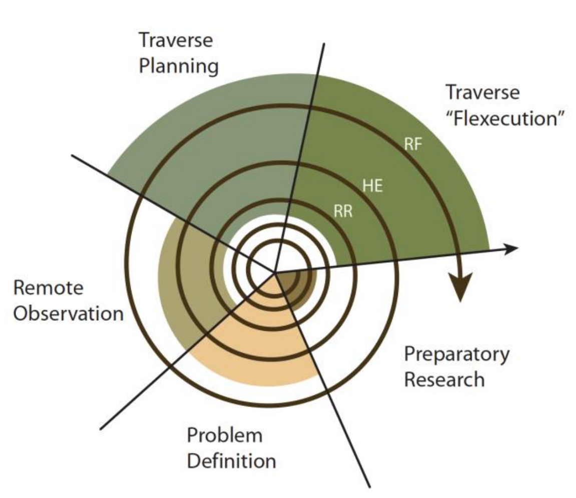


VR Traverse Briefing – Tinguaton

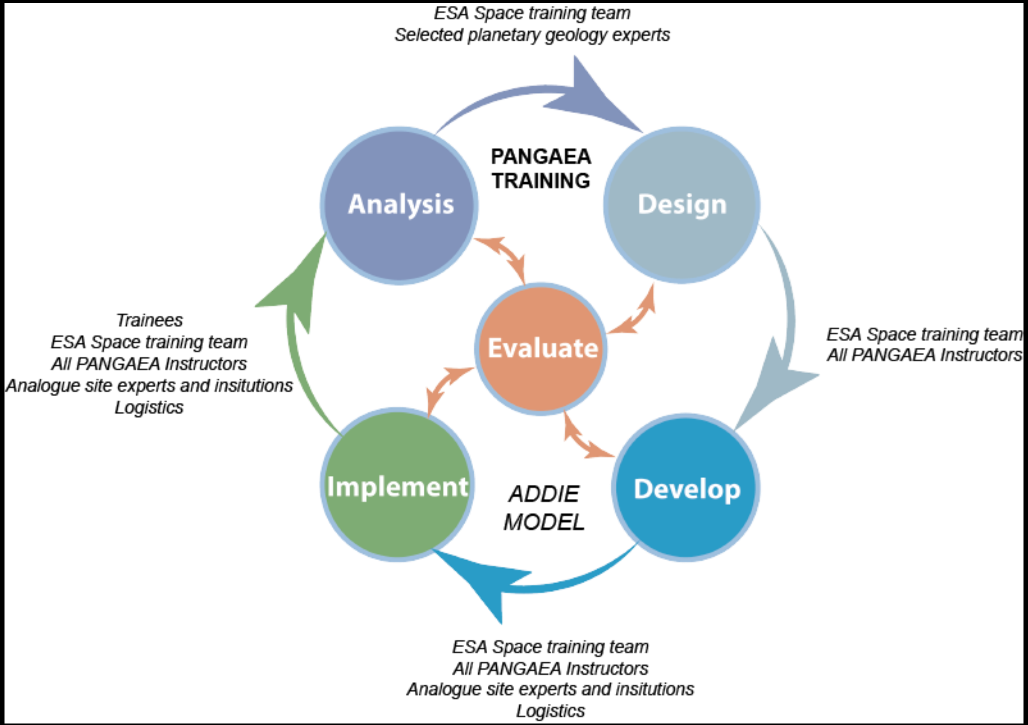


Field Training: Self-guided Traverses

- Team must balance:
  - Safety
  - Timeline limits
  - Exploration goals
  - Scientific goals
  - Communication with “Ground”
- Team is self led – flexible execution
- Teamwork is essential for success



Addie Model


ESA Space training team
Selected planetary geology experts
PANGAEA
TRAINING
Analysis
Design
Evaluate
Implement
Develop
ADDIE
MODEL
ESA Space training team
All PANGAEA Instructors
Trainees
ESA Space training team
All PANGAEA Instructors
Analogue site experts and insitutions
Logistics
ESA Space training team
All PANGAEA Instructors
Analogue site experts and insitutions
Logistics

WHO: International Astronauts 7 ESA, 2 NASA, 1 Roscosmos in 5 editions

2016

Luca
Parmitano
(IT)

Matthias
Maurer
(GE)

Pedro
Duque
(ES)

2017

Samantha
Cristoforetti
(IT)

2018

Thomas
Reiter
(GE)

Sergey Kud-
Sverchkov
(URSS)

2021-2022

Kate
Rubins
(USA)

Andreas
Mogensen
(NL)

2022

Alexander
Gerst
(GE)

Stephanie
Wilson
(USA)