



ARTEMIS

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Artemis Geology and Lunar
Science Training Overview
PAC meeting, July 2024

Artemis Geology Training: Introduction



Basic message: Crew training in geology, including lunar science and field methods, is a critical step for successful Artemis missions.

- Provide overview of the training conducted over the past year, and discussion of future geology training for Artemis crew
- Bottom Line: NASA is now providing training in geology and lunar science to astronauts assigned Artemis missions, as well as Artemis Flight Controllers



Geology Training Background and Context



- Crew training (from planning to implementation) is cross-agency and multi-institutional effort.
- Artemis planetary science will be achieved through lunar surface traverses.
 - The operational burden for EVAs is high – both physically and mentally
 - Training in geology, EVA skills, and field skills are all necessary to build the “muscle memory” to achieve both safe EVA operations and science objectives
- We have been building plans, developing the relationships, and delivering geology training to the crew office and the exploration community for 15 years.
 - Build the crew’s knowledge base over time, starting with incoming Astronaut classes
 - Partner closely with the xEVA Trainers and Crew Training Office in JSC’s Flight Operations Directorate.
 - Together, all parties acknowledge the importance of **integrated training and skill development** across science and operations for the lunar surface.

Astronaut Training – Geology Science Training Flow



PHASE 1

Initial Training

New Astronaut Classes
Laying the foundation

- JSC Classroom Training (80 hrs)
 - Geo-Science Fundamentals
 - Earth Systems
 - Planetary Science & Missions
- Field Training (80 hrs)
 - Established NM and AZ locations
 - Basic Geo Mapping & Traverse Planning
 - Sampling and Tools
- Expeditionary Components



PHASE 2

Building/Maintaining Skills

Before/Between
Flight Assignment

Lunar Focused Training

Lunar Fundamentals

- Lunar Classroom Content (32 hrs)
- Field Principles (Flagstaff Geo101) (28 hrs)

Lunar Integrated Testing

- Lunar Hardware & Ops Testing (NBL, ARGOS, RY)
- Lunar Field Tests (e.g., JETT Tests)

Proficiency Training

- Analog Mission Opportunities
 - PANGAEA, NEEMO, DRATS, CAVES, etc.

PHASE 3

Assigned Crew Training

- Mission Science Training
- Science/Ops Training L-24 mo.

Artemis

- Advanced Science Classroom
 - Surface and Orbital
- Fieldwork (5 locations)
 - Includes Science, Sci/Ops Sim
- Mission-specific Science
 - Science Traverse Planning
 - Payloads



ISS

- Crew Earth Observation
- ISS Specific Geo Science Training



Astronaut Training – Geology Science Training Flow



PHASE 1

Initial Training

- ✓ New Astronaut Classes
Laying the foundation

- JSC Classroom Training (80 hrs)
 - Geo-Science Fundamentals
 - Earth Systems
 - Planetary Science & Missions
- Field Training (80 hrs)
 - Established NM and AZ locations
 - Basic Geo Mapping & Traverse Planning
 - Sampling and Tools
- Expeditionary Components



PHASE 2

Building/Maintaining Skills

- ✓ Before/Between
Flight Assignment

Lunar Focused Training

- ✓ **Lunar Fundamentals**
 - Lunar Classroom Content (32 hrs)
 - Field Principles (Flagstaff Geo101) (28 hrs)
- ✓ **Lunar Integrated Testing**
 - Lunar Hardware & Ops Testing (NBL, ARGOS, RY)
 - Lunar Field Tests (e.g., JETT Tests)
- ✓ **Proficiency Training**
 - Analog Mission Opportunities
 - PANGAEA, CAVES, DRATS, NEEMO, etc.

PHASE 3

Assigned Crew Training

- ✓ Mission Science Training
Science/Ops Training L-24 mo.

Artemis

- Advanced Science Classroom
 - Surface and Orbital
 - Fieldwork (5 locations, 7 trips)
 - Includes Science & Sci/Ops Sims
 - Mission-specific Science
 - Science Traverse Planning
 - Payloads

Under development



- ✓ **ISS**
 - Crew Earth Observation
 - ISS Specific Geo Science Training



Astronaut Training – 2023-24 Accomplishments



PHASE 1

Initial Training

New Astronaut Classes
Laying the foundation

- JSC Classroom Training (80 hrs)
 - Geo-Science Fundamentals
 - Earth Systems
 - Planetary Science & Missions
- Field Training (80 hrs)
 - Established NM and AZ locations
 - Basic Geo Mapping & Traverse Planning
 - Sampling and tools
- Expeditionary Components



Establishing the Base

Completed training the 2021 class (Astronaut class 23).

- Geology, field methods, introduction to importance of sample curation, overview of NASA's planetary science.
- Included 6 field days in N. Arizona, with a capstone exercise – traverses, observations, and mapping

Starting to plan for 2025 class



Astronaut Training – 2023-24 Accomplishments



PHASE 2

Building/Maintaining Skills

Before/Between
Flight Assignment

Lunar Focused Training

Lunar Fundamentals

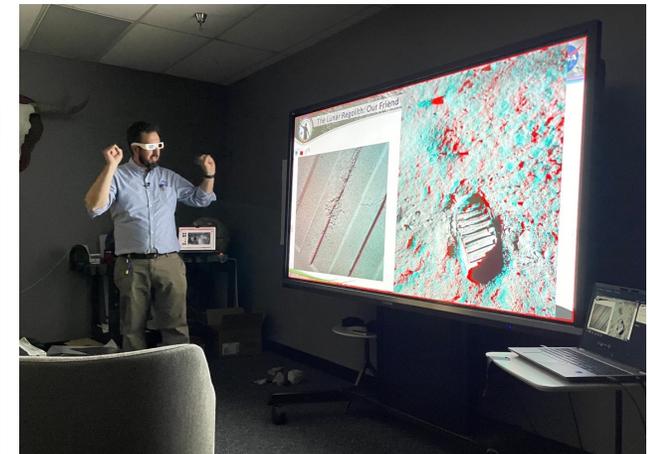
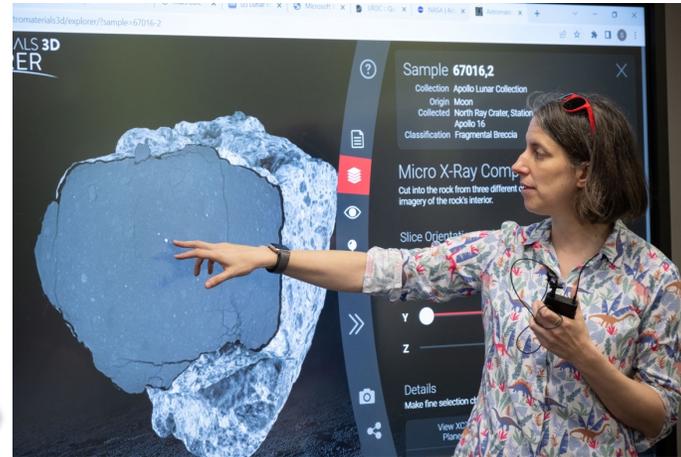
- Lunar Classroom Content (32 hrs) – 2 classes
- Field Principles (Flagstaff Geo101) - 2 classes

Lunar Integrated Testing

- Lunar Hardware & Ops Testing (NBL, ARGOS, Rockyard)
- Lunar Field Tests (e.g., JETT Tests)

Proficiency Training

- Analog Mission Opportunities
 - PANGAEA, NEEMO, DRATS, CAVES, etc.



Astronaut Training – 2023-24 Accomplishments: Artemis II



PHASE 3

Assigned Crew Training

Mission Specific
Science Training (Launch-24 mo)

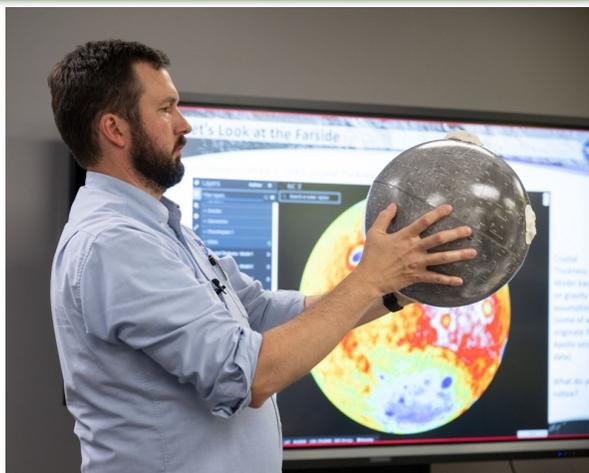
Artemis 2

- Lunar Fundamentals
- Fieldwork - Kamestastin
- Mission-specific Science/Ops
 - Planetary processes - Iceland
 - Orbital Observations
 - In work: Dedicated Sims



Artemis II - First opportunity since Apollo for humans to directly observe and document the Moon from a lunar orbit

- Lunar Fundamentals training: first crew training in lunar science in preparation for a lunar mission since 1972
 - Outstanding science questions about the Moon
 - Historical context of our growing knowledge about the Moon
 - Introduction to major geologic processes, lunar environment, lunar volatiles, and sample science
 - Introduction to new lunar data sets and tools for exploring the Moon
- Field training at Kamestastin Crater: impact crater processes and products
- Field training in Iceland: planetary processes, volatiles, feedback for Art. 3



Astronaut Training –Accomplishments: Artemis III



PHASE 3

Assigned Crew Training

Mission Specific
Science Training (Launch-24 mo)

Artemis

- Advanced Classroom (~80 hrs)
- Fieldwork (~5 locations)
- Dedicated Surface Ops Sims
- Mission-specific Science/Ops
 - Science Traverse Planning
 - Payloads
 - Orbital Observations



ISS

- Crew Earth Observation
- ISS Specific Geo Science Training



Work to Date

- Ready to deliver: Lunar Fundamentals
- Content in review: Advanced lunar science material (lunar processes, environment, samples, volatiles, and sample science)
- Robust field portfolio: plans, products (maps and data), field objectives, and logistics are in work
 - Cross-correlating science training objectives and required geology/EVA skills to field training plans and the Artemis 3 SDT
- Ongoing discussions with Training Office, xEVA trainers, and Crew Office.

Crew Earth Observations protocols and Artemis 2 operations → leveraged for Artemis 3 Orbital observations

Geology Training for the Artemis Community



- **Lunar Fundamentals**
 - 2 classes in 2023; 29 students (Astros, Flight Directors, Flight Operations personnel)
- **Geo101 (2.5 day field class): Geology and Field Methods for Engineers and Managers**
 - 78 students in 2023 and 2024
 - Since 2019: 166 students from across the science, management, engineering, and operations communities
 - Includes NASA Assoc. Administrators, Artemis 2 & 3 Mission Mangers, Flight Directors, Program Managers, EVA suit and tool engineers, EVA software developers, EVA trainers, training/testing facility managers, flight operations staff, human factors engineers, public affairs, ...
- **Joint EVA Test Team (JETT):** Collaborate with and leverage the efforts of hardware, operations, and integrated testing (e.g., JETT 5)
 - includes crew training, surface ops, science, EVA/flight control



Geology Training for Artemis: Summary



- NASA has been providing geology and field training to Astronaut Office continuously for more than 15 years
 - **All astronaut classes since 2009** have received the basic geology/field training
- We have regular opportunities to pull crew members into additional field expeditions and testing scenarios with science operations
- We are actively training the **Artemis II crew** for their observations of the Moon
- Development of advanced lunar science content and field training for Artemis lunar surface missions is well underway
 - Progressively integrates geology knowledge, field skills, and operational xEVA skills
- We are steadily filling in the geology & planetary science training “heat map” for NASA human spaceflight/exploration community





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<https://www.nasa.gov/humans-in-space/artemis/>

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