National Aeronautics and
Space Administration

Artemis III Science Definition Team Report Briefing

NAC HEOC/SC Joint Meeting

Renee Weber, MSFC, Committee co-chair

Jan. 14, 2021

THE MOON ENABLES SCIENTIFIC EXPLORATION

A CORNERSTONE
For Solar System science and exoplanet studies

A NATURAL LABORATORY
To study planetary processes and evolution

A TRAINING GROUND
To learn how to conduct scientific exploration from a planetary surface, working synergistically with crew and robotic explorers

AN OPPORTUNITY
To use infrastructure and resources associated with human exploration to leverage support for autonomous scientific investigations

Charge to the Committee

The Artemis III SDT was charted by Thomas Zurbuchen for NASA SMD. The Committee was charged to:

- Define compelling and executable science objectives for the Artemis III mission, the first human mission to the surface of the Moon in the 21st century.
- Assess objectives for the mission to achieve the science goals articulated by NASA including investigation approaches, key surface science activities, and potential inputs into the concept of operations.
- Submit a final report to the Planetary Science Division that contains prioritized science objectives for all aspects of the Artemis III mission, including sampling strategies and science goals and priorities of deployable instrument packages.

Schedule

- White Papers due September 8
- First meeting September 10
- Town Hall #1 September 14 (LEAG meeting)
- Draft report released October 14
- Town Hall #2 October 22
- Public comments deadline October 26
- Final report submitted November 13 & released publicly on Dec. 7th

Artemis III Science Definition Team Report

(available at www.nasa.gov/reports)

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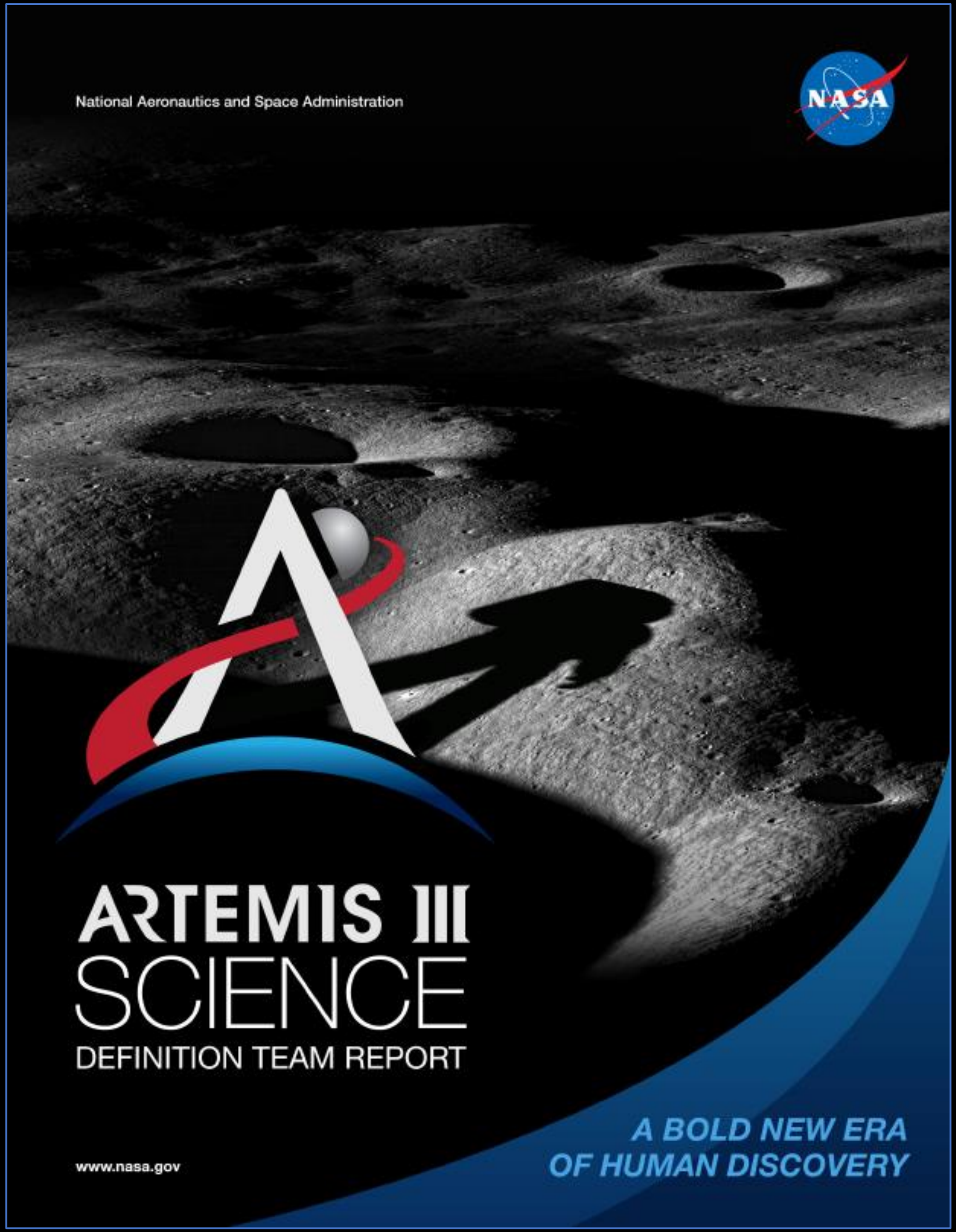
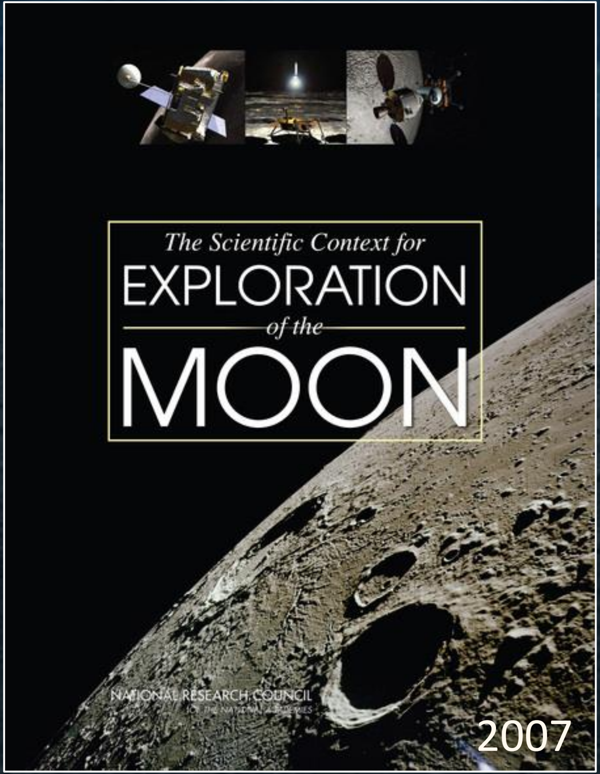
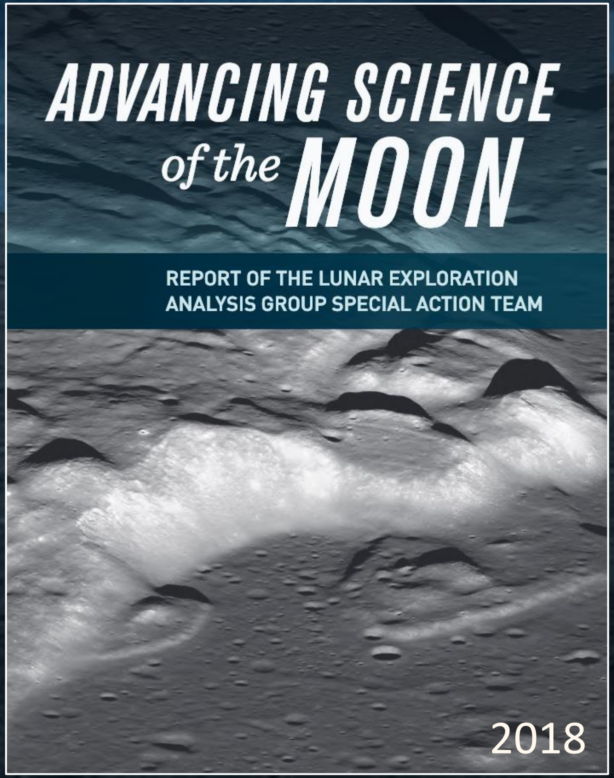
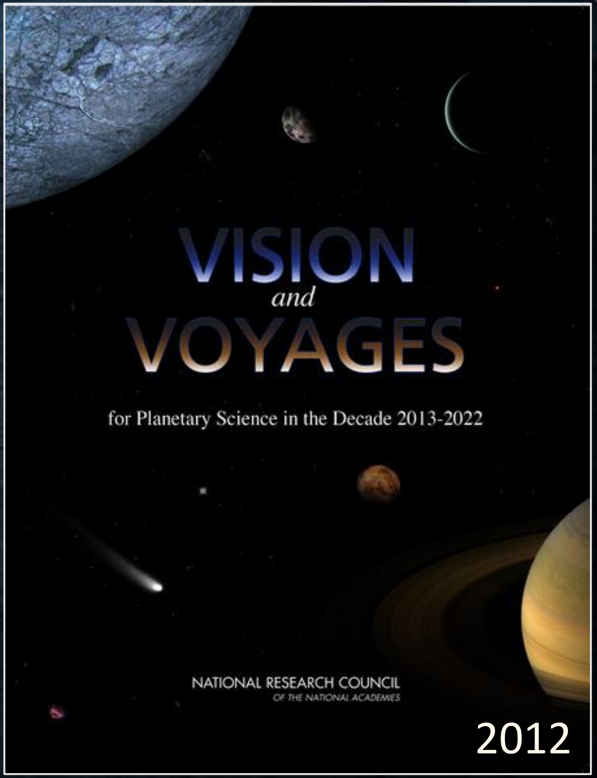


Guiding Community Documents

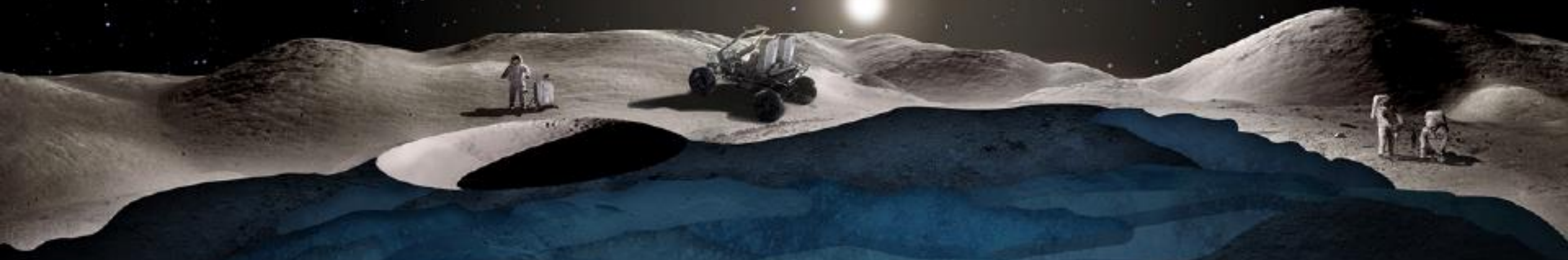






… as well as community-submitted white papers and draft report comments

Artemis Science Objectives and Traceability to Science Priorities



NASA HQ’s Artemis Plan laid out seven Science Objectives:

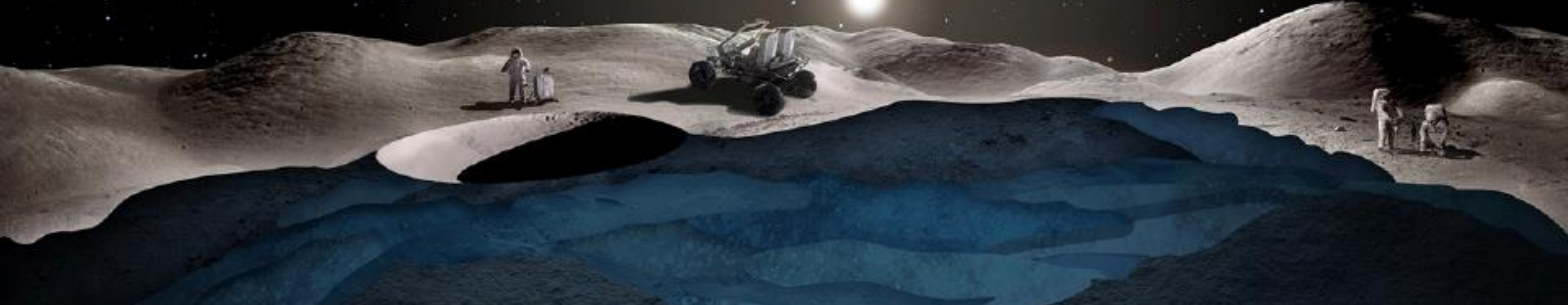
- Objective 1: Understanding Planetary Processes
- Objective 2: Understanding the Character and Origin of Lunar Volatiles
- Objective 3: Interpreting the Impact History of the Earth-Moon system
- Objective 4: Revealing the Record of the Ancient Sun and Our Astronomical Environment
- Objective 5: Observing the Universe and the Local Space Environment from a Unique Location
- Objective 6: Conducting Experimental Science in the Lunar Environment
- Objective 7: Investigating and Mitigating Exploration Risks

The SDT was charged with expanding upon science these Objectives. We chose to map science Goals (areas of research) down to Investigations (specific activities undertaken to address Goals).

Candidate Program

- We constructed a candidate program that captures the highest-priority science for Artemis III and provides the greatest feed-forward to follow-on missions and the build-up to the Artemis Base Camp
- Our cohesive program contains a mix of activities encompassing
  - Field geology and sample return
    - Contingency sample (bulk)
    - Small clast (rake)
    - Large clast (hand)
    - Sealed core (drill)
    - Sealed surface (bulk)
    - Regolith surface (CSSD)
  - *In situ* measurements and long-lived experiments
    - Volatile monitoring
    - Environmental monitoring
    - Deployed geophysics
    - Geochemistry/mineralogy
    - Geotechnical properties
    - Traverse geophysics
- A more detailed mission operations plan based off this program will need to be developed by NASA when HLS system capabilities, a landing site, and other architectural details come into sharper focus

SDT Report Recommendations



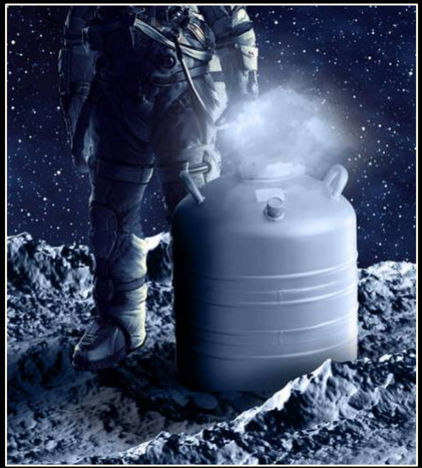
The SDT report contains 15 major findings and accompanying recommendations to NASA for actions to address each finding, encompassing:

- Crew training
- Coordinated sampling strategies
- Enabling capabilities (*e.g.*, needed technology development)
- Artemis program architecture
- Science implementation strategy
- Cartographic considerations
- Landing site selection criteria

SDT Report Recommendations (highlights)

1. Value of geology training

The optimal sample return program is built upon geologic context observations made by well-trained astronauts, aided by modern tools and real-time communication with scientists on Earth.



2. Importance of samples (particularly sealed samples)

The return of hermetically sealed volatile bearing samples from the lunar south polar region can preserve lunar volatile signatures within the sample containment system and prevent gas-exposure hazards in the crew cabin.

3. Importance of deployed experiments

The Artemis III mission is an opportunity lost if the first of a series of geophysical and environmental network nodes is not deployed, which can be augmented by later missions (both crewed and robotic).

4. Need for essential technology development

Our campaign of field geology, sample return, in-situ measurements and long-lived experiments requires supporting technology development and architectural elements, including

- Pre-deployed assets (e.g. via CLPS)
- Surface mobility (e.g. LTV)
- Sustained power and communication

Artemis III SDT Membership

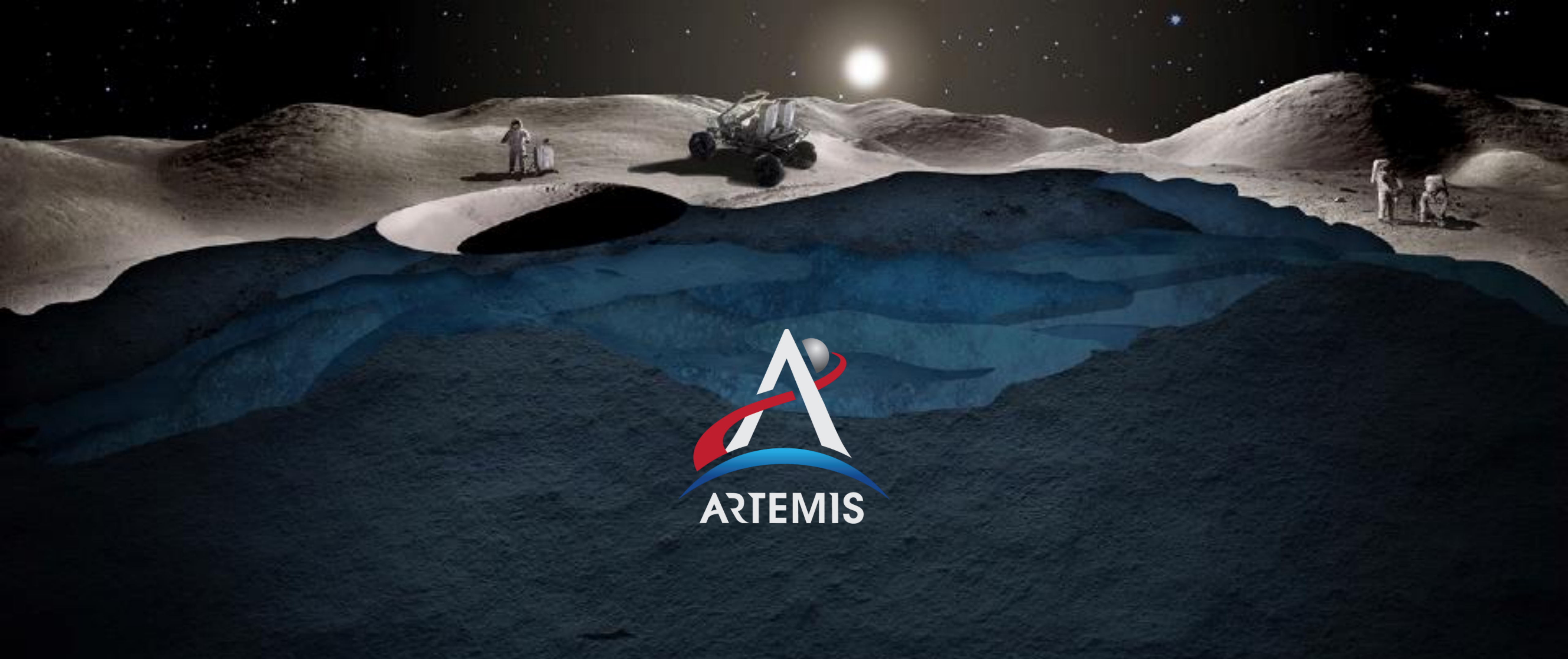
Co-chairs
- Renee Weber, NASA MSFC
- Barbara Cohen, NASA GSFC
- Sam Lawrence, NASA JSC

Community consultants
- Amy Fagan, LEAG Chair
- Carlé Pieters, SSERVI Chief Scientist
- Juliane Gross, CAPTEM Lunar Sample Subcommittee Chair

Executive Secretary
- Amanda Nahm, SMD PSD

Civil Servant Members
- Jeremy Boyce, NASA JSC
- Michael Collier, NASA GSFC
- Caleb Fassett, NASA MSFC
- Lisa Gaddis, USGS Astrogeology (now at LPI)
- John Gruener, NASA JSC
- Jennifer Heldmann, NASA ARC
- Noah Petro, NASA GSFC
- Kelsey Young, NASA GSFC

- ***Ex officio observers:*** Sarah Noble (PSD), Debra Needham (ESSIO), James Spann (HPD), Kevin Sato (BPS), Jake Bleacher (HEOMD), Julie Mitchell/Francis McCubbin (JSC curation), David Draper (OCS)



BACKUP (report recommendations)

Recommendations: Crew Training

- Astronauts should participate in an Apollo-style course in geology and planetary science, including both field and classroom components, in order to provide optimal *in situ* geologic characterization of lunar sample collection sites. A dedicated team of scientists should serve in an Earth-based Artemis III Science Mission Center with real-time two-way audio and one-way video between the crew and the Science Mission Center.
- Astronauts should be trained and equipped to collect a variety of surface and sub-surface samples. NASA should plan to return total sample masses in excess of previous lunar sample return missions.

Recommendations: Coordinated sampling strategies

- NASA should ensure that sample collection and *in situ* measurements are carefully choreographed to maximize science return. Examples of such coordination include the characterization of rock samples with *in situ* instrumentation to aid in prioritization of samples selected for Earth return, and *in situ* volatile measurements made in conjunction with sample collection to characterize volatile losses from sample collection, transport, and/or curation, and efforts to provide "ground truth" for orbital remote sensing datasets.
- NASA should ensure that *in situ* imaging and assessment capability is available to crews during extra-vehicular activity (EVA) to document site characteristics, sampling, and instrument deployment.

Recommendations: Enabling capabilities

- NASA should develop lightweight, double-sealed vacuum containers to return volatile bearing lunar samples to Earth.
- NASA should develop and implement hardware and operations to return a subset of samples at cryogenic temperatures (low enough to preserve water ice and other volatiles of interest) in the solid state throughout the journey from the lunar surface to Earth-based laboratories. Cryogenic sample return will increase the scientific fidelity of sample analyses of volatiles and ices.
- Minimizing the mass penalty for both vacuum-sealed and cryogenic sample return results in increased scientific yield of the mission because more mass can be allocated to the lunar samples instead of the sampling hardware.

Report recommendations: Enabling capabilities

- The Artemis III mission is an opportunity lost if the first of a series of geophysical and environmental network nodes is not deployed. The Artemis III node can be augmented by both robotic and human future missions, thus building towards a global network.
- While incremental science can be obtained with short-lived experiments, NASA should pursue solutions for long-lived power and communications to enable networked operation of ALSEP-like packages at multiple landing sites, as needed, to enable meaningful progress on many Artemis III science goals and feeding forward to future Artemis missions.
- Geodetic monitoring via Earth-based laser ranging requires no lunar surface power or communication to function and hence will provide science return even in the absence of such capabilities. We advocate for geodetic monitoring capability to be prioritized for Artemis III.

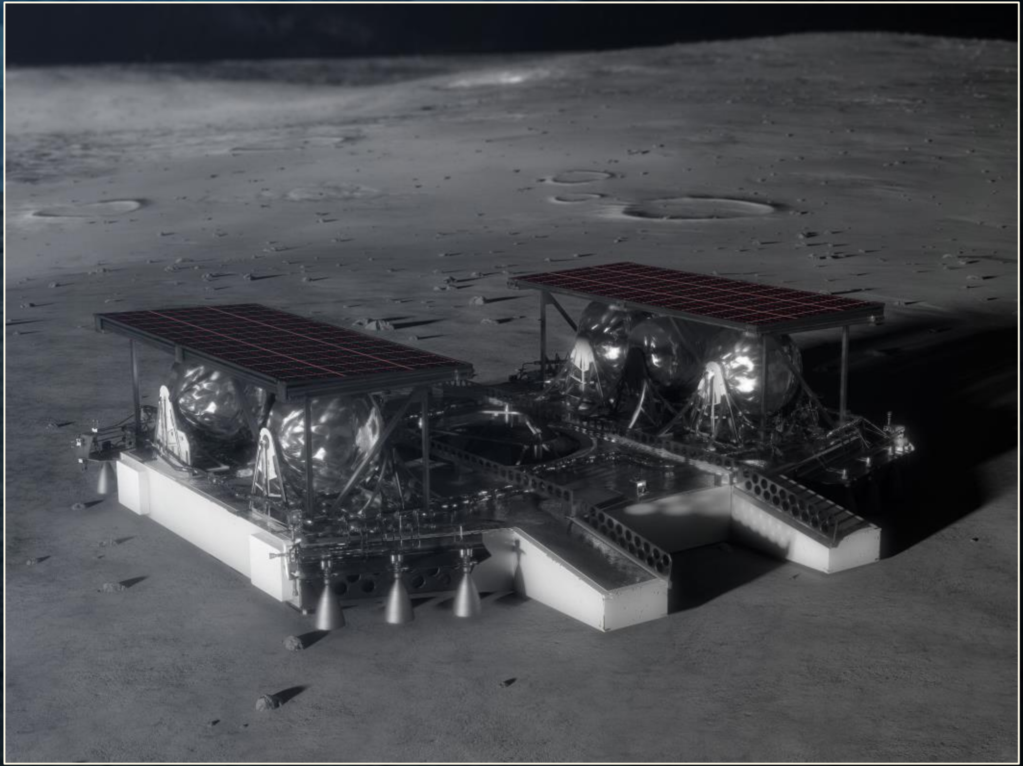
Recommendations: Enabling capabilities

We recommend NASA provides 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).

This requires prior establishment of high bandwidth communication that is capable of extensive real-time data transmission to accommodate use of valuable measurements from modern sensors.

Recommendations: Artemis program architecture

- NASA should solicit the development of instruments that are capable of addressing more than one measurement need and/or science Investigation.
- NASA should consider pre-positioning science assets in the vicinity of the Artemis III landing site. This could consist of an inert cache of tools/instruments to be accessed by crew upon arrival, and/or one or more instrumented landers or rovers for environmental monitoring.
- NASA should include a rover or other mobility solution for crew use on the lunar surface starting as early in the Artemis program as possible, ideally for Artemis III.



Report recommendations: Science implementation strategies

- A standing working group comprising scientific leadership of the Artemis program in SMD should be established and closely coordinate with representatives of STMD and HEOMD to ensure clear lines of communication and facilitate program implementation.
- NASA's existing Program Analysis Groups, such as LEAG and CAPTEM, serve an important role synthesizing community input across diverse stakeholders in the engineering, science, and commercial communities, and should be leveraged as the Artemis program continues to promote external community engagement to the fullest practical extent.

LEAG
LUNAR • EXPLORATION • ANALYSIS • GROUP

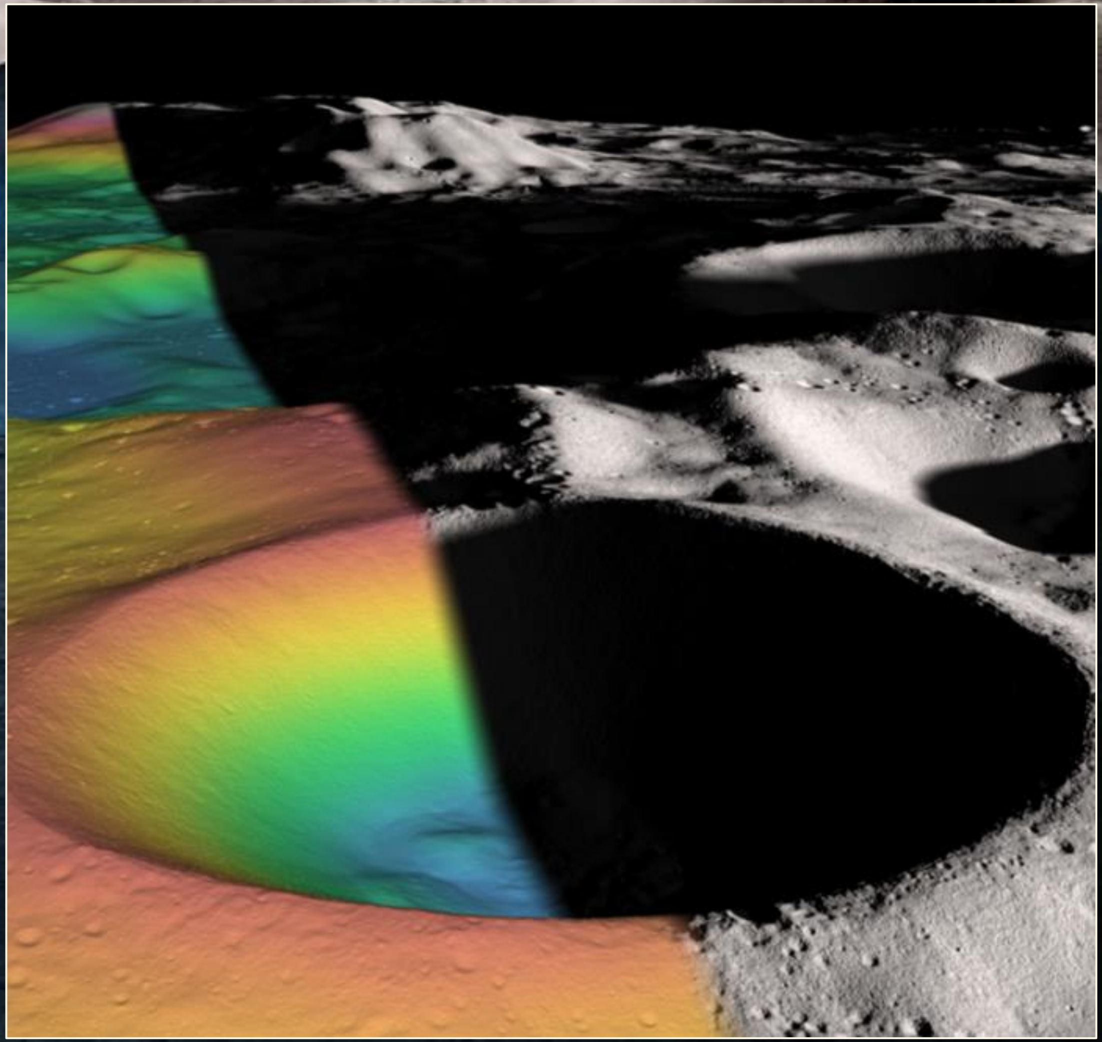
CAPTEM
Curation and Analysis Planning
Team for Extra-terrestrial Materials

Report recommendations: Cartographic considerations

- Any needed updates to the standard lunar geodetic coordinate reference frame (e.g., currently used by LRO) should be identified in 2021, and foundational products should be mapped onto it and/or developed to use it directly. Establishing a standardized coordinate reference frames can significantly improve data reliability and reduce the risk of errors.
- Standards for cartographic and time controls for surface measurements (photographs, video, and surface measurements) should be defined in the near term so that those standards can be implemented in instrument development. This should also include high-fidelity time coding for all surface measurements time-synced with Earth in UTC.
- We recommend maintaining sufficient funding to the Planetary Data System (PDS) to maintain the online tools needed to search, access, and use lunar data.

Report recommendations: Cartographic considerations

- To support the level of accuracy and precision needed for landing and surface operations, new cartographic products, including mosaics and topographic models, for the south pole should be developed using the highest quality data available and using the standard (possibly updated) lunar geodetic coordinate reference frame.
- New derivation of higher-order data products from existing missions should also be supported where needed for Artemis III. For example, it is vital that more detailed geologic mapping of candidate landing sites be accomplished at a scale similar to what was done in preparation for Apollo.

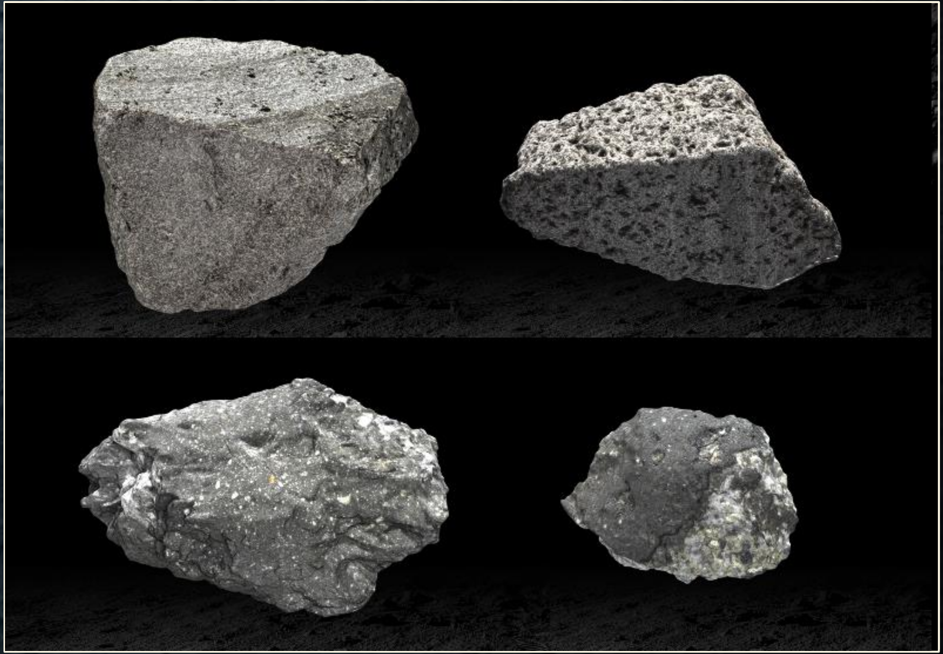


Report recommendations: Landing site considerations

The scientific return of the Artemis III mission will be intrinsically linked to the Artemis III landing site.

The SDT suggested the following factors be considered in the Artemis III site selection process in order to fully inform the ultimate selection of the Artemis III landing site, in addition to other physiographic parameters such as block abundance, crater frequency, and slope:

- Sufficient illumination for long-duration solar power stations to enable long-lived surface experiments (if solar power is used);
- Availability of a range of sizes of craters for radial traverses and sampling, which will inform our understanding of the impact process;
- Comprehensive sampling which will inform our understanding of the complex geology of the landing site and its link to both surface and internal processes;



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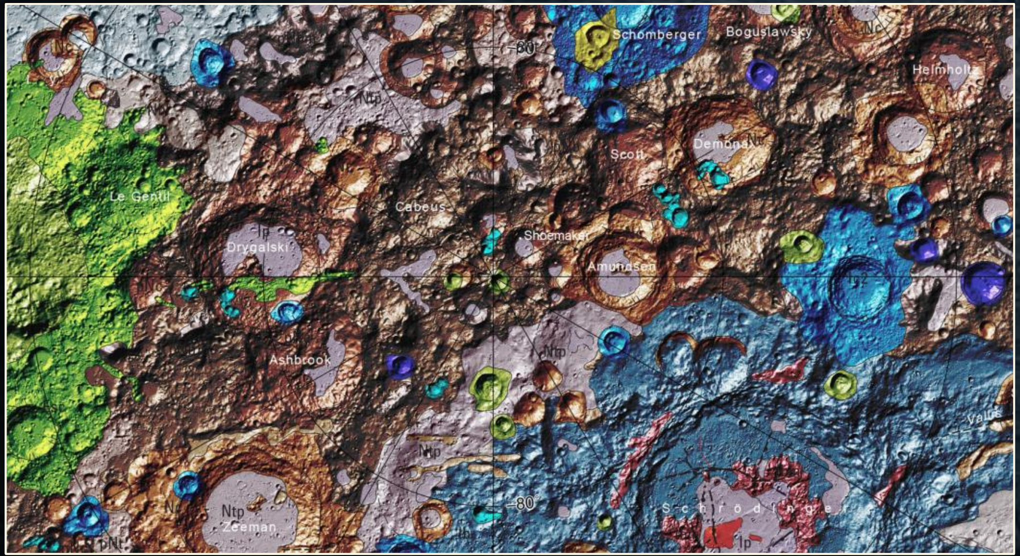

- Accessibility of larger blocks to enable sampling of large crater ejecta;
- Proximity and accessibility of mostly or permanently shadowed regions to understand volatile processes;
- Proximity to multiple geologic units of differing time-stratigraphic age;
- Proximity to geologic units that enable specific, high-priority investigations (SPA and PSRs)

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