National Aeronautics and Space Administration

NASA

EXPLORE SCIENCE

Exploration Science Strategy and Integration Office (ESSIO)

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Deputy Associate Administrator for Exploration
Science Mission Directorate

Planetary Advisory Committee
March 1, 2021

Vision

Define and lead the science strategy for Artemis and Moon to Mars

Exploration science integration between SMD Divisions, SMD/STMD/HEOMD, other government agencies, and international partners

Promote a lunar economy to produce rapid, frequent, and affordable access to the lunar surface and cislunar space

ESSIO Organization Chart

Dr. Joel Kearns
Deputy Associate Administrator for Exploration

Resource Analyst: Renee Leck
Office Support: Mackenzie Howard
Admin. Assistant: Wendy Tuttle

Associate DAAX (Vacant)

Program Executives

- **Jay Jenkins**

- **Angela Melito**

- **Dr. Zachary Pirtle**

Program Scientists

- **Dr. Brad Bailey**

- **Dr. Debra Needham**

- **Dr. Sarah Noble**

- **Dr. Ryan Watkins**

PSD

- PESTO (NPLP & DALI):
  - Ryan Stephan
- PMPO (LRO & LSITP)

JSC

- CLPS Office:
  - Chris Culbert

Outline

- Artemis Science Integration
  - Science Definition Team (SDT) report
  - Lunar Surface Science Workshops
- CLPS update
- Science updates
  - LRO
  - ANGSA

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 these Objectives using community documents to guide them.

Artemis III Science Definition Team Report

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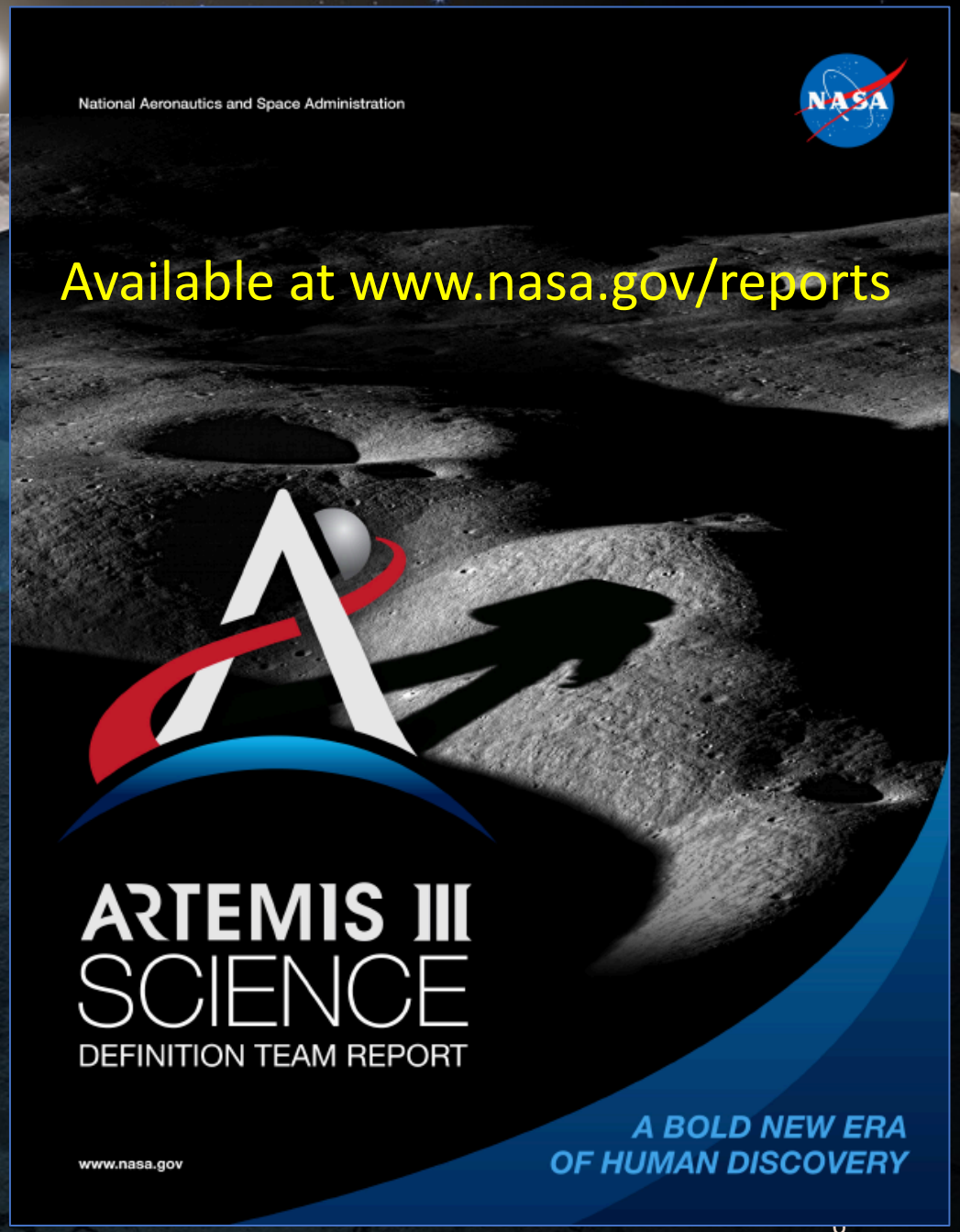


The SDT constructed a notional program that captures the highest-priority science for the first human landing and provides the greatest feed-forward to follow-on missions and the build-up to the Artemis Base Camp. This program contains three cohesive elements:

Sample collection and return	In situ and field science	Deployed experiments
Contingency sample (bulk) Small clast (rake) Large clast (hand) Sealed core (drill) Sealed surface (bulk) Regolith surface (CSSD)	Volatile monitoring Environmental monitoring Geochemistry/mineralogy Geotechnical properties Traverse geophysics	Volatile monitoring Environmental monitoring Geophysics

A successful surface mission hinges on addressing all three program elements

- The team did a great job under difficult circumstances and a very tight timeline. We are also grateful for the white papers and feedback from the lunar community.
- The SDT focused specifically on the needs of the first human landing, but the report has implications for the entire Artemis program
- The results are being briefed across NASA to help guide development and decision making to accommodate science needs
- We continue to seek input from the community through the Lunar Surface Science Workshops and other opportunities

Lunar Surface Science Workshops

- Series of ~monthly 1-day workshops to get community input on our highest priority questions.
- Was originally scoped as a 3-day in-person workshop scheduled for last April, canceled due to COVID.
- Jointly organized by PSD/ESSIO/HEO/OCS with support from SSERVI and the LPI
- Many of the early sessions relied on abstracts submitted to the original workshop, but for certain topics we have had additional abstract calls
- Getting ~200-300 participants per session. Strong participation from both inside and outside NASA, including internationals
- Science community input is being incorporated into and driving discussions within the Artemis program

Lunar Surface Science Workshop Schedule

- Community input and early integration of science into the exploration architecture are essential to maximizing the science return from the Artemis missions.
- We appreciate the effort and time the community has put into these sessions
- Talks are recorded and discussion notes organized into deliverable products

Previous sessions:

- Overview and Background (May)
- Tools and Instruments (May)
- Volatiles (July)
- Samples (July)
- Dust and Regolith (August)
- Planetary Protection (September)
- The Value of Mobility (October)
- Foundational Data Products (November)
- Space Biology – joint with BPS (January)
- Structuring Real-Time Science Support of Artemis Crewed Operations (February)

Upcoming Sessions:

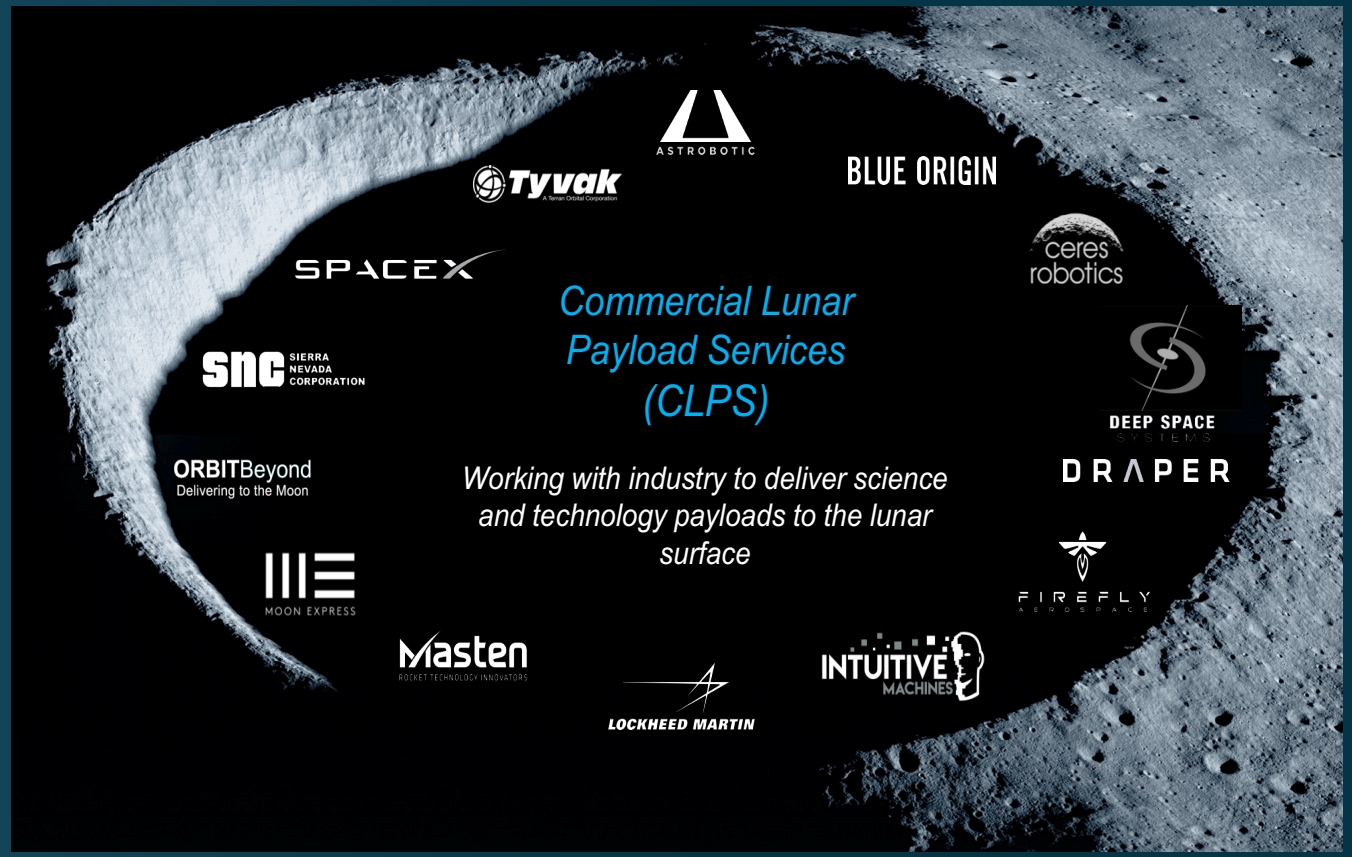
- **April 29th – Updates from HQ**
- Physical Sciences (Summer/Fall 2021)
- Fundamental Physics (Summer/Fall 2021)

https://lunarscience.arc.nasa.gov/lssw

Commercial Lunar Payload Services (CLPS)

Goal: Utilize commercial end-to-end delivery services to enable access to the lunar surface

- Deliveries initiated using a Task Order (TO)
  - Any of the 14 companies on the catalog can respond to a task order
  - Expected Task Order cadence of 2 per year
- Task Orders list what NASA wants delivered and any constraints
  - E.g., landing site, specific needs of instruments
- First 6 lunar surface deliveries awarded with deliveries commencing in 2021
  - 2021: Non-polar delivery (Astrobotic & Intuitive Machines) – TO 2A & 2B
  - 2022: Polar delivery (Masten) – TO 19C
  - 2022: PRIME-1 (Intuitive Machines)
  - 2023: Crisium (Firefly Aerospace) – TO 19D
  - 2023: Volatiles Investigating Polar Exploration Rover (VIPER) to Moon's south polar region (Astrobotic) – TO 20A

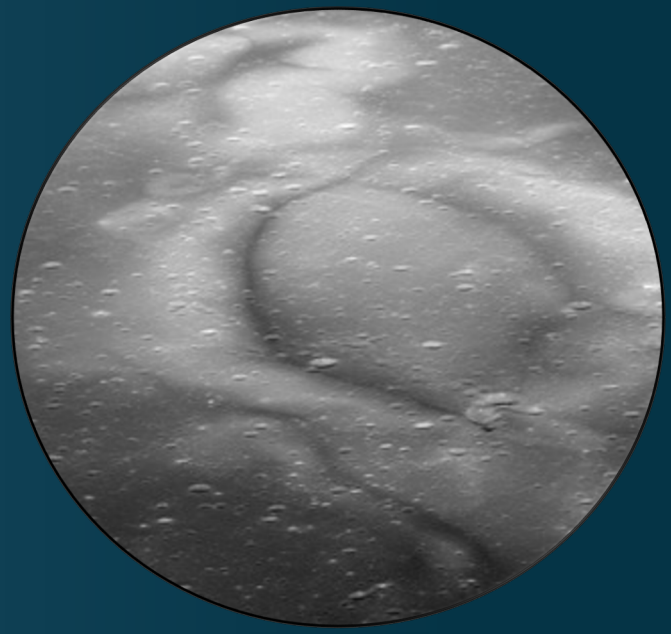


Innovative Science Deliveries to the Moon

SCHEDULE-DRIVEN

Get to the lunar surface quickly and conduct science

NPLP, LSITP



SCIENCE-DRIVEN

Achieve high-priority science objectives across the lunar surface

DALI, PRISM

DECADAL-CALIBER SCIENCE

Promote development of advanced technology that enhances science return across the lunar surface

PRISM – Science-driven payloads

- We expect PRISM calls to occur on a regular cadence
  - PRISM instruments will feed the manifests for Task Orders for CLPS deliveries from late 2023 onwards
  - The first call requests science investigations utilizing multi-instrument suites to maximize the science for named locations
  - High-value ‘location agnostic’ and campaign science instruments may be called for in upcoming PRISM solicitations
- The locations are high science-value targets, as discussed in numerous community documents, and where significant progress can be made utilizing CLPS platforms. The locations for this call are:
    - ❖ Reiner Gamma magnetic anomaly (lunar swirl)
    - ❖ Schrödinger far side basin impact melt
- The destinations for these two deliveries were announced in July, allowing PIs time to prepare to propose science optimized for those locations
  - Step 1 proposals were received in December 2020, and step 2 proposals were received February 3, 2021

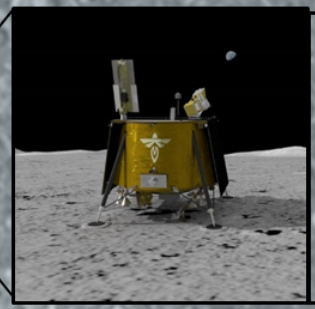
CLPS Deliveries 2021-2024

Delivery Site:
Oceanus Procellarum
Provider:
Intuitive Machines
Task Order (TO) 2 | 2021

Delivery Site:
Lacus Mortis
Provider:
Astrobotic
TO2 | 2021

Delivery Site:
Lunar Pole
Provider:
Astrobotic
VIPER | 2023

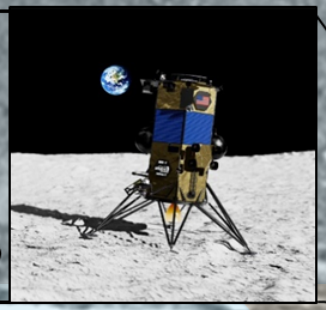
Delivery Site:
Reiner Gamma
Provider: TBD
PRISM-1a | 2023



Delivery Site:
Mare Crisium
Provider:
Firefly
TO19D | 2023

Delivery Site:
Schrödinger Basin
Provider: TBD
PRISM-1b | 2024

Delivery Site:
South Pole
Provider:
Intuitive Machines
TO PRIME-1 | 2022



Delivery Site:
South Pole
Provider:
Masten
TO19C | 2022

Supporting Other NASA Mission Directorates

- CLPS is a NASA resource and we have been looking at maximizing its value to the agency
  - MOU with HEOMD and STMD to enable maximum utilization of each SMD-led CLPS delivery
    - Flying other MDs payloads
    - Data buys
  - SMD also receives payload space on CLPS deliveries led by each of the other MDs

- Enabling CLPS deliveries led by other MDs
  - PRIME-1 (STMD) Task Order for the delivery of STMD's PRIME-1 instrument to a polar region

- Partnerships and Payloads with Other Government Agencies

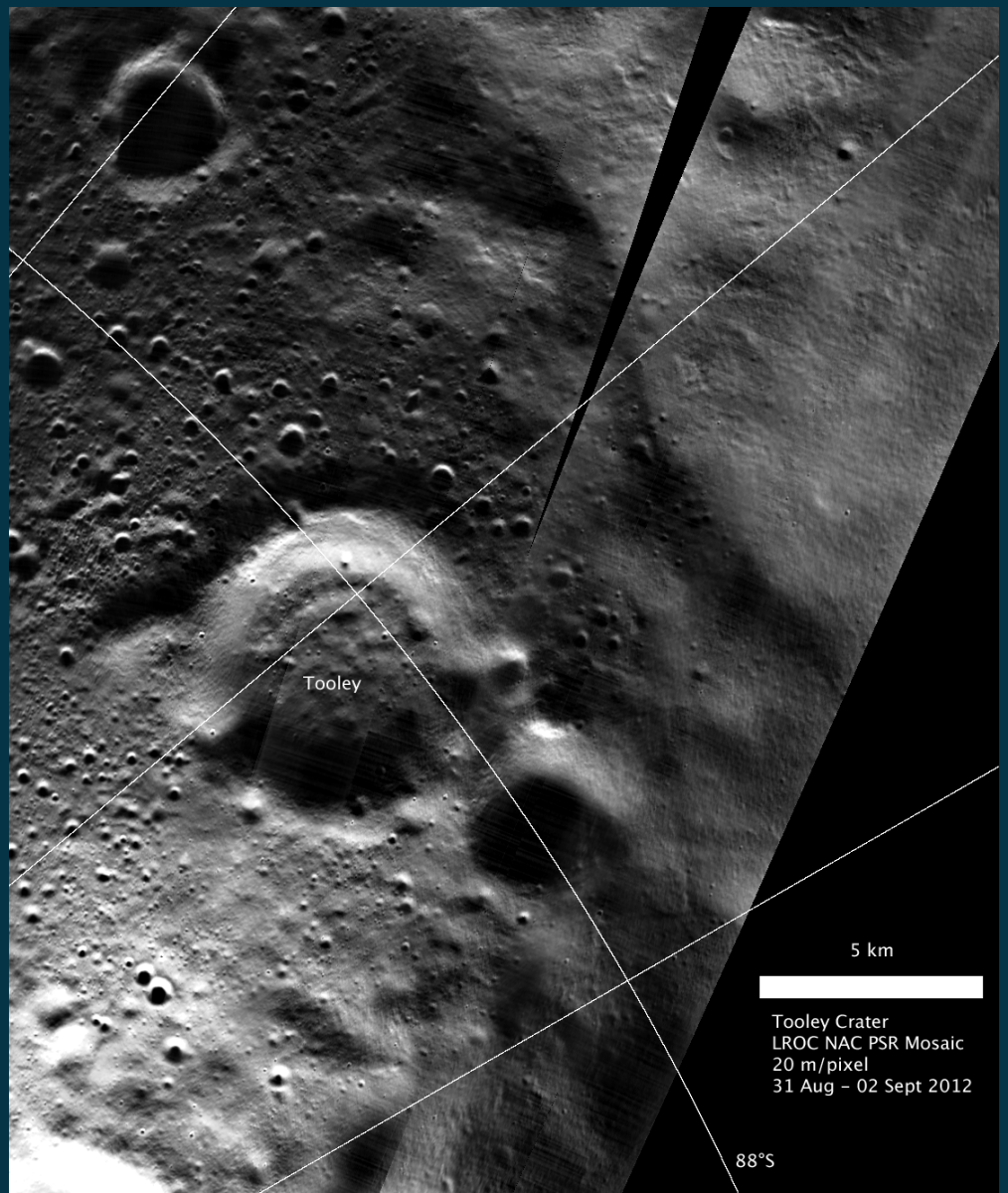
Examples of International Interest

- Canadian Space Agency (CSA)
  - Small rover with a US payload (~3kg) delivered via CLPS
  - Other science payloads
- European Space Agency (ESA)
  - Large Retroreflector on PRISM-1a delivery to Reiner Gamma
  - PROSPECT volatiles investigation package to polar region
- Japan Aerospace Exploration Agency (JAXA)
  - US contribution of Neutron Spectrometer to LuPEX Rover
  - Small retroreflector on SLIM
  - Other science payloads
- Korea (KASI)
  - Four science payloads across multiple deliveries
- Other countries expressing interest: Australia, Italy, Luxembourg, Monaco, Poland, Switzerland, United Arab Emirates, United Kingdom

Lunar Reconnaissance Orbiter

Still going strong after more than 11 years in orbit!

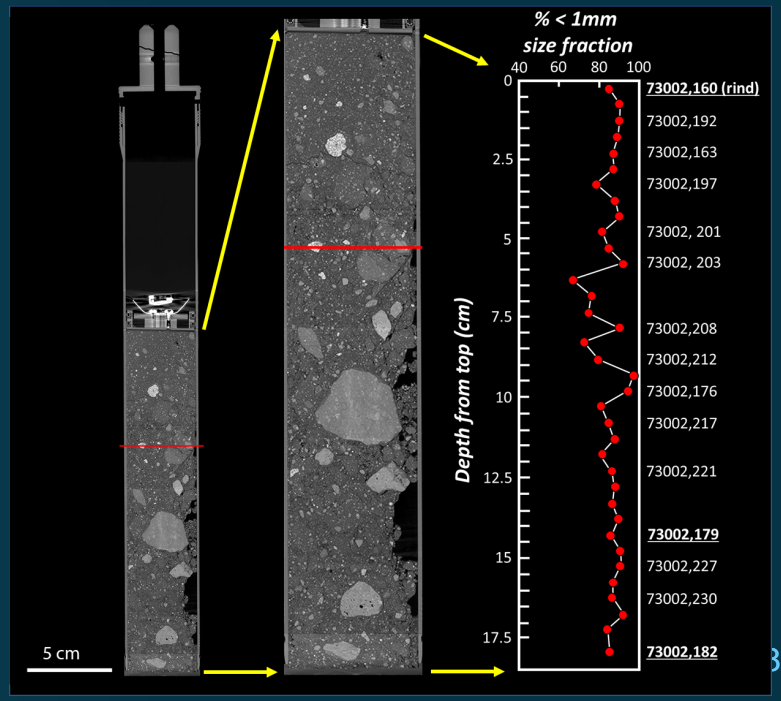
After starting its life as an Exploration asset under ESMD, then transitioning to a science workhorse that has revolutionized our global understanding of the Moon, LRO is once again being called upon to serve our exploration needs by providing input to landing site characterization for Artemis and CLPS landers.

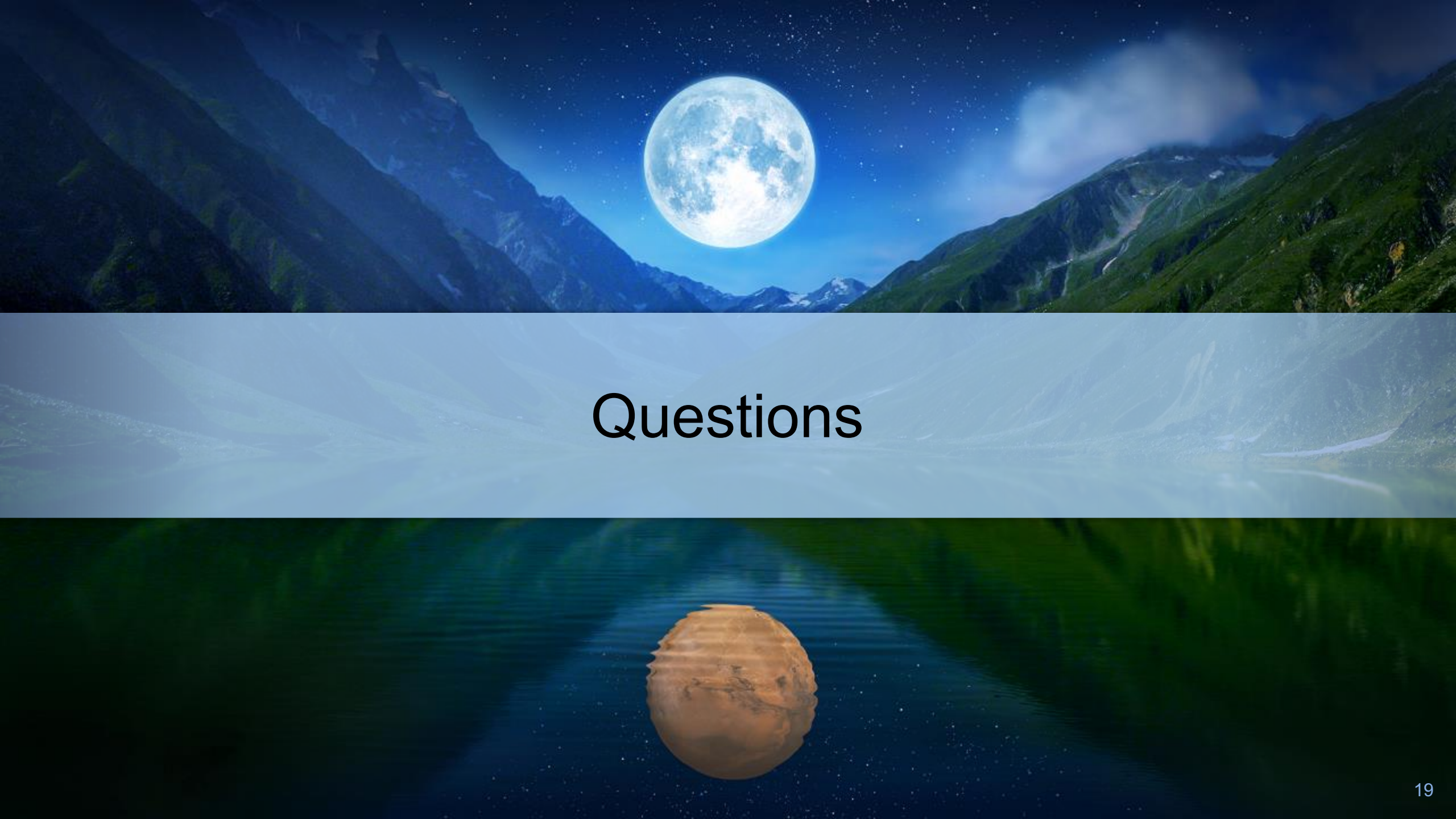


Tooley crater is a 7 km crater in a permanently shadowed region of Shoemaker crater near the lunar south pole.

ANGSA progress

- Upper double drive tube 73002 (430g) extruded into a N atmosphere glovebox.
- Multi-generational preliminary examination team carried out. Prepares a new generation for samples return by Artemis.
- First samples were sent off for analysis just prior to COVID-19 closing of curation and labs. (organics, stable isotopes D/H, O, Cl).
- Due to COVID-19 there was a delay in getting material out to labs. Starting in November 2020 material started reaching labs.
- In a collaboration between ANGSA team members in the USA and ESA a gas extraction tool has been developed for opening Core Sample Vacuum Container (CSVC) 73001. Tool will be used in summer of 2021 to capture and analyze lunar gases.
- First results reported at AGU
- Special session at LPSC





Questions

Backup

2021 CLPS Delivery Manifests

Payloads largely selected from NASA Provided Lunar Payloads (NPLP)

Astrobotic

- Surface Exosphere Alterations by Landers (SEAL)
- Photovoltac Investigation on Lunar Surface (PILS)
- Near-Infrared Volatile Spectrometer System (NIRVSS)
- Mass Spectrometer Observing Lunar Operations (Msolo)
- PROSPECT Ion-Trap Mass Spectrometer for Lunar Surface Volatiles (PITMS)
- Linear Energy Transfer Spectrometer (LETS)
- Neutron Spectrometer System (NSS)
- Neutron Measurements at the Lunar Surface (NMLS)
- Fluxgate Magnetometer (MAG)
- Navigation Doppler Lidar for Precise Velocity and Range Sensing (NDL)

Key

- Science
- Technology
- Exploration
- HEOMD/STMD

Intuitive Machines

- Lunar Node 1 Navigation Demonstrator (LN-1)
- Stereo Cameras for Lunar Plume-Surface Studies (SCALPSS)
- Low-frequency Radio Observations from the Near Side Lunar Surface (ROLSES)
- Navigation Doppler Lidar for Precise Velocity and Range Sensing (NDL)
- Radio Frequency Mass Gauge (RFMG)

2022 CLPS Delivery Manifests

Payloads largely selected from Lunar Surface Instrument and Technology Payloads (LSITP)

Masten Space Systems - South Pole

- Sample Acquisition, Morphology Filtering & Probing of Regolith (SAMPLR)
- Camera System for lunar science on commercial vehicles (Heimdall)
- Near-Infrared Volatile Spectrometer System (NIRVSS)
- Linear Energy Transfer Spectrometer (LETS)
- Lunar Compact Infrared Imaging System (L-CIRiS)
- Moon Rover with Exploration Autonomy (Moon Ranger)
- Laser Retroreflector
- Neutron Spectrometer System (NSS) – Deployed on Moon Ranger
- Mass Spectrometer Observing Lunar Operations (Msolo)

Key

- Science
- Technology
- Exploration

Firefly Aerospace - Crisium

- Lunar Environment Heliophysics X-Ray Imager (LEXI)
- Next Generation Lunar Retroreflectors (NGLR)
- Radiation Tolerant Computer System
- Sample Acquisition & Delivery System for Instruments & Sample Return (PlanetVac)
- Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity (LISTER)
- Lunar Magnetotelluric Sounder (LMS)
- Regolith Adherence Characterization (RAC)