Exploration Science Strategy and Integration Office (ESSIO) formulates & executes an integrated strategy for exploration science

Implementation Strategy

- Develop lunar surface science instruments
- Use commercial companies to deliver payloads to the Moon
- Develop mobility systems to expand and enhance science investigations on the surface
- Leverage international partnerships for additional opportunities (e.g., instruments, rovers)
- Obtain new scientific data from lunar orbit using smallsats
- Use new human exploration systems, such as Gateway and human landing system, to enable science
- Lead the science mission planning for humans on the lunar surface
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
  - Any of the 14 companies on the catalog can respond to a task order
  - Expected Task Order cadence of 2 per year
- Task order lists what NASA wants delivered, and any constraints
  - E.g., landing site, specific needs of instruments
- First 4 lunar surface delivery task orders awarded with deliveries commencing in 2021
  - 2021: Non-polar delivery (Astrobotic and Intuitive Machines) – TO 2A & 2B
  - 2022: Polar delivery (Masten) – TO 19C
  - 2023: Volatiles Investigating Polar Exploration Rover (VIPER) to Moon’s south polar region (Astrobotic) – TO 20A
CLPS Deliveries & Future Payloads

Payloads and Research Investigations for the Surface of the Moon (PRISM)

- PRISM RFI: 238 Responses from the community received
  - Catalog of potential instruments
- PRISM stage-2 solicitations will state location for each delivery, allowing PIs to propose science optimized for those locations
  - High-value ‘location agnostic’ instruments will be called for in PRISM-2
  - International contributions to PRISM investigations may be included at up to 30% the total cost of the investigation
  - PRISM instruments will feed the manifests for Task Orders for deliveries from late 2023 onwards
  - Can be expanded to include orbital payloads
- July 20 community announcement provided a heads-up on the first Stage 2 call and also identified the destinations for the 2 deliveries
  - Reiner Gamma magnetic anomaly (lunar swirl)
  - Schrödinger farside basin impact melt
- Payloads from other NASA mission directorates are also incorporated into Task Orders
CLPS Deliveries 2021-2024

Delivery Site: **Mare Serenitatis**  
Provider: **Intuitive Machines**  
Task Order (TO) 2 | 2021

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

Delivery Site: **South Pole**  
Provider: **Astrobotic**  
**VIPER** | 2023

Delivery Site: **Mare Crisium**  
Provider: TBD  
**TO19D** | 2023

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

Delivery Site: **South Pole**  
Provider: **Masten**  
**TO19C** | 2022
TO2 – INTUITIVE MACHINES
October 2021 launch

• Interface Control Documents virtually done; working through details of Payload Integration Plans
• Environmental test plan baselined
TO2 – ASTROBOTIC TECHNOLOGY
July 2021 Launch

- New facility for Astrobotic is complete
- Most recent milestone in Sept ’20
December 2022 Launch

• Held payload kick off meeting; regular interactions going well
• Selected their launch vehicle provider
• Payload requirements draft complete and sent to the instrument Principal Investigators
TO20A – Astrobotic Technology 2023 Launch

- Strong start to understanding interfaces and concept of operations
- Astrobotic list of VIPER deliverables communicated and accepted
- Established 3x per week meeting cadence between Payload Integration Manager, Astrobotic, and VIPER team
The Moon Enables Scientific Exploration

A CORNERSTONE
For Solar System science and exoplanet studies

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

A NATURAL LABORATORY
To study planetary processes and evolution

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

- Study of Planetary Processes
- Understanding Volatile Cycles
- Impact History of Earth-Moon System
- Record of the Ancient Sun
- Fundamental Lunar Science
- Platform to Study the Universe
ROLSES: Low-frequency Radio Observations from the Near Side Lunar Surface

- Lead Development Organization: NASA GSFC
- Payload PI: Robert MacDowall
- Lander Partner: Intuitive Machines
- Payload Delivery Date: Q1 2021
- Payload Mass: 14.6 kg
- Payload Dimensions: 18 x 15 x 15 cm
- Payload Description:
  - The ROLSES payload is a low-frequency radio astronomy receiver system that is based on the STEREO spacecraft WAVES instrument.
  - The four deployable, monopole, stacer antennas are based on those used for STEREO WAVES and will be combined as dipoles to improve measurement sensitivity.
  - The payload will employ a low-frequency radio receiver system to determine the photoelectron sheath density and scale height.
LSITP-0027
LuSEE: The Lunar Surface Electromagnetics Experiment

• Lead Development Organization: University of California, Berkeley
• Payload PI: Stuart Bale
• Payload Delivery Date: Q2 2024
• Payload Mass: 14.0 kg
• Payload Dimensions: 12 x 14 x 25 cm
• Payload Description:
  o LuSEE is a flight-spare payload from the FIELDS experiment on the recently-launched Parker Solar Probe spacecraft
  o LuSEE will measure the electromagnetic and electrostatic environment of the Lunar surface, including surface electric potentials, magnetic fields, and electrostatic signatures of dust
  o The LuSEE suite will also measure radio emissions from the Sun, Earth, and outer planets
  o The surface potential measurements will address the formation, and structure, of the Lunar photoelectron sheath and the interaction of the Lunar surface with plasma from the solar wind and terrestrial magnetotail
• Lead Development Organization: University of Maryland
• Payload PI: Douglas Currie
• Payload Delivery Date: Q2 2023, 19D delivery to Mare Crisium
• Payload Mass: 1.2 kg
• Payload Dimensions: 13 x 13 x 15 cm
• Payload Description:
  o The NGLR will improve the accuracy for a single range measurement, as compared to the Apollo retroreflector arrays, by a factor of 100.
  o The deployment of a NGLR will extend the scientific and technical heritage of the Lunar Laser Ranging (LLR) Program.
  o The increased accuracy will result in improved science by ranging to the deployed NGLR. Specific improvements will be realized for:
    ➢ Lunar core oblateness, elastic tides, Lunar tidal dissipation, Core/Mantle boundary dissipation, Free physical librations, Lunar cartography, and gravitomagnetism.
CLPS Manifest Selection

- CLPS delivery manifests are selected through the CLPS Manifest Selection Board (CMSB)
  - The CMSB includes representatives from SMD, HEOMD, STMD, OIIR, and the CLPS Project Office
- Selected payloads are chosen from among solicitations to the community, directed work, and international contributions; payloads are based on priorities and available budget from each respective Mission Directorate
  - Each Mission Directorate has a dedicated allocation on every CLPS delivery
- SMD will primarily use the Payloads and Research Investigations for the Surface of the Moon (PRISM) solicitation, planned approximately annually.
  - PRISM solicitations are open to HEOMD/STMD and will state the location for each delivery, allowing PIs to propose science optimized for those locations
    - High-value 'location agnostic' instruments and network science will be in future calls
    - International contributions to PRISM investigations may be included at up to 30% the total cost of the investigation
  - PRISM will also call out previously identified payloads for a particular delivery in order to solicit for complementary investigations and reduce redundancy
LUNAR SOUTH POLE TARGET SITE

ARTEMIS: Landing Humans On the Moon in 2024

Lunar Reconnaissance Orbiter: Continued surface and landing site investigation

Artemis I: First human spacecraft to the Moon in the 21st century

Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st Century

Gateway begins science operations in lunar orbit with launch of Power and Propulsion Element and Habitation and Logistics Outpost

Initial human landing system delivered to lunar orbit

Artemis III: Orion and crew dock to human landing system for crew expedition to the surface

Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers

Volatile Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey

Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions
Backup
ANGSA: Apollo Next Generation Sample Analysis

- Nine teams selected to analyze untouched Apollo samples
- Samples returned by Apollos 15 & 17 have been stored in pristine condition
- Will use techniques not available in the 1970s
NASA MISSIONS TO THE MOON

SCIENCE
HUMAN EXPLORATION AND OPERATIONS
SPACE TECHNOLOGY
Payloads largely selected from NASA Provided Lunar Payloads (NPLP)

2021 CLPS Delivery Manifests

**Astrobotic**
- Surface Exosphere Alterations by Landers (SEAL)
- Photovoltaic 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)

**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)

**Key**
- Science
- Technology
- Exploration
- HEOMD/STMD
2022 CLPS Delivery Manifests

Polar

Masten Space Systems – South Pole

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

Non-Polar

TBD – 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)

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

Key

- Science
- Technology
- Exploration
Advancing Beyond the Apollo Paradigm

• Field Geology with Significant Mobility
  o Study the origin and evolution of the Earth-Moon system on the lunar surface
    ❖ The Moon has experienced geologic processes that shape all terrestrial planets: Impact Cratering, Volcanism, and Tectonism
    ❖ Mobility on the surface is a key factor for enabling a range of scientific activities (e.g., accessing multiple geologic units, deploying experiments over a broad area)
    ❖ Best achieved as a human/robotic partnership

• New Samples Are Critical
  o The geologic diversity of the Moon coupled with careful selection of samples for return to Earth will address a plethora of science questions

• Surface Instrumentation
  o Humans facilitate the placement of delicate surface instrumentation.
    ❖ Radio experiment on the radio-quiet farside offers a unique opportunity for sensitive measurements of the early Universe

• Access to Regions with Cold Temperatures
  o Our knowledge of surface temperatures enable a volatile rich sample to be collected