National Aeronautics and Space Administration

NASA

Integrated Lunar Science Strategy

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From the Decadal Recommendations:

"PSD should develop a strategic lunar program that includes human exploration as an additional option to robotic missions to achieve decadal-level science goals at the Moon."

"Conducting decadal-level science should be a central requirement of the human exploration program."

What is an “Integrated Lunar Science Strategy”?

An opportunity to:

a) think strategically about the tools available to us and how they map to the high priority lunar science we want to accomplish at the Moon, and

b) build a plan, within budget constraints, that defines a path forward that is flexible enough to react to the changing landscape as our capabilities grow and priorities evolve.

What is it not?

A document, carved in stone, that will come down from the proverbial mountain top and be handed to the community.

What is our approach?

We will present here a path for developing a strategy to meet the biggest challenges for lunar science, as defined by the community, and with direct input from the community.

How long will this take?

NASA will start several mission studies and Science Definition Teams (SDTs) over the next couple of years to make informed decisions about our strategic direction.

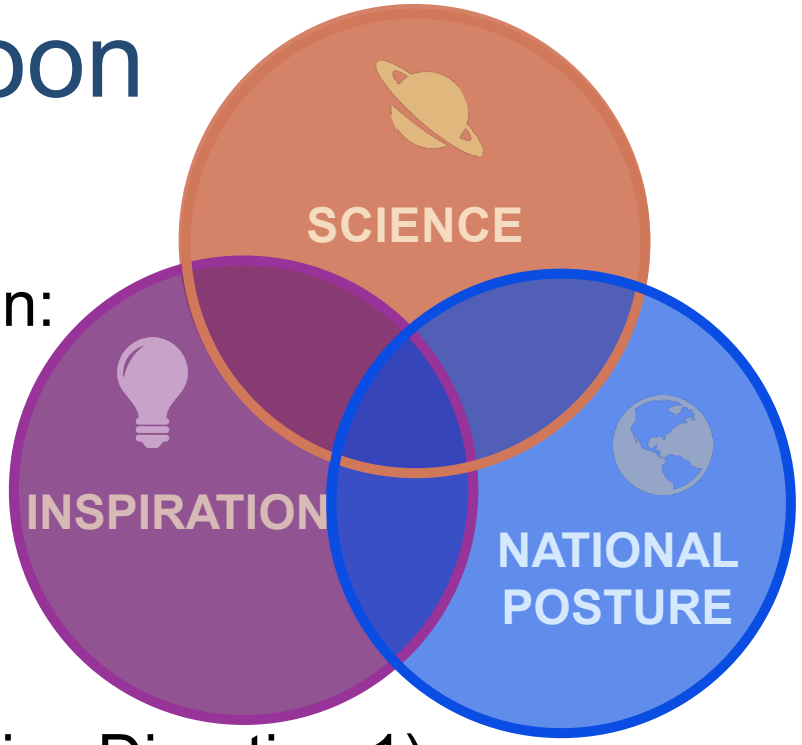
Who is developing it?

NASA has assembled a joint working group between the Planetary Science Division (PSD) and the Exploration Science Strategy and Integration Office (ESSIO) whose members include:

- Sarah Noble, Amanda Nahm (PSD/ESSIO)
- Shoshana Weider, Bobby Fogel, Jeff Grossman, Kathleen Vander Kaaden, Bo Trieu (PSD)
- Brad Bailey, Debra Needham, Ryan Watkins (ESSIO)

Community participation will be enabled through studies, SDTs, workshops, townhalls, and the Lunar Exploration Analysis Group (LEAG) Specific Action Teams (SATs).

Agency Priorities at the Moon



- Why NASA explores – Three Pillars of Exploration:
  - Science
  - National Posture
  - Inspiration
- Safe transport and return of astronaut crew
- Human landings at Lunar South Pole (Space Policy Directive-1)
- Promote a lunar economy to produce rapid, frequent, and affordable access to the lunar surface and cislunar space
- Prepare for human exploration of Mars and beyond

Science From the Moon

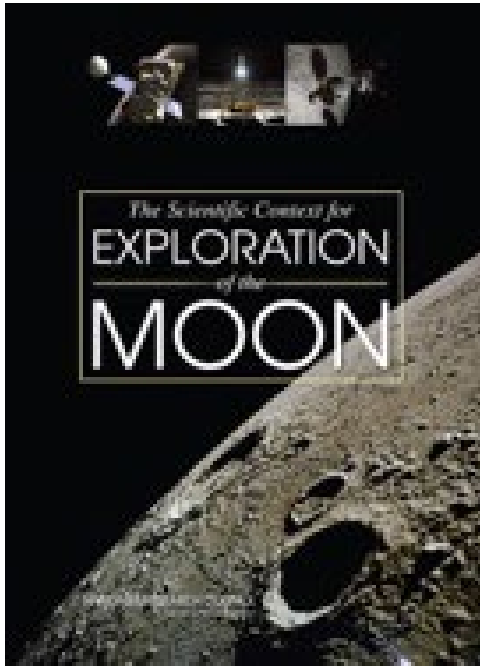
- ESSIO is integrating Artemis Science across SMD

- Lunar Surface Science Workshop (LSSW) on May 25th (tentative)

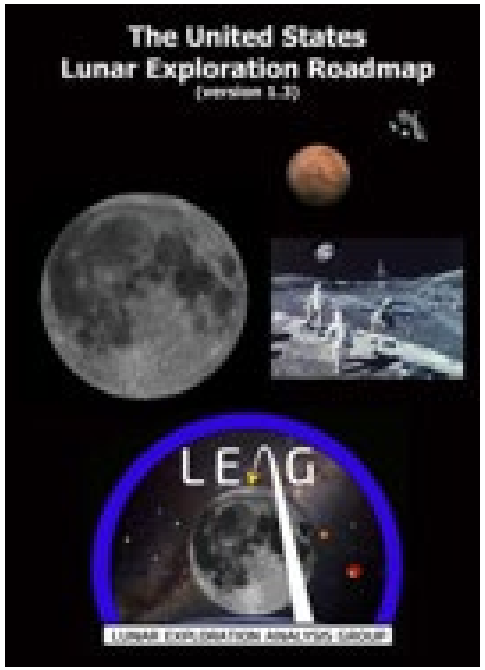
  “Integrating Science into Artemis: Updates from HQ and Artemis”

- Particularly looking to engage with communities interested in Artemis beyond planetary and lunar sciences, including:
  - Biological and Physical Sciences (BPS)
  - Heliophysics
  - Astrophysics

Planetary Community Science Priorities



2007



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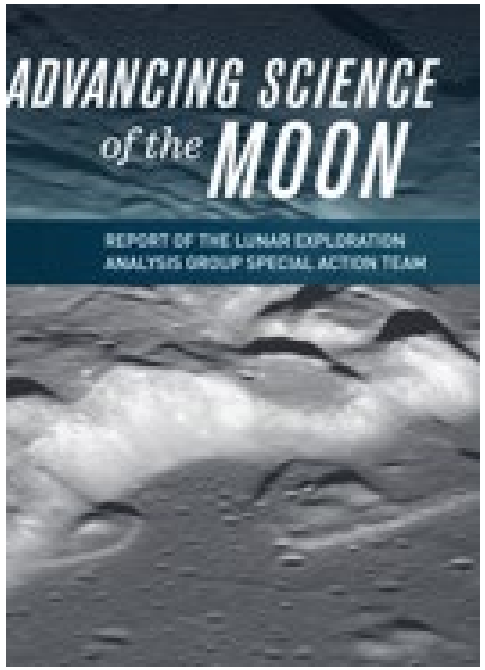

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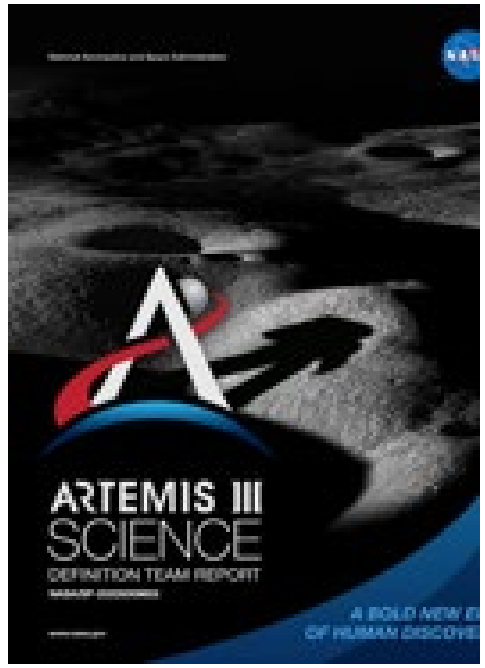
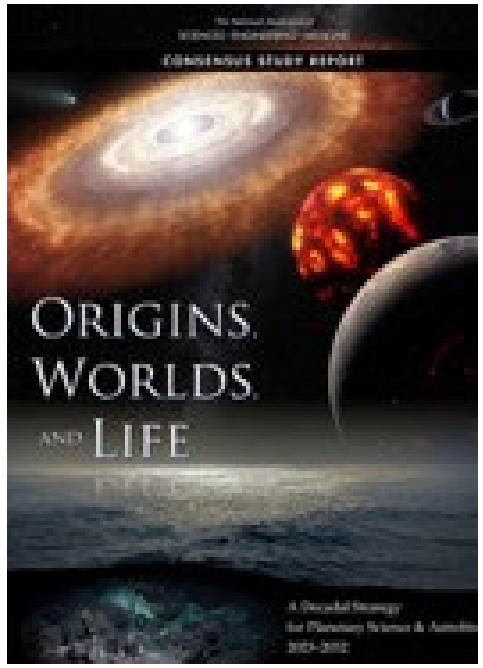


2020



2022

The Big Challenges
(i.e., science that requires a strategy to accomplish)

Specific missions that can be achieved through multiple architecture options:

- South Pole-Aitken (SPA) Sample Return
- Lunar Geophysical Network
- Cryogenic Volatile Sample Return

Objectives that require a build up of knowledge and global access to samples to achieve:

- Lunar Chronology
- Lunar Formation/Evolution

All five of these challenges implement Strategic Research defined for Decadal Science Questions.

Moon2Mars Objectives:
Lunar/Planetary Science (LPS) Goals

LPS-1^{LM}: Uncover the record of solar system origin and early history, by determining how and when planetary bodies formed and differentiated, characterizing the impact chronology of the inner solar system as recorded on the Moon and Mars, and characterize how impact rates in the inner solar system have changed over time as recorded on the Moon and Mars. (SPA Sample Return, Lunar Formation/Evolution)

LPS-2^{LM}: Advance understanding of the geologic processes that affect planetary bodies by determining the interior structures, characterizing the magmatic histories, characterizing ancient, modern, and evolution of atmospheres/exospheres, and investigating how active processes modify the surfaces of the Moon and Mars. (Lunar Geophysical Network, Lunar Chronology)

LPS-3^{LM}: Reveal inner solar system volatile origin and delivery processes by determining the age, origin, distribution, abundance, composition, transport, and sequestration of lunar and martian volatiles. (Cryogenic Volatile Sample Return)

Implementation Strategy: SPA Sample Return

Options for achieving this:

- New Frontiers
- Endurance-A (or other rover design)
- Human sortie to interior of basin (will not get all the science of a 1000+ km traverse)
  - Two (or more) human sorties
- Commercial Lunar Payload Services (CLPS) sample return mission w/mobility (no current capability)
- Some combination of the above

Path to a decision:

- Mission Study to better define the Endurance mission concept and look at different approaches for a long-duration sample-collecting rover (in progress)
- SDT to get community input on the science of an Endurance mission
- National Academy study on non-polar sorties for human exploration
- Alternative mobility options also under consideration:
  - Mobility as a CLPS Service

Implementation Strategy: Lunar Geophysical Network

Options for achieving this:

- New Frontiers
- Multiple CLPS deliveries of a long duration lander or self-contained long-duration payload
- Polar and non-polar human sorties
- Some combination of the above

Path to a decision:

- National Academy study on non-polar sorties for human exploration
- Payload design study
- CLPS capability assessment

Implementation Strategy: Cryogenic Volatile Sample Return

Although this is still a big challenge, architecturally, this is the simplest of the tall poles because we have a viable path to achieve this through Artemis. Still, we should not underestimate the difficulty of collecting, transporting, curating and analyzing a cryogenic sample.

Efforts are primarily led through the Exploration Systems Development Mission Directorate (ESDMD) and Johnson Space Center (JSC).

Path forward for Sample Return:

- Develop requirements for freezer/sample containers – 3 phase plan:
  - Sealed container (unconditioned)
  - -85°C freezer
  - Cryo-freezer
- Current JSC/ESDMD studies:
  - Laboratory studies
  - Roadmap for cold sample return
  - Non-Orion return options
  - Study on “What does a freezer look like?”
- Contamination Control Scientist onboarded (Andy Needham)
  - Working to get new Artemis Curation Lead and a Contamination Control Engineer into place asap

Implementation Strategy: Lunar Chronology

Options for achieving this:

- In situ dating
- CLPS sample return (no current capability)
- Artemis polar and non-polar sorties
- Some combination of above

Path to achieving this:

- Development of in-situ dating tools
- Work towards CLPS sample return
- National Academy study on non-polar sorties for human exploration

Implementation Strategy: Lunar Formation/Evolution

By achieving other goals, we will also make progress on this one:

- SPA sample return
- Lunar Geophysical Network (LGN)
- Many of the same locations for sample return as Lunar Chronology

Path to achieving this:

- Make decisions on SPA and LGN
- National Academy study on non-polar sorties for human exploration

Components of the Strategy

- Orbital Strategy
- CLPS Strategy
- Artemis Strategy
- Research and Analysis (R&A) Strategy

Orbital Strategy

As much as we would like it to, the Lunar Reconnaissance Orbiter (LRO) isn't going to last forever. However, orbiting assets are critical for achieving high priority science objectives and to enhance science return from human exploration.

- The Continuous Lunar Orbital Capabilities Specific Action Team (CLOC-SAT) report was clear that a large "LRO-class" orbiter is required due to pointing and duration requirements.
- However, they also noted "A single LRO-class satellite is unlikely to meet all science and exploration orbital needs alone" (CLOC-SAT 6.1.1) and recommended a diversity of implementation methods.
  - NASA is considering ways to leverage the CLPS/Artemis infrastructure for medium (Trailblazer) and small (Lunar Polar Hydrogen Mapper (LunaH-Map)) lunar orbiter opportunities.

Path to decision:

- Goddard Space Flight Center (GSFC) has begun a pre-phase A study for the Lunar Exploration and Science Orbiter (LExSO), an LRO-class orbiter based on community needs as delineated in the CLOC-SAT report.

CLPS Strategy

The capabilities of our CLPS vendors continues to evolve and they are eager for input on where to put their future development efforts. Neither we, nor they, can afford to go down all the paths simultaneously, so we need to make choices and develop a strategy that will maximize science while maintaining the establishment of a sustainable lunar economy.

- Survive the night
  - 1-2 nights
  - 6+ years (needed for LGN?)
- Increased mobility
- Complex instrument deployments
- Sample return

Path to decision:
- Regular surveys of vendor pool
- Payloads and Research Investigations on the Surface of the Moon (PRISM) is giving us a better sense of cost for capability
- Decision on using CLPS for LGN and whether lander needs to survive or just payload

Artemis Strategy

The capabilities of our human missions will continue to grow and we are working to provide input to maximize the science we can do through Artemis.

- Artemis III capabilities will be limited, but will grow with each subsequent mission
  - Freezers, mobility (Lunar Terrain Vehicle (LTV) and Pressurized Rover (PR)), power and comms infrastructure, enhanced sample return capabilities, etc.
- Building instrument capabilities through targeted calls and programs, including the Development and Advancement of Lunar Instrumentation (DALI), Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO), Maturation of Instruments for Solar System Exploration (MatISSE), and PRISM.
- Input from the community through the LSSW series has been invaluable.

Path to decision:

- National Academy study on non-polar sorties for human exploration
- National Academy study on science in the “sustained human presence” phase
- Endurance study and SDT

R&A Strategy

In order to be prepared to take full advantage of Artemis, we need to strengthen the sample science and field geology communities, and also ensure that our instrument pipeline is meeting our needs for both Artemis and CLPS.

- NASA is targeting specific calls to expand the communities and capabilities we need to grow, I
  - DALI /PRISM,
  - the Apollo Next Generation Sample Analysis (ANGSA) Program,
  - Analog Activities call,
  - Solar System Exploration Research Virtual Institute (SSERVI) Cooperative Agreement Notice 4 (CAN-4), which specifically encouraged sample science.
- High priority research areas may be called out specifically in the Lunar Data Analysis Program (LDAP), the Planetary Data Archiving, Restoration, and Tools (PDART) program, the Laboratory Analysis of Returned Samples (LARS) program, and others.
  - CLPS data will be incorporated into LDAP, with supplemental budget from ESSIO.
- We are trying to do all of this with intention and use the expansion of the communities as an opportunity to also diversify the communities.
- We are working with the Astromaterials Acquisition & Curation Office and the OSIRIS-REx team to develop the Astromaterials Data System (AstroMat) as a repository for sample data and to ensure it will meet the needs of Artemis and CLPS sample return.
- With help from the USGS, we are developing a Lunar Spatial Data Infrastructure (SDI) community
  - Also, geologic mapping – LSSW later this summer
- We are also thinking about laboratory needs, particularly for cold-curated samples.


Questions?