The Importance of Human Exploration in Accomplishing High Priority Lunar Science Objectives

A LEAG-sponsored white paper for submission to the 2023-2032 Decadal Survey on Planetary Science and Astrobiology

LUNAR EXPLORATION ANALYSIS GROUP

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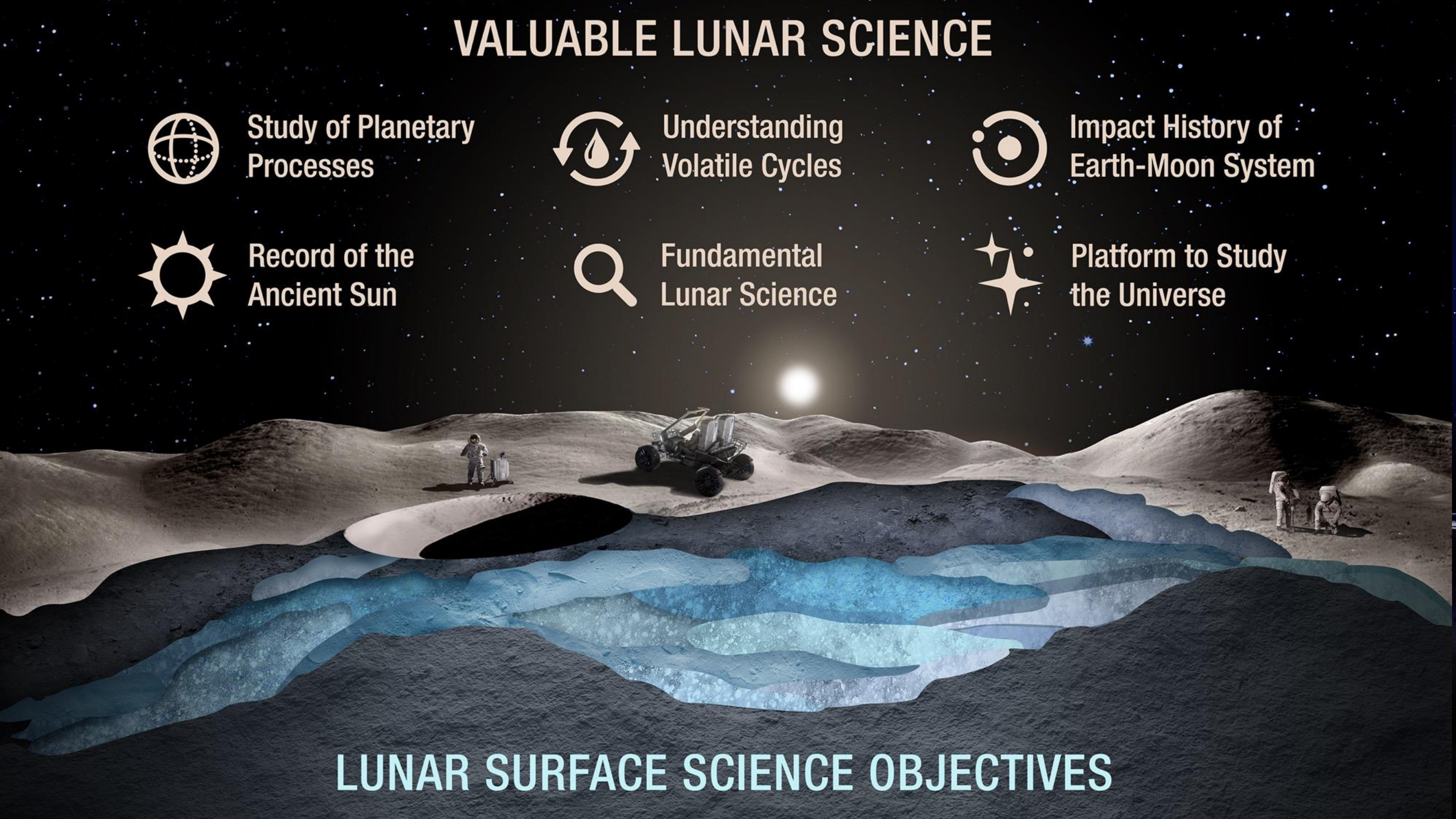
Introduction

- Although orbital, lander, and robotic missions are critical in closing scientific knowledge gaps, the scientific advances possible with human exploration cannot be underestimated
- Human cognition, mobility, dexterity, etc. are all capabilities brought to scientific exploration with crewed missions
- We suggest the 2023-2032 Decadal Survey include recommendations for lunar decadal science that would be enhanced by human exploration:
    - Recommendation #1: Integrate the lunar science community with the human spaceflight community to ensure adequate understanding of lunar science objectives and criteria for success.
    - Recommendation #2: Include a strategy in the 2023-2032 Decadal Survey for maximizing lunar science through human exploration, not just through the more traditional orbital and landed missions.


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
LUNAR SURFACE SCIENCE OBJECTIVES

Discovery-Based Science and Operational Flexibility

- A well-trained astronaut is capable of reacting real-time to *in situ* observations, which is critical in accomplishing lunar decadal science
  - Astronaut’s binocular vision, natural predisposition for pattern recognition, ability to make and contextualize observations, rapid decision-making capability, etc.
- Example: A rover can easily identify a boulder, but it’s challenging for it to identify a possible piece of SPA with possible lunar mantle

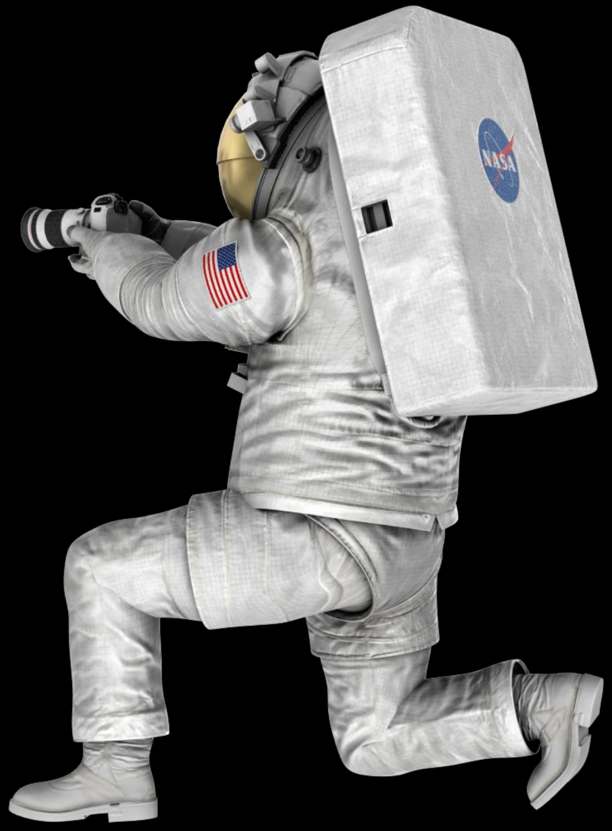
Dexterity

- Sample return is vital in addressing high priority lunar science objectives (Valencia et al., 2020)

- Recent robotic missions have included robotic arms capable of sampling and close approaches, but astronauts can easily navigate complex terrains as well as sample boulders and outcrops, which can be challenging to robotic systems

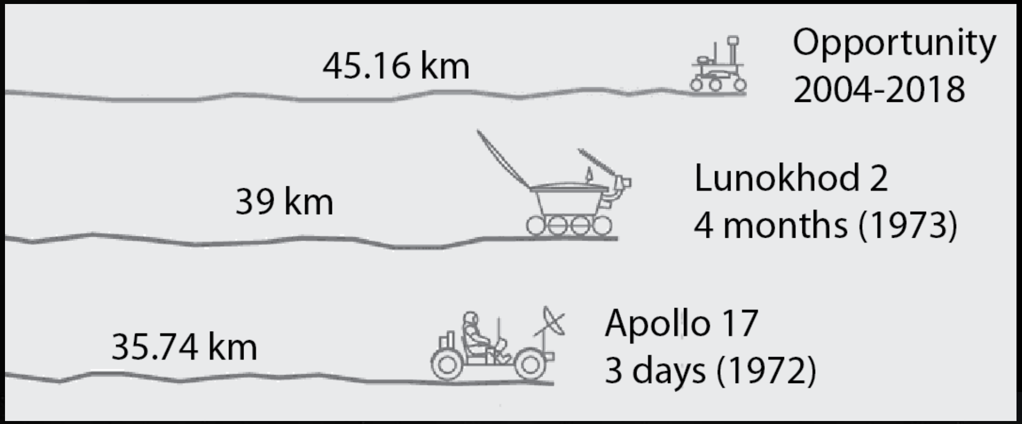
- Example: Apollo 17 astronauts navigating and sampling series of boulders and regolith/shadowed regions under boulders (Meyer, 2010)

- Suited astronauts more capable of manipulating smaller, more complex samples and payloads than robotic systems



The Importance of Mobility

- Increased mobility capability allows for:
  - access to greater diversity of terrains,
  - increased carrying capacity (payloads, samples, etc.),
  - ability to access complex terrains outside of where landers can land (i.e. central peaks)
- Apollo J missions show the value of increased mobility



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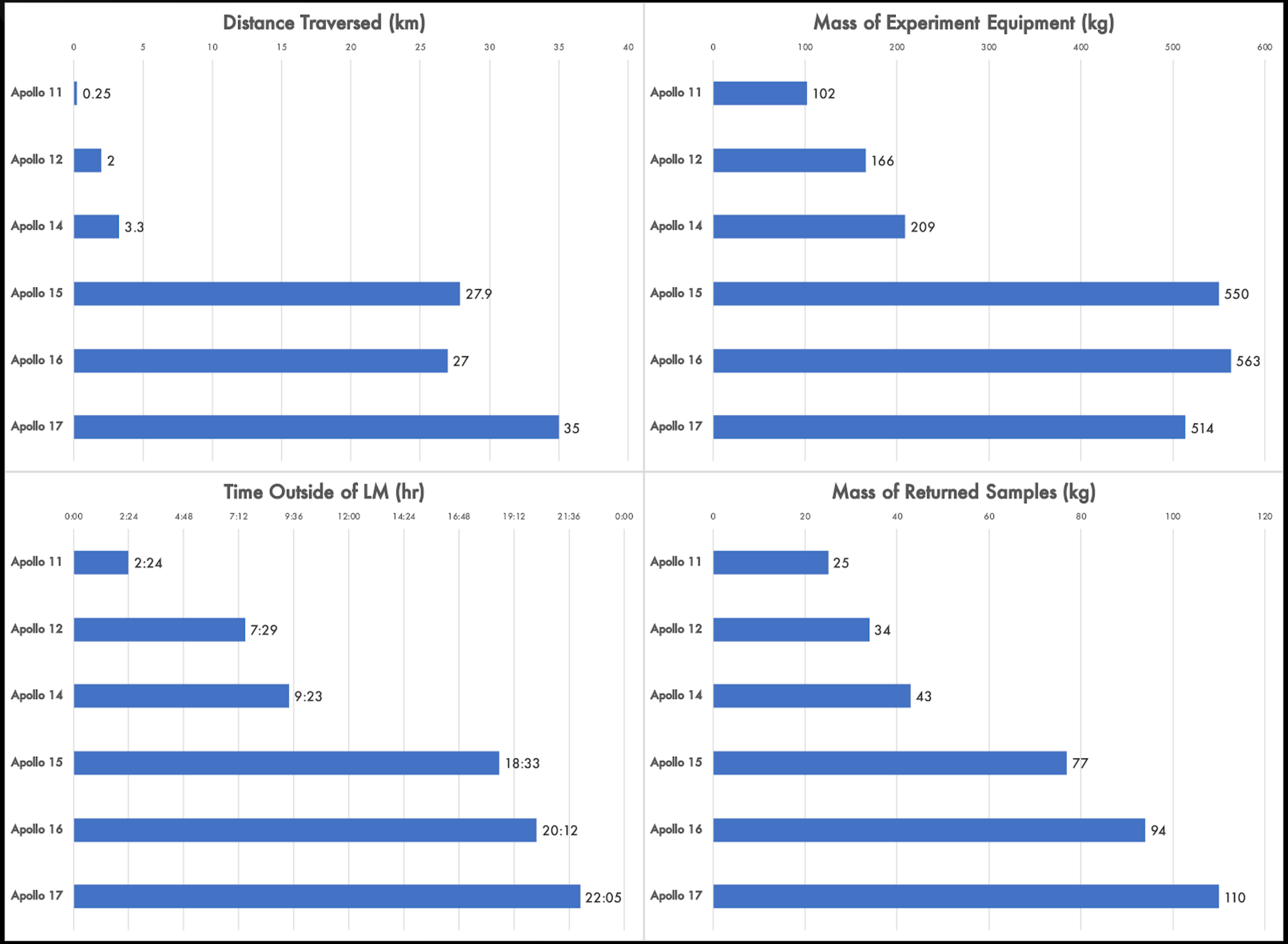
Apollo Lessons Learned

- Data from the Apollo 17 Preliminary Science Report (1973) demonstrate the value of increased human exploration capability on science return
  - Apollo 11 returned 25kg of samples, Apollo 17 returned 110kg
  - Apollo 11 had 2:24 hours outside the LM, Apollo 17 had 22:05 hours



Recommendation #1: Integrate the lunar science community with the human spaceflight community to ensure adequate understanding of lunar science objectives and criteria for success

- How is science currently being integrated across Artemis?
  - Lunar Surface Science Workshop: broad community engagement
  - NASA HQ cross-directorate Science & Technology Utilization and Utilization Coordination Integration Group
  - Artemis 3 Science Definition Team: relied on all available community documents
- Other efforts to integrate science into human spaceflight
  - LSIC: Lunar Surface Innovation Consortium, advancing suite of technology areas to support lunar exploration
  - Astronaut training: coordinated by NASA scientists with instructors pulled from academic community
  - Science integrated within tools, technology, and architecture teams across Artemis

Recommendation #1: Integrate the lunar science community with the human spaceflight community to ensure adequate understanding of lunar science objectives and criteria for success

- LEAG: advocacy and engagement both within the community and up-and-out
  - Key documentation, vetted by LEAG and CAPTEM, are critical resources for Artemis (Lunar Exploration Roadmap, 2010 CAPTEM-LEAG Report)
- NASA SMD-funded and HEO-funded analog missions
  - Increase number of scientists with operational experience
  - High-fidelity analog projects create an integrated exploration workforce in between human spaceflight missions
  - PSTAR and SSERVI provide some of this funding but more is needed to adequately prepare the community
  - Joint funding opportunities between SMD and HEOMD would show greatest flexibility and commitment to exploration science

Recommendation #2: Include a strategy in the 2023-2032 Decadal Survey for maximizing lunar science through human exploration, not just through the more traditional orbital and landed missions

- Legacy of successful Participating Scientist Programs
- Lessons learned from Apollo, Mars exploration, International Space Station, etc.
- SMD R&A programs have been shown to bridge the gap, but would benefit from increased funding for analog testing
- Opportunity to find synergies between ‘traditional’ SMD payloads and the capabilities of human deployed/tended science payloads
  - Human exploration can leverage SMD investments (smaller, low-powered, very capable instruments on rovers/landers) while also increasing possible payload complexity due to astronaut capability
- Conference participation: premier science conferences tend to minimize the importance of analog science and missions as well as the importance of human exploration in accomplishing high-priority science objectives

The Artemis Program is an integrated campaign of missions and launch opportunities (crewed lunar surface, CLPS, CubeSats, etc.). Due to this new landscape of lunar exploration, the Decadal Survey should provide recommendations on how best to accomplish high priority lunar science objectives, and how to support and develop the lunar science workforce.