

# Lunar Discovery and Exploration program





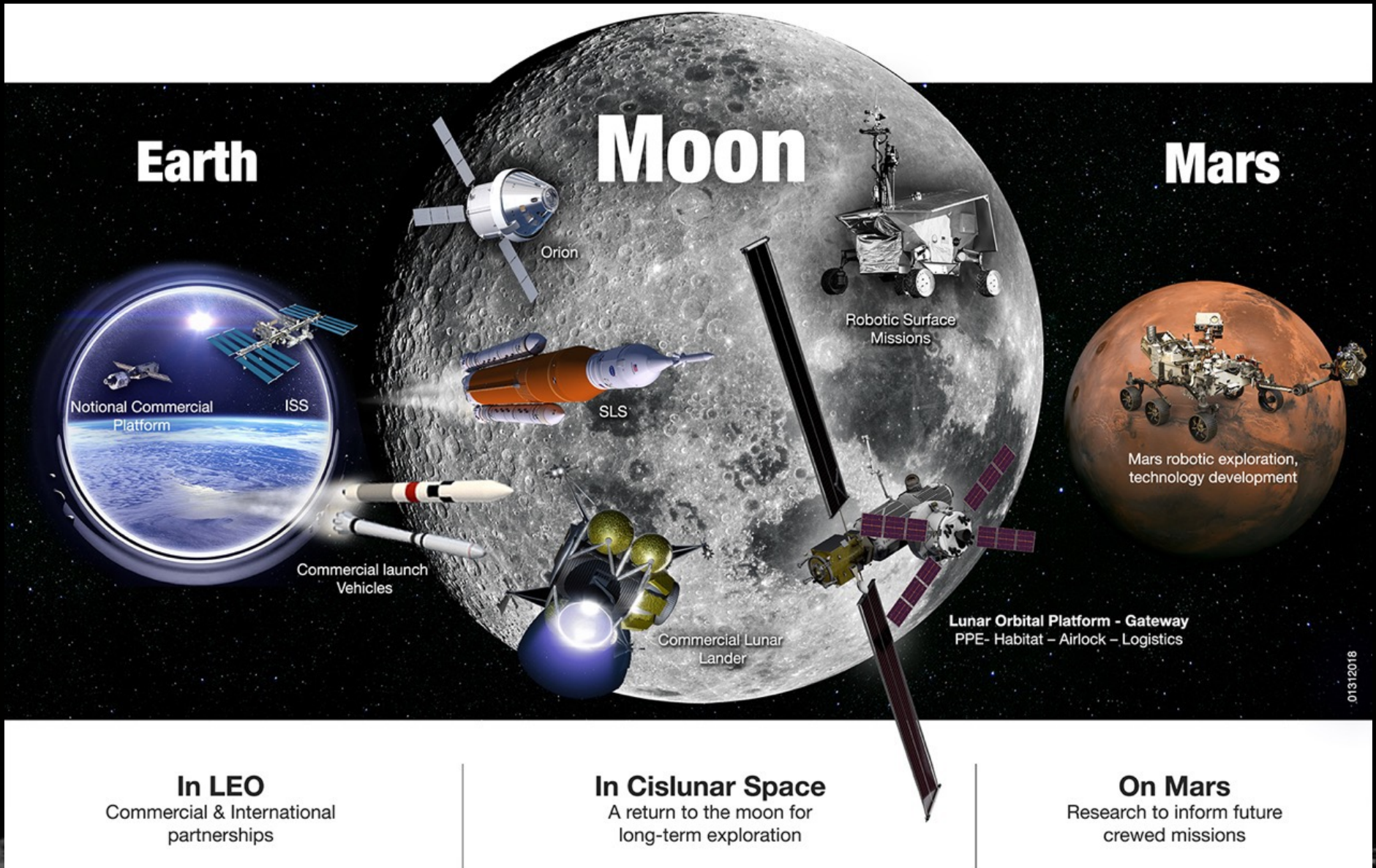
Space Policy Directive-1 (December 11, 2017) amends the National Space Policy to include the following paragraph:

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations;”





# The Lunar Exploration Campaign



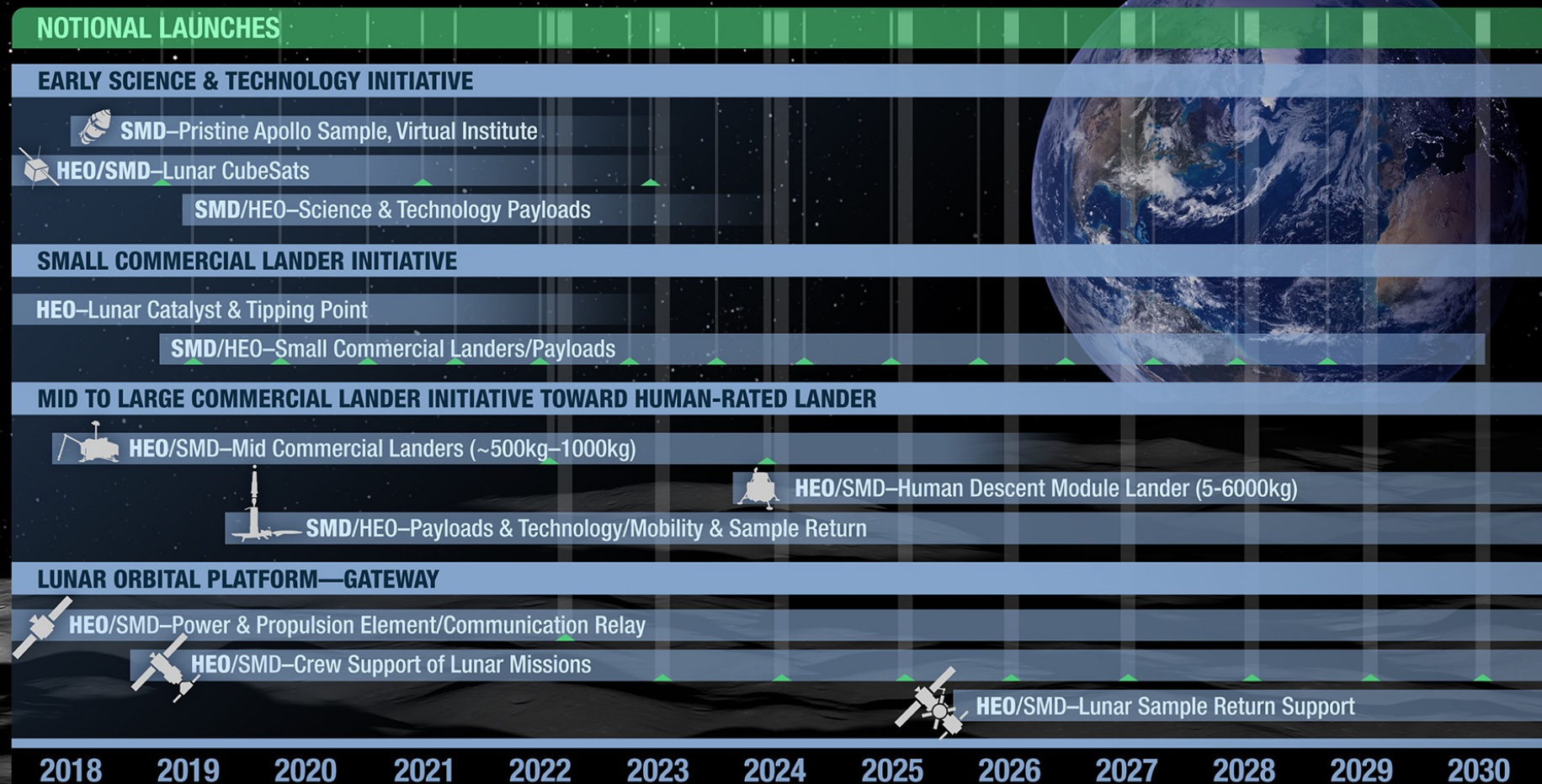




# Lunar Exploration Campaign

A robotic Lunar Discovery and Exploration program, that supports commercial partnerships and innovative approaches to achieving human and science exploration goals.

## NASA Lunar Exploration Campaign



Timelines are tentative and will be developed further in FY 2019

02.05.18



# Lunar Exploration Campaign

## EARLY SCIENCE & TECHNOLOGY INITIATIVE



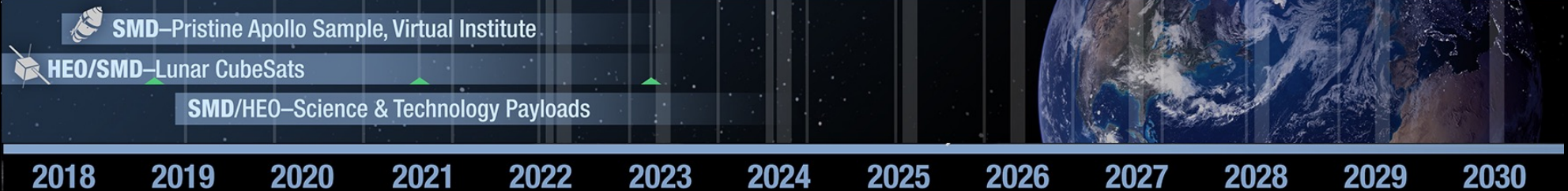
- Research
  - SSERVI CAN3 – draft to be released soon
  - ROSES18: Enhanced Lunar Sample Analysis Campaign
    - Perhaps opening one of the sealed drive tubes
  - Developing archive system for lunar (and other) sample data, and digitizing lunar curation data
- CubeSats
  - Current: LunaH-Map, HEOMD cubesats
  - Future: SIMPLEX SALMON3-PEA– call is open to all INCLUDING Lunar proposals
- Korean Pathfinder Lunar Orbiter Participating Scientist Program
  - Launch 12/2020
- LRO continues to operate and provide excellent data for future missions





# Lunar Exploration Campaign

## EARLY SCIENCE & TECHNOLOGY INITIATIVE

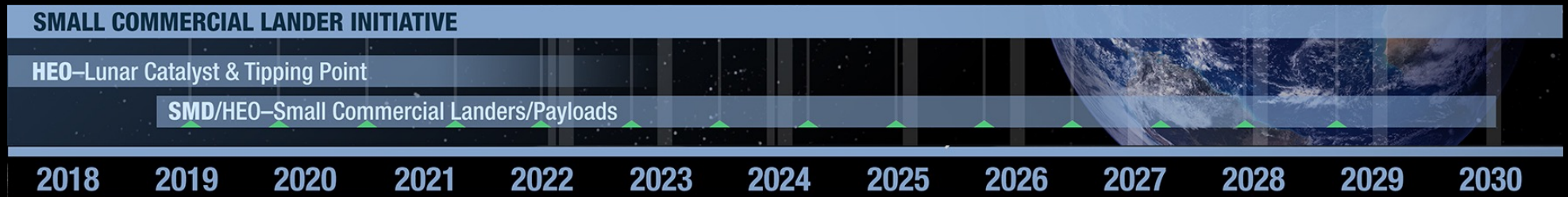


## DALI – Development and Advancement of Lunar Instrumentation

- ROSES18 call C22 (step 1 due April 3rd, step 2 due June 5th)
- Lunar instruments that support NASA's broader lunar exploration goals, including human exploration and in situ resource utilization (ISRU), as well as lunar science.
- All lunar instrument types, including rover-based and orbital, but particularly instruments for small stationary landers.
- Technologies that will reach at least TRL 6 by end of grant,
- Optimally for flight hardware builds for landers with flight opportunities as early as ~2021



# Lunar Exploration Campaign

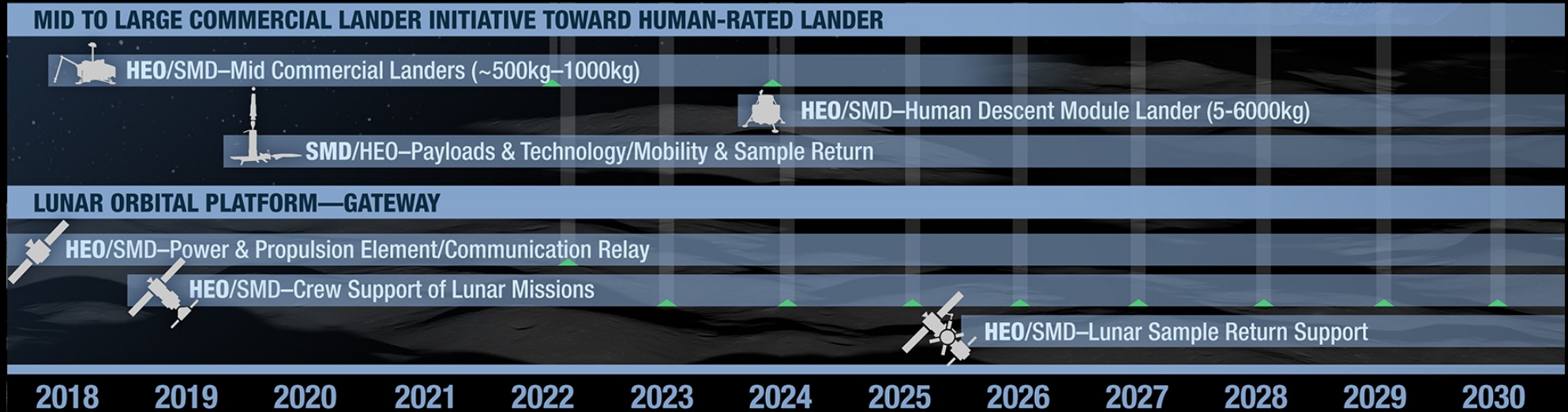


## Small Commercial Landers/Payloads

- RFP to commercial companies for hosting payloads
- GSFC to build retro-reflectors
- We will be looking for instruments to fly
  - Expect a new SALMON PEA
  - Open to Heliophysics/Astrophysics/Planetary as well as HEO/ISRU
  - Significant international participation will be permitted



# Lunar Exploration Campaign



Building towards bigger, more capable, landers and sample return capabilities

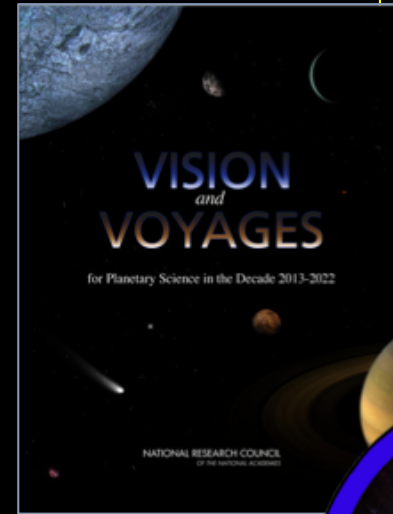






# Community Input

- SCEM report (2007)
- Decadal Survey (2012)
- LEAG SATS (reports out soon)
  - Advancing Science of the Moon (ASM-SAT)
  - Next Steps on the Moon (NEXT-SAT)
- Lunar Science for Landed Missions Workshop
  - Talks archived here: <https://lunar-landing.arc.nasa.gov/>
- Transformative Lunar Science Whitepaper
- New Views of the Moon II book





# SCEM Concepts

1. The bombardment history of the inner solar system is uniquely revealed on the Moon
2. The structure and composition of the lunar interior provide fundamental information on the evolution of a differentiated planetary body
3. Key planetary processes are manifested in the diversity of lunar crustal rocks
4. The lunar poles are special environments that may bear witness to the volatile flux over the latter part of solar system history
5. Lunar volcanism provides a window into the thermal and compositional evolution of the Moon
6. The Moon is an accessible laboratory for studying the impact process on planetary scales
7. The Moon is a natural laboratory for regolith processes and weathering on anhydrous airless bodies
8. Processes involved with the atmosphere and dust environment of the Moon are accessible for scientific study while the environment remains in a pristine state





# ASM-SAT (SCEM update)

- Progress toward each goal evaluated
  - Nearly all had at least some progress; none were “done”
  - Each section ends with summary of progress still needed
- No effort was made to reprioritize
- Identified Concepts and Goals not called out in SCEM
  - The lunar ‘water’ cycle
  - The origin of the Moon
  - Lunar tectonism and seismicity

“We are now in a much stronger position to take advantage of landed missions and identify ideal landing sites to address the SCEM goals.


While there is still real progress to be made from orbital missions, the advancement of many of these goals requires landed missions.”







# NEXT-SAT

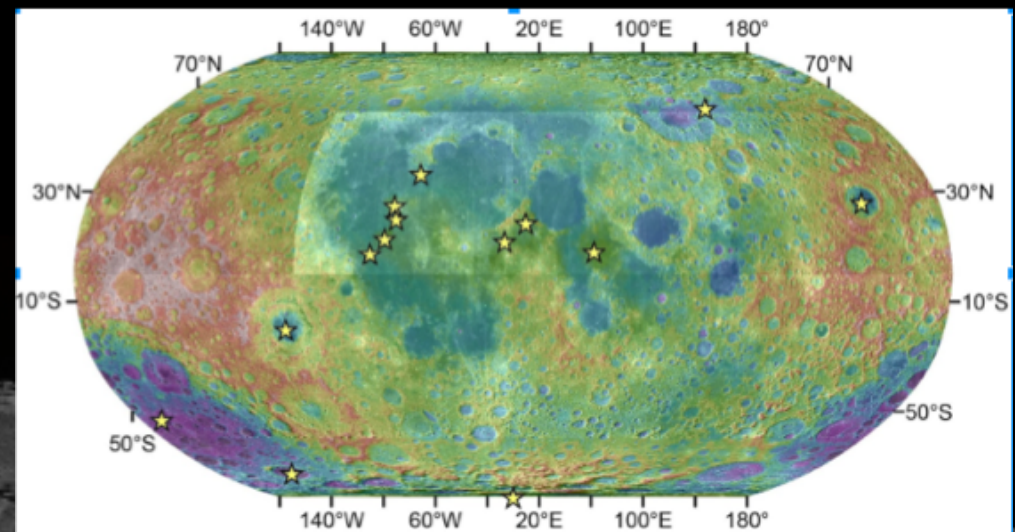
- **FINDING:** Lunar science presently has a well-developed slate of compelling science questions that are profoundly impactful for understanding the entire Solar System. **There are numerous options for lunar missions to address these questions that would provide openings to make dramatic, paradigm-shifting advances in planetary science.**
- FINDING: NEXT-SAT references the Finding 3 arising from the 2017 LEAG Commercial Advisory Board meeting. **Commercial entities should be employed to the fullest practical extent to increase competition, decrease costs, and increase the flight rate.**
- FINDING: There are numerous potential opportunities for commercial services, with NASA as a customer, to play a role in lunar surface exploration.
- FINDING: LRO observations of the Chang'e-3 mission activities on the surface pointed to the kinds of science and operational support that LRO data can enable and support for future missions.  Future mission teams should leverage active targeting from LRO instruments to ensure that data for site selection certification is readily available, and interface with the LRO project team to enable comprehensive mission support and new science.



# Lunar Science for Landed Missions

- Workshop held at Ames Jan 10-12, co-chaired by SSERVI and LEAG.
- Targets in contributed talks were evaluated for both science and human exploration interests, aligned in sessions topically:
  - Lunar volatiles
  - Lunar Magmatism and Volcanic Deposits (pyroclastics, pits and lava tubes, unusual volcanism)
  - Age dating and impact processes (Solar System chronology, basins and impact processes)
  - Lunar crust and dust
  - Geophysics and Astrophysics
  - Magnetism and Swirls
- Eight lunar commerce companies participated in 2 panel sessions; additional international session included with Japanese, European contribution
- Report in formulation; to be reviewed by community and presented to HQ 3/18

## Lunar Science Targets For Landed Missions Workshop





# Transformative Lunar Science

SMD AA requested SSERVI produce white paper on key areas of lunar science in new era of lunar exploration

delivered to SMD late January; also delivered to HEOMD

Areas addressed include:

- establish period of giant planet migration;
- provide absolute chronology for Solar System events;
- use accessible vantage from lunar far side to view universe;
- understand water cycles;
- characterize lunar interior;
- evaluate plasma interactions w/ surfaces;

*Provides a response to the question  
“**What transformative lunar science issues can be addressed in the currently evolving space science era?**”*

## Transformative Lunar Science

Recommendations from scientists of the  
Solar System Exploration  
Research Virtual Institute (SSERVI)

**Principal Contributors:**

Dr. Carl M. Pieters [Brown University]  
Dr. Robin Canup [Southwest Research Institute]  
Dr. David Kring [USRA Lunar and Planetary Institute]  
Dr. James W. Head, III [Brown University]  
Astronaut David R. Scott [Apollo 15 Commander]

Prepared: January 2018

The accessible  
differentiated  
cousin of Earth

USRA, gravity data were provided as a digital terrain model of the Moon's surface





# New Views Of The Moon II

- NVM-2 will synthesize the recent revolution in our understanding of the Moon (NVM was published in 2006)
- To be published in Reviews in Mineralogy and Geochemistry

## 21 Chapters:

- Summaries of Recent Missions
- Endogenous Volatiles
- The Contribution of Lunar Meteorites
- Origin of the Moon and Earth System
- Magmatic Evolution 1: Initial Differentiation
- Magmatic Evolution 2: A New View of Post-
- Volcanic Features and Processes
- Impact History of the Moon
- Lunar Impact Chronology
- Lunar Impact Features & Processes
- Origin and Evolution of the Moon's Dynamo
- The Structure of the Lunar Interior
- Evolution of the Lunar Crust
- Lunar Tectonics
- Surface Volatiles
- Dust, Atmosphere, and Plasma
- Space Weathering
- Surface Processes (Regolith)
- Lunar Resources
- Development of the Moon & Cislunar Space
- A Framework for Lunar Surface Scientific Exploration





# Benefits of Near-Term Lunar Missions

- Return Science
  - Reduce costs and risk for high priority science (Decadal Survey, SCEM, etc.)
  - Ensure the strength of the lunar science community
- Benefit Exploration
  - Volatiles may be key to future exploration architectures and characterizing volatiles entrainment in regolith is the first step
- Encourage Industry Participation
  - Expand the economic sphere to cis-lunar space
  - Foster initial R&D for resource acquisition and processing
  - Leverage investments in commercial landers
- Demonstrate Technologies
  - Precision Landing/Hazard Avoidance and Ascent
  - Improvements in power generation and storage
  - Extreme environment instruments/systems for day/night survival/operations - relevant to Icy Moons
- Advance planning for Mars and other destinations
  - Enables deep-space architectures
  - Reduces logistics chain from Earth
  - Flight qualifies critical technologies such as precision landing and ascent vehicles



# Questions?

