**Accomplishments During Current Cycle: ESM5 Accomplishments**

1. list the science objectives proposed for the current mission phase in the previous PMSR, and progress toward meeting those objectives
2. Table 1: “Level 1” science objectives from ESM5 (c.f. Table 1, Appendix A, plus any narrative).

Data from LRO have formed the basis of many new paradigms in our understanding of lunar geology, exogenous influences, and the exosphere. As LRO finishes ESM4, we are continuing to collect the data needed now, and in the future, to answer key questions about polar volatiles, the exosphere and space environment, interior and crustal processes, volcanic and tectonic activities, as well as impacts and regolith processing, including the evolution of the Moon over time. Many of these shifts in knowledge have come about as a result of the decade-plus mission lifetime as well as through combined instrument investigations leveraging different techniques and types of observations. Our ESM4 accomplishments listed against objectives, are provided in Table 1. Below we highlight just a few results from ESM5.

|  |  |  |  |
| --- | --- | --- | --- |
| # | Objective | Status | Comments |
| 1 | How does the presence of volatiles affect the surface and near-surface properties of lunar polar craters? |  |  |
| 2 | How do the concentration/distribution of volatile reservoirs at the north pole differ from the south pole? |  |  |
| 3 | How do seasonal temperature changes drive volatile migration and evolution at the polar regions?  Are there measurable differences between seasonally shadowed regions and other illumination regions? |  |  |
| 4 | How does the new solar cycle affect the lunar exosphere and space environment of the Moon?  How active is the near-surface dust environment? |  |  |
| 5 | What do exposures of deep crustal and mantle compositions reveal about the Moon’s interior? |  |  |
| 6 | How do silicic materials inform crustal processes and magma generation on planetary bodies without plate tectonics? |  |  |
| 7 | What is the extent and heterogeneity of the earliest mare eruptions? |  |  |
| 8 | What is the distribution, ages, and extent of the youngest mare activity? When was the Moon last volcanically active? |  |  |
| 9 | Do ancient wrinkle ridges reflect an evolving nearside lithosphere? What do mega-clusters of lobate scarps suggest about the Moon’s mechanical properties and current stress state? |  |  |
| 10 | Is there evidence of current tectonic activity on the Moon? Can detectable changes be related to coseismic slip events on faults associated with young landforms? |  |  |
| 11 | How quickly do impact craters of different sizes and on different targets degrade, and do different ejecta materials degrade at different rates? |  |  |
| 12 | What was the rate of space weathering over the past 10 years and what is the relative importance of  different processes?  Does Earth’s magnetotail detect energetic protons? |  |  |
| 13 | What is the present-day cratering rate and how does it modify the lunar surface? |  |  |

***ESM5 accomplishments: Mission support contribution:***

LRO has been actively supporting landing site selection and characterization and mission planning with new targeted observations and data products related to mission concept studies, CLPS, Artemis, and activities of international space agencies (via direction from NASA HQ). To name a few, LROC has >2600 non-polar and >9200 south-polar acquired observations with coverage of CLPS landing sites, including geostereo pairs, controlled mosaic observations, nadir NAC observations with a wide range of illumination conditions, and oblique images (Figure ??). Diviner has acquired observations at multiple landing sites before and after touchdown (including some during the active mission operation phase), providing information on the current local thermal environment, as well as targeted polar emission phase function (EPF) observations to characterize the surface roughness and thermal behavior of regolith near future polar landing sites. In ESM5, the LRO LLand IT group (LRO Landing Site Investigative Team) worked extensively with CLPS-supported instrument teams to provide new observations and data products essential for their landing site selection and mission planning. Since ESM4, the LRO team has also worked extensively to support Artemis planning efforts, providing much needed data products, including illumination maps and simulations, and LOLA digital elevation models (DEMs) with accurate geodetic control and improved horizontal and vertical uncertainty with fewer artifacts (Figure 2). Additional information on current and ongoing LRO support for Artemis is detailed in Section ##.

Figure: Examples of LRO’s history of mission support: Suggestions for this figure: one or more examples of CLPS support and an example from Artemis support?

* Oblique view of CS-3 landing site (farside, equatorial) with explanation of how it changed the landing site selection process.
* Diviner high resolution temperature plots/figures?:
* Quad Chart figure: Nighttime temperature anomaly map derived from Diviner showing elevated temperatures due to fresh crater and boulder field. Yellow star and white box is the  proposed CP-21 landing site and rover operation area.
* LOLA Artemis support (illumination map?)

**Select Instrument Team ESM5 Mission Support Accomplishments** (to be shortened and put into sentence form):

***LROC ESM5 mission support accomplishments:***

* IM-1 observations for localization
* Observation suites, including localization, on international sites: Luna 25, Chandraya’an-3, SLIM, Chang’e-6, Hakuto-R Mission 2.
* Support and acquisition of specialized images and data products for specific CLPS vendors and payloads
* Tested multi-axis slew for upcoming stereo observations of landing sites near the poles - this creates the opportunity to extend stereo coverage closer to the pole.
* Pre-landing image suite complete for current known landing sites
* Creation of 25 dtms and 14 control mosaics,  captured 29 oblique observations of CLPS landing sites during ESM5
* Acquisition of 19 specialized images and data products requested by CLPS vendors and project scientists

***LOLA ESM5 mission support accomplishments:***

* Collected passive radiometry photometric measurements of landing sites (CLPS/PRISM, Chandra-3)
* Ongoing ranging to the miniature LRAs on landers (Chandra-3, Chang’e 6, SLIM, IM-1). Successfully ranged to Ch-3, CE-6 & SLIM.
* We successfully ranged from LOLA to multiple LRAs on the lunar surface (Chandra-3, Chang’e 6, SLIM). The measurement result verifies the design and deployment of the LRAs, validates the concept of using miniature LRAs as fiducial points on planetary surfaces, and paves the way for future lidars to range to a network of LRAs on the lunar surface. Laser ranging to LRAs distributed spatially on the lunar surface can help us to obtain a more precise and accurate solution of the LRA position in the lunar geodetic frame and improve understanding of the Moon’s dynamics and internal structure. LOLA will continue to range to the current and future LRAs on the surface to build up a robust dataset also useful for characterizing the pointing and ranging uncertainties in preparation for future lidars.

***Diviner ESM5 mission support accomplishments:***

* Targeted IM-1, SLIM, Hakuto-R Mission 1, and Chang’E 6 observations before/after landing
* Targeting future mission sites (nadir and off-nadir): CP-11, CP-21, CP-32, TO-20A, Artemis III Nobile 2
* Polar EPF observations (relevant to understanding roughness/regolith characteristics near poles)
* High resolution gridded data products for CLPS sites (TO2-AB, CP-12, CP-21, CS-3) and international sites (Chandraya’an-3, Hakuto-R Mission 1)

***LAMP ESM5 mission support accomplishments:***

* Collected FUV spectral measurements of landing sites (CLPS/PRISM, Chandraya’an-3, etc. - ride-alongs with off-nadir pointed slews) for improved photometric constraints
* Investigated landing exhaust plume viewability for various landed events, but none offered feasible viewing geometries for FUV emission
* Targeted comet observations obtained atomic oxygen, hydrogen, and carbon emission brightness measurements for comets C/2022 E3 (ZTF), C/2023 H2 (Lemmon), 12P/Pons-Brooks, and C/2023 A3 (Tsuchinshan-ATLAS)

***CRaTER ESM5 mission support accomplishments:***

* Published predictions of the solar-cycle modulated radiation dose at the Earth/Moon system and radiation-limited permissible mission durations based on CRaTER data and solar cycle patterns (Artemis)
* Created maps of terrain-dependent radiation dose at the lunar south pole, and a generalized prediction of spatially-dependent radiation dose within a generic crater (Artemis)
* Published predictions of the frequency of, and the conditions which favor, potentially hazardous electrostatic breakdown on the lunar surface during large solar particle events (Artemis, Blue Ghost RAC+RadPC)

***Mini-RF ESM5 mission support accomplishments:***

* X-band bistatic observations:
  + Pre-landing:
    - Mare Crisium, Gruithuisen Domes Delta (CLPS)
    - Leibnitz Beta Plateau, Nobile Rim 1, Malapert (Artemis)
  + Post-landing:
    - Luna-24, Chang’e-5, and IM-1