# Creating A Planetary Data System Archive Of Select Lunar Mapping and Modeling Program (LMMP) Products

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## I. Introduction

NASA's Lunar Modeling and Mapping Program (LMMP) was a Lunar Precursor Robotic Program (LPRP) project tasked in 2006 by the Exploration System Mission Directorate (ESMD) Advanced Capabilities Division to create useful cartographic products and visualization and analysis tools from past and recent lunar datasets. Delivery of these products was planned via the LMMP web portal (http://lmmp.nasa.gov/) in support of the Constellation Program (CxP) as well as other research and potential lunar exploration activities. Primary LMMP goals included providing high-resolution and cartographically controlled data sets for "...landing site evaluation and selection, design and placement of landers and other stationary assets, design of rovers and other mobile assets, developing terrain-relative navigation capabilities, and assessment and planning of science traverses." For CxP, 50 sites of high scientific interest (CxP regions of interest or ROIs) were targeted specifically by the Lunar Reconnaissance Orbiter Camera (LROC) to obtain high-resolution stereo image coverage so that intensive characterization of each site could be conducted, and the information delivered to waiting exploration and science teams in a timely fashion.

We are now preserving these important LMMP data products and associated documentation in a Planetary Data System (PDS) archive. This effort will preserve and make more accessible select LMMP data products, including controlled orthomosaics, digital elevation models (DEMs), and derived slope, hillshade, and confidence maps for most of the 50 ROIs.

## III. The LMMP Data Collection

Several different types of data products were produced for the ROIs under the auspices of the LMMP. Institutions involved in generation of LMMP data products include the U. S. Geological Survey, University of Arizona, Arizona State University, NASA Ames Research Center (See Figure 2 for coverage), and NASA's Jet Propulsion Laboratory. The LMMP data collection includes regional and local visible-wavelength image base maps of the Moon derived from the Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (~50 cm/pixel), Apollo Metric Camera (~20 m/pixel) and Panoramic Cameras (as high as 1-2 m/pixel). These high resolution controlled base maps are essential for visualization and mapping and modeling activities, including orthoprojection of images onto Digital Elevation Models (DEMs) surfaces. Figure 3 illustrates a sample product (LROC-NAC mosaic).

The LMMP collection also includes regional- and local-scale lunar digital elevation models (DEMs) for most of the 50 ROIs. Topographic models provide visual elevation and slope references for science support and mission planners and crew. In addition to the image base maps and DEMs, the LMMP generated products for assessing landing safety and/or hazards at each site, including hillshade, slope, and confidence maps. Because the LMMP data products are geodetically controlled, the images and other relevant lunar surface data products allow users to correlate at known levels of accuracy the different types of information contained across the various data products. Figure 4 provides a sample product suite.

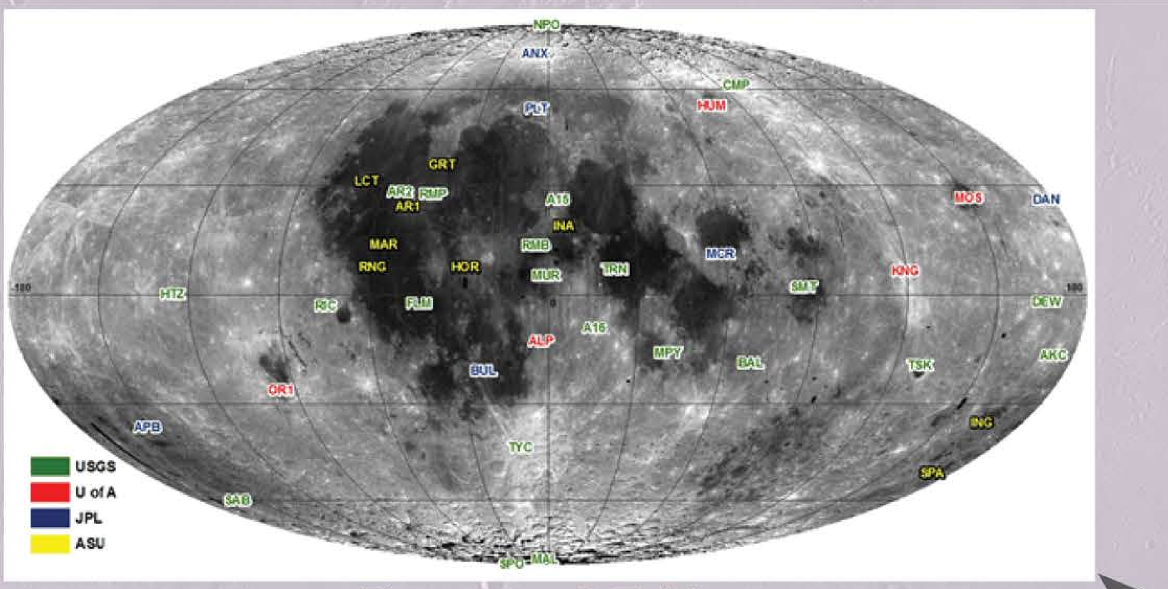



**Figure 1** & Table 1.
*LMMP DEMs and Mosaics (local-sites per facility).*

| Count | Producer | LROC NAC (Local Name) | Abbrev | LatNLonE | Cellsize |
|---|---|---|---|---|---|
| 1 | ASU | Aristarchus 1 | AR1 | 25N311E | 2mp |
| 2 | ASU | Sulpicius Gallus | SPG | 20N010E | 2mp |
| 3 | ASU | Gruithuisen Domes | GRT | 36N320E | 2mp |
| 4 | ASU | Hortensius Domes | HOR | 07N332E | 2mp |
| 5 | ASU | Ina | INA | 19N005E | 2mp |
| 6 | ASU | Lichtenberg | LCT | 32N293E | 2mp |
| 7 | ASU | Mare Ingenii | ING | 36S164E | 2mp |
| 8 | ASU | Marius Hills | MAR | 14N304E | 2mp |
| 9 | ASU | Reiner Gamma | RNG | 07N301E | 2mp |
| 10 | ASU | South Pole-Aitken Rim | SPA | 51S171E | 2mp |
| 11 | JPL | Anaxagoras Crater | ANX | 73N350E | 150cmp |
| 12 | JPL | Apollo Basin | APB | 37S206E | 150cmp |
| 13 | JPL | Bullialdus Crater | BUL | 20S337E | 400cmp |
| 14 | JPL | Dante Crater | DAN | 26N178E | 150cmp |
| 15 | JPL | Mare Crisium | MCR | 10N58E | 150cmp |
| 16 | JPL | Plato Ejecta | PLT | 53N354E | 150cmp |
| 17 | JPL | Tsiolkovskiy Crater | TSK | 19S129E | 150cmp |
| 18 | UofA | Alphonsus Crater | ALP | 13S358E | 2mp |
| 19 | UofA | Humboldtianum Basin | HUM | 55N077E | 3mp |
| 20 | UofA | King Crater | KNG | 06N120E | 2mp |
| 21 | UofA | Mare Moscoviense | MOS | 26N150E | 200cmp |
| 22 | UofA | Orientale 1 | OR1 | 26S265E | 2mp |
| 23 | USGS | Aitken Crater | AKC | 17S173E | 150cmp |
| 24 | USGS | Apollo 15 | A15 | 26N004E | 150cmp |
| 25 | USGS | Apollo 16 | A16 | 09S015E | 150cmp |
| 26 | USGS | Aristarchus 2 | AR2 | 28N307E | 150cmp |
| 27 | USGS | Balmer Basin | BAL | 19S070E | 150cmp |
| 28 | USGS | Compton Belkovich Th Anomaly | CMP | 61N099E | 150cmp |
| 29 | USGS | Flamsteed | FLM | 02S317E | 150cmp |
| 30 | USGS | Hertzsprung | HTZ | 00N234E | 150cmp |
| 31 | USGS | Npole (mosaic only) | NPole | NPole85.5 | 1mp |
| 32 | USGS | Spole (mosaic only) | SPole | SPole85.5 | 1mp |
| 33 | USGS | Malapert Massif | MAL | 86S356E | 3mp |
| 34 | USGS | Mare Smythii | SMT | 02N085E | 150cmp |
| 35 | USGS | Mare Tranquillitatis | TRN | 07N022E | 150cmp |
| 36 | USGS | Montes Pyrenaeus | MPY | 16S041E | 150cmp |
| 37 | USGS | Murchison Crater | MUR | 05N000E | 150cmp |
| 38 | USGS | Riccioli Crater | RIC | 03S286E | 150cmp |
| 39 | USGS | Rima Bode | RMB | 13N356E | 150cmp |
| 40 | USGS | Rimae Prinz | RMP | 27N318E | 150cmp |
| 41 | USGS | South Pole-Aitken Basin Interior | SAB | 60S200E | 150cmp |
| 42 | USGS | Stratton Dewar | DEW | 02S167E | 150cmp |
| 43 | USGS | Tsiolkovskiy Crater | TSK | 19S129E | 150cmp |
| 44 | USGS | Tycho Crater | TYC | 43S349E | 150cmp |
| 45 | USGS | Aristarchus 1 | AR1 | 25N311E | 5mp |
| 46 | USGS | Aristarchus 2 | AR2 | 28N307E | 3mp |
| 47 | USGS | Tsiolkovskiy Crater | TSK | 19S129E | 5mp |
| 48 | AMES | Apollo 15 Metric Regional | None | regional | 1024ppd |
| 49 | AMES | Apollo 16 Metric Regional | None | regional | 1024ppd |
| 50 | AMES | Apollo 17 Metric Regional | None | regional | 1024ppd |

**Figure 2.**
*Apollo 15, 16, 17 (blue, green, red respectively) Metric coverage map. This is an approximate representation of the LMMP regional DEMs and Mosaics as generated by NASA Ames Research Center.*

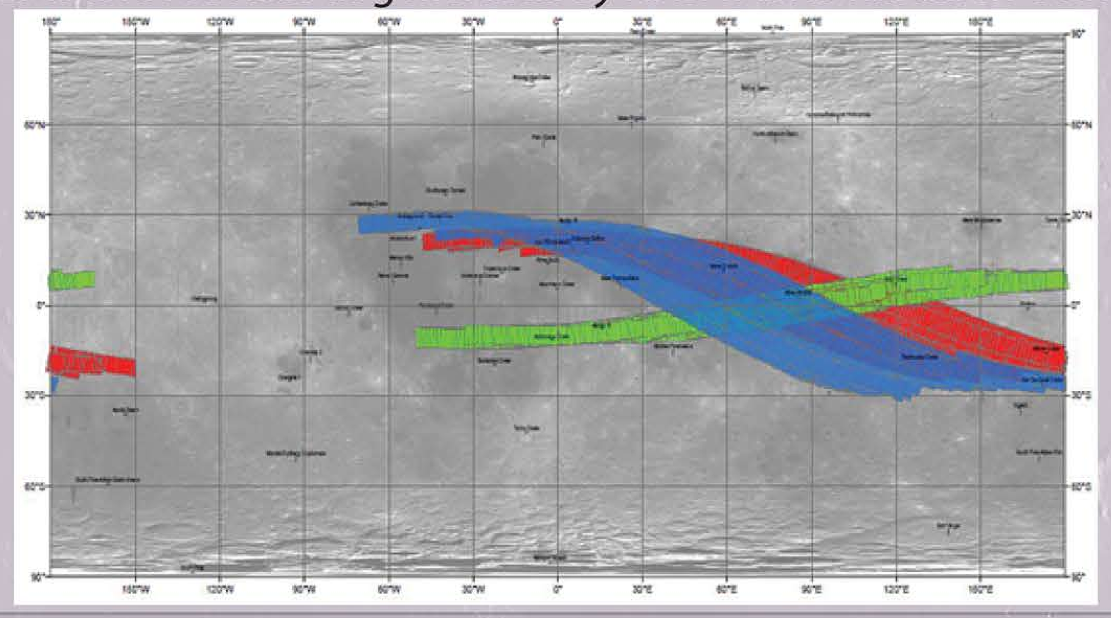
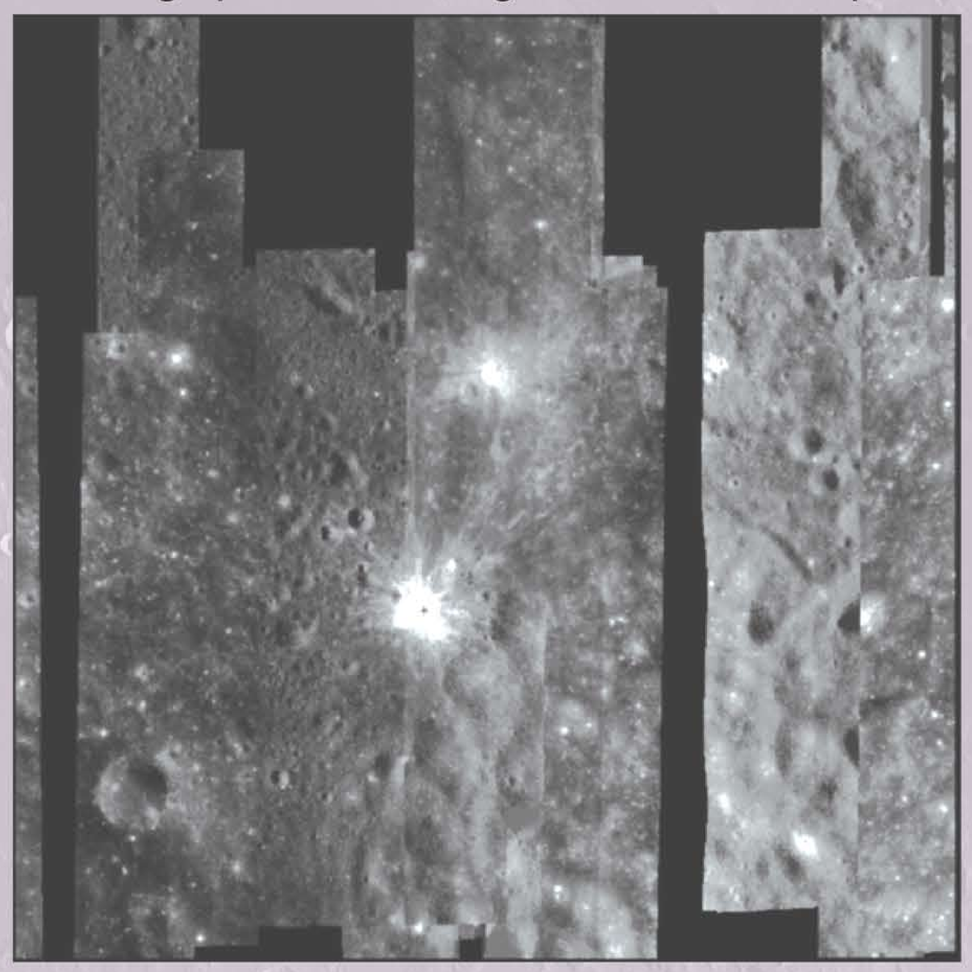
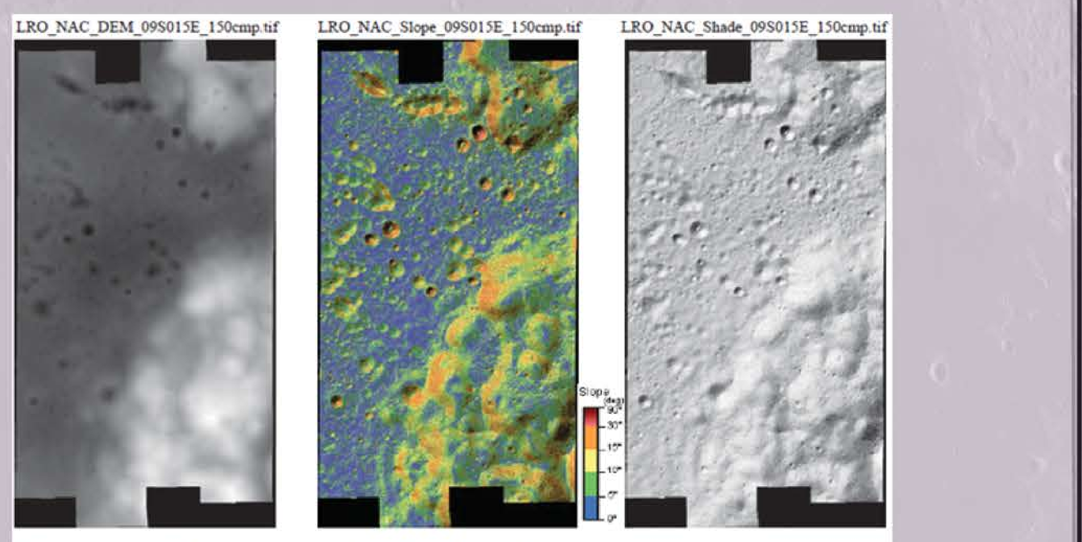


**Figure 3.**
*Example 40x40 km local-site LROC-NAC image mosaic showing Apollo 16 landing site at 0.5 meters/pixel.*





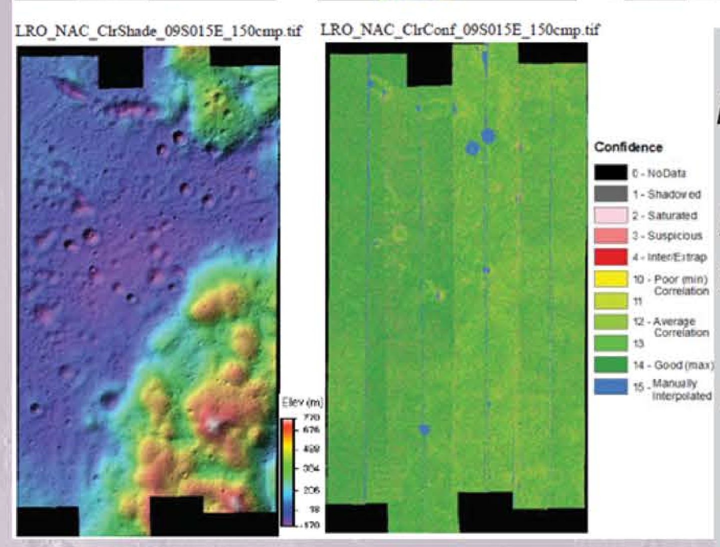



**Figure 4.**
*Example 16x31 km local-site LROC-NAC derived topography (DEM) and related products showing the Apollo 16 landing site at 1.5 meters/pixel.*

## II. Significance of LMMP Data Products

The LMMP data products are important resources in support of current and future scientific research and exploration activities on the Moon and other Solar System bodies. The 50 ROI sites (Figure 1 & Table 1) were identified by a Lunar Exploration Analysis Group (LEAG) special action team. Each ROI had scientific or operational characteristics that warranted its selection as a potential site for future robotic or human landings recognizing these sites remained of high science interest to the international lunar science community.

For example, detailed site characterization and analyses of remote sensing data for the ROIs at former Apollo landing sites contribute significantly to our understanding of regional and local hazards, position of artifacts and location of critical components of the lunar geodetic network, geologic and geophysical context of samples, effects of topography on remotely observed characteristics, communications requirements at landing sites, and the physical properties of soils. Additionally, LMMP data products can provide valuable knowledge for future landing site planning, and development of surface operational maps on bodies other than the Moon, including asteroid and satellites such as Phobos and Deimos. Finally, future proposals regarding high-interest sites such as the South Pole-Aitken Basin on the lunar far side will benefit from LMMP products, including detailed information on the topography, slopes and roughness of the surface, crater size and distributions, boulder populations, and hazard and lighting maps.

## IV. The Archive Plan

A Planetary Data System (PDS) archive provides public access to both data products and accompanying ancillary support files. Archive content will be compatible with the current PDS4 standards, ensuring the long-term usability and preservation of the LMMP products. The total estimated digital volume of the select LMMP data products being archived is approximately 700 GB.

*Data and Metadata Conversion.* All archive products will require PDS labels. For purposes of this archive, the labels are being generated by parsing existing metadata as provided by the LMMP project. In this case, a conversion process will involve the generation of related labels by utilizing and parsing existing metadata as provided by the LMMP project. In addition, the existing LMMP products will require conversion from existing data formats to PDS4 compliant formats.

*PDS label design and generation.* PDS labels are required for describing content and format of all entities within an archive. PDS labels will be generated so as to identify and fully describe the organization, content, and format of data products, documentation, and accompanying ancillary information.

*Documentation, Metadata, and Ancillary Files.* Supplementary reference materials will be formulated and included with archive products, as required, to improve their long-term value. These documents augment product labels and provide further information for understanding the data and accompanying materials.

PDS4 model design requirements result in high level documentation and cataloging for all aspects of the archive. This content also provides the mechanism by which the archive will ultimately be ingested into the PDS to enable long term preservation and integrated search and retrieval capabilities via PDS and other related web services.

*Peer Review.* A peer review will be conducted after completion of the archive to ensure the data and supporting metadata are complete, scientifically useful, and are in compliance with PDS standards.

*Data Delivery to the PDS and NSSDCA Deep Archive.* The finalized archive will be ingested into the PDS and a copy will be sent to the NASA Space Science Data Coordinated Archive (NSSDCA) for deep archive

## V. Delivery Schedule

This two-year project began with data conversion testing and preparation along with initial documentation preparation in the first year (FY2016). Development of final products and full archive population are now occurring in year two. Full access to the complete archive is anticipated for September 2017.

## VI. Acknowledgement

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**References: See full abstract (#1622) for reference list.**



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