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Lunar Reconnaissance Orbiter Project

Data Management and Archive Plan

LRO GSFC CMO

June 26, 2007

RELEASED

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LRO CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

Questions or comments concerning this document should be addressed to:

LRO Configuration Management Office
Mail Stop 451
Goddard Space Flight Center
Greenbelt, Maryland 20771

Signature Page

Prepared by:

13 JUN 2007

Karen North Date
Computer Engineer
NASA/GSFC, Code 586

Reviewed by:

6/25/07

Stan Scott Date
LRO Project Science Data Manager
NASA/GSFC, Code 586

2007/06/13

Arlin Bartels Date
LRO Project Payload Systems Manager
NASA/GSFC, Code 451

Approved by:

6/25/07

Craig Tooley Date
LRO Project Manager
NASA/GSFC, Code 451

6/19/2007

Gordon Chin Date
LRO Project Scientist
NASA/GSFC, Code 693

Concurred by:

Edwin Grayzeck Date
Planetary Data System Program Manager
NASA/GSFC, Code 690.1

Signature Page

Prepared by:

Electronically Signed on NGIN ________ Date
Karen North
Computer Engineer
NASA/GSFC, Code 586

Reviewed by:

Electronically Signed on NGIN ________ Date
Stan Scott
LRO Project Science Data Manager
NASA/GSFC, Code 586

Electronically Signed on NGIN ________ Date
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LRO Project Payload Systems Manager
NASA/GSFC, Code 451

Approved by:

Electronically Signed on NGIN ________ Date
Craig Tooley
LRO Project Manager
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Electronically Signed on NGIN ________ Date
Gordon Chin
LRO Project Scientist
NASA/GSFC, Code 693

Concurred by:

________ 6/11/07
Edwin Grayzeck Date
Planetary Data System Program Manager
NASA/GSFC, Code 690.1

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LUNAR RECONNAISSANCE ORBITER PROJECT

CHANGE HISTORY LOG

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Rev -	Released per 431-CCR-000319	C. Tooley	6/26/2007

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date

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1.0 INTRODUCTION

1.1 PURPOSE

This Data Management and Archive Plan (DM&AP) for the Lunar Reconnaissance Orbiter (LRO) Mission describes the roles and responsibilities of the LRO Mission Operations Center (MOC), LRO Instrument Science Operations Centers (SOCs), and the Planetary Data System (PDS), including the relationships between these entities, with regard to measurement and support data flow.

1.2 SCOPE

This Data Management and Archive Plan describes and dictates the relationship of the SOCs to the PDS and to the MOC. It addresses measurement and support data flow between the MOC, SOCs, and PDS. It does not address the technical means by which the data flows (which are documented in Interface Control Documents), data management within SOCs (which are documented in their individual Data Management and Archive Plans), nor data flow from the flight instruments to the MOC.

1.3 APPLICABLE DOCUMENTS

The following documents apply only to the extent they are cited:

ESMD-RLEP-0010 Lunar Reconnaissance Orbiter Requirements
431-ICD-000049 Lunar Precursor and Robotic Program (LPRP) Lunar Reconnaissance Orbiter Project: External Systems Interface Control Document for the Lunar Reconnaissance Ground System
431-OPS-000042 Lunar Reconnaissance Orbiter Mission Concept of Operations
431-PLAN-000079 Lunar Reconnaissance Orbiter Mission Readiness Test Plan
431-ICD-000049 External Systems Interface Control Document for the Lunar Reconnaissance Ground System

PDS reference documents:

- Planetary Data System Standards Reference, JPL D-7669, Part 2 http://pds.jpl.nasa.gov/documents/sr/index.html
- Planetary Science Data Dictionary Document, JPL D-7116 http://pds.jpl.nasa.gov/documents/psdd/psdd.pdf
- Planetary Data System (PDS) Proposer's Archiving Guide (PAG), JPL D-26359 http://pds.jpl.nasa.gov/documents/pag/index.html
- Planetary Data System Archive Preparation Guide (APG), January 20, 2005, Version 0.050120, JPL D-31224

1.4 SCHEDULE FOR DATA DELIVERY TO THE PDS

The phrase “within 6 months of creation” as used herein should be considered shorthand for the following level 1 requirement:

"RLEP-LRO-P110 Measurement Investigation Requirements The time required to […] make the initial data products available via the PDS to the Headquarters and the Program office shall be six months or less from delivery to Earth. New or improved data product releases and derived data products shall be delivered to the PDS as soon as they are available."

The LRO Data Working Group (LDWG) has clarified this as follows:

The six core SOCs will deliver 3-6 month old data every 3 months starting at launch + 8 months (completion of commissioning + 6 months). Subsequent versions and derived products are required to go to PDS "immediately" (at the next scheduled 3 month delivery). Final data versions are required to go to PDS by 6 months after the end of the primary mission, and by 6 months after the end of an extended mission. Any instrument data from the commissioning phase may be archived in PDS at the instrument Principal Investigator's discretion at launch + 8 months.

The Mini-RF technology demonstration data is delivered to the PDS Geosciences Node every 6 months, where the data are 6-9 months old. This schedule would coincide with every other data delivery for the other LRO instruments, starting with their second deliveries at launch plus 11 months.

The MOC data delivery schedule to the SOCs and PDS NAIF is described in the document entitled: "Lunar Precursor and Robotic Program (LPRP) Lunar Reconnaissance Orbiter Project: External Systems Interface Control Document for the Lunar Reconnaissance Ground System". This document is referenced as the GS ICD in this document.

To ensure successful data delivery, the SOCs will send test data to the PDS Nodes according to a test schedule determined by the LDWG. MOC test data deliveries to the SOCs and SOC deliveries to the MOC where applicable of test versions of Activity Requests, will be performed as part of Mission Readiness Testing (MRT) #5 and #6, where these tests will occur during the period November 2007 through June 2008.

LRO Science Data Management Schedule

2007

Activity or Document	J	F	M	A	M	J	J	A	S	O	N	D
GS Single Design Review	X											
LRO Proj->PDS: MISSION.CAT, INSTHOST.CAT (2)			1		2							
MOR									X			
FORR												
LRO Launch												
SOC Risk Assessment Plan		1		2								
SOC IT Security/Contingency Plan (1)				1		2						
SOC->PDS: EDR Data Prod SIS (1)			1		2							
EDR Data Prod SIS Peer Review (2)				X	X							
SOC->PDS: EDR Archive Vol SIS (1)			1		2							
SOC Test Plan (1)							1		2			
SOC->PDS: RDR DataProdSIS (1&3)											1	
RDR Data Prod SIS Peer Review (2)												X
SOC->PDS: RDR ArchiveVolSIS(1&3)											1	
I/F Tests: SOC-PDS Node (4)												
GS&O MRT #5&6 I/F Tests (5)											X	X
GS&O ORE/Sims/Rehersals (5)										X	X	X
SOC->PDS: INST.CAT, DATASET.CAT, PERSON.CAT, REF.CAT												
SOC->PDS: DP methodology&algorithms												
SOC Operations												
SOC/PDS: New LRO Data (6&7)												
MRF SOC/PDS: New LRO Data (6&7)												

2008

Activity or Document	J	F	M	A	M	J	J	A	S	O	N	D
GS Single Design Review												
LRO Proj->PDS: MISSION.CAT, INSTHOST.CAT (2)												
MOR												
FORR						X						
LRO Launch										X		
SOC Risk Assessment Plan												
SOC IT Security/Contingency Plan (1)												
SOC->PDS: EDR Data Prod SIS (1)												
EDR Data Prod SIS Peer Review (2)												
SOC->PDS: EDR Archive Vol SIS (1)												
SOC Test Plan (1)												
SOC->PDS: RDR DataProdSIS (1&3)		2										
RDR Data Prod SIS Peer Review (2)	X	X										
SOC->PDS: RDR ArchiveVolSIS(1&3)		2										
I/F Tests: SOC-PDS Node (4)			X	X	X							
GS&O MRT #5&6 I/F Tests (5)	X	X	X	X	X	X						
GS&O ORE/Sims/Rehersals (5)	X	X	X	X	X	X	X	X	X	X		
SOC->PDS: INST.CAT, DATASET.CAT, PERSON.CAT, REF.CAT							X					
SOC->PDS: DP methodology&algorithms								X				
SOC Operations										X	X	X
SOC/PDS: New LRO Data (6&7)												
MRF SOC/PDS: New LRO Data (6&7)												

2009

Activity or Document	J	F	M	A	M	J	J	A	S	O	N	D
GS Single Design Review												
LRO Proj->PDS: MISSION.CAT, INSTHOST.CAT (2)												
MOR												
FORR												
LRO Launch												
SOC Risk Assessment Plan												
SOC IT Security/Contingency Plan (1)												
SOC->PDS: EDR Data Prod SIS (1)												
EDR Data Prod SIS Peer Review (2)												
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GS&O ORE/Sims/Rehersals (5)												
SOC->PDS: INST.CAT, DATASET.CAT, PERSON.CAT, REF.CAT												
SOC->PDS: DP methodology&algorithms												
SOC Operations	X	X	X	X	X	X	X	X	X	X	X	X
SOC/PDS: New LRO Data (6&7)						X			X			X
MRF SOC/PDS: New LRO Data (6&7)						X						X

Schedule Date: 2007-05-14 Author: Stan Scott /LRO Project

Notes: (1) Document versions: 1= draft, 2 = final
(2) Allow 2 months for Data Product SIS Peer Review by PDS and for SIS revision; final version depends on outcome of peer review
(3) RDR Pipeline Data Prod SIS & Archive Vol SIS drafts due Nov 15, 2007; cumulative RDR SISs & data delivery due near end of mission
(4) Electronic data delivery test between SOC and PDS, if applicable
(5) GS&O Testing- actual dates within those specified, test types, test data used, and test goals are as agreed between GS&O & SOC Lead
(6) SOC data deliveries to PDS in time for public release at 3 month anniversaries of start of LRO post-commissioning operations
(7) Mini-RF (MRF) data deliveries to PDS coincide with every other release from other teams

2.0 MISSION OVERVIEW

2.1 LRO CONTEXT AND GOALS

LRO is the first mission of the Lunar Precursor and Robotic Program (LPRP). LRO is scheduled for launch in October 2008. The goal for the LPRP is to prepare for future human exploration of the Moon. LRO specific objectives are:

- Characterize the lunar radiation environment, biological impacts, and potential mitigation
- Determine a high resolution global, geodetic grid of the Moon in 3 dimensions
- Assess in detail the resources and environments of the Moon's polar cap regions
- Perform high spatial resolution of the Moon's surface

2.2 LRO INSTRUMENTS

The LRO instrument complement includes six core instruments and one demonstration instrument:

- Cosmic Ray Telescope for Effects of Radiation (CRaTER): CRaTER will investigate the effect of solar energetic particles and galactic cosmic rays on tissue-equivalent plastics as a constraint on models of biological response to background space radiation.
- Diviner Lunar Radiometer Experiment (DLRE): Diviner will map the temperature of the entire lunar surface at 500-meter horizontal scales to identify cold-traps and potential ice deposits.
- Lyman-Alpha Mapping Project (LAMP): LAMP will observe virtually the entire lunar surface in the far ultraviolet. LAMP will search for surface ices and frosts in the polar regions and provide frost abundance, landform and surface UV spectral maps of permanently shadowed regions illuminated only by starlight and interplanetary Lyman alpha.
- Lunar Exploration Neutron Detector (LEND): LEND will map the flux of neutrons from the lunar surface to search for evidence of water ice and provide measurements of space radiation environment which can be useful for future human exploration.
- Lunar Orbiter Laser Altimeter (LOLA): LOLA will determine the global topography of the lunar surface at high resolution, measuring landing site slopes and search for polar ice in shadow regions.
- Lunar Reconnaissance Orbiter Camera (LROC): LROC will acquire targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards. LROC will also produce wide-angle images at multiple wavelengths of the lunar poles to document the changing illumination conditions and potential resources.
- Mini-Radio Frequency technology demonstration (Mini-RF): Mini-RF will fly as a technical demonstration of a unique miniaturized multi-mode dual frequency (X&S band), dual polarization radar observatory. The primary image data products will be multi-mode Stokes parameters (or their primitives), a major pioneering capability in space-based radar astronomy. Additional communications and navigation demonstrations will also be made to validate new instrument technologies.

3.0 ROLES AND RESPONSIBILITIES

3.1 LRO PROJECT OFFICE (LPO)

The LRO Project Office has overall responsibility for the acquisition, integration, launch, and operation of the LRO Observatory, and ensures compliance by all parties with contractual requirements. With regard to mission measurement and support data, the LPO provides data coordination via chairing the LRO Data Working Group (LDWG). The LDWG coordinates the planning for data product generation, data validation, and release of Planetary Data System (PDS)-compliant archives to the PDS. LDWG membership includes representatives from the LPO, Mission Operations Center (MOC), Science Operations Centers (SOCs), PDS, and other interested parties selected to ensure that measurement data, generated products, engineering data sets, and documentation are archived in PDS. During the active mission the LDWG will provide the coordination needed to ensure that archives are assembled, validated, and delivered to the PDS according to schedule.

Documentation to be provided by the LPO:

- This LRO Data Management and Archive Plan

Documentation to be provided by the LPO to the PDS in compliance with PDS standards:

- High-level mission description (MISSION.CAT)
- High-level spacecraft description (INSTHOST.CAT)
- References (REF.CAT)

3.2 MISSION OPERATIONS CENTER (MOC)

The LRO MOC is LRO's central collection and distribution center for measurement and support data. MOC responsibilities include measurement data Level 0 processing for Science Operations Centers (SOCs) that request it, daily distribution of measurement data (raw data or NASA Level 0 data according to SOC choice) and associated information to the SOCs, and archiving spacecraft housekeeping, and health and safety data, as well as MOC-generated SPICE data in the PDS.

3.3 SCIENCE OPERATIONS CENTERS (SOCs)

Instrument Team Science Operations Centers are responsible for all measurement data related activities for their instrument from receipt of data from the MOC to submission of initial data to the PDS within 6 months of creation. This includes designing, implementing, documenting, and peer reviewing as appropriate:

- Data receipt from the MOC
- Data storage, internal transmission, and backup
- Generate Activity Requests containing instrument command sequences
- Algorithm development for product generation
- Product generation processing and reprocessing
- Data validation for both science and engineering aspects

- Special data delivery to the LPO or other special requesters
- Data submission to the MOC for redistribution as applicable
- Data preparation, validation, and submission to the PDS for archive
- Configuration management processes
- SOC information technology security
- Distribution in fulfilling the obligations of a PDS Data Node for those SOCs serving as a PDS Data Node
- Distribution as part of education and public outreach activities

A SOC may arrange, with project and PDS concurrence, to become a PDS Data Node. The LOLA team and the PDS Geosciences Node have signed the LOLA Data Node Memorandum of Agreement. The LROC proposal was approved with the requirement and funding for the LROC team to host the LROC Data Node. The LOLA and LROC Data Nodes will abide by the guidelines and obligations that go with Data Node status, including archive and distribution requirements. LOLA and LROC are PDS Data Nodes for the duration of the LRO mission. Within six months of the completion of the LRO Mission, and extended mission if applicable, the LOLA and LROC archives will be transferred respectively to the PDS Geosciences and Imaging Nodes.

Documentation to be provided by the SOCs to the LPO (Maintained under SOC configuration management):

- SOC Requirements Document
- SOC Risk Assessment Plan and IT Security/Contingency Plan
- SOC Data Management & Archive Plan (DM&AP)
- SOC Test Plan

Documentation to be provided by the SOCs to the PDS in compliance with PDS standards:

- SOC-PDS Discipline Node Interface Control Document (Jointly developed)
- Software Interface Specifications (SISs) for data products and for archive volumes
- High-level instrument description (INST.CAT)
- High-level data set description (DATASET.CAT)
- Key personnel (PERSON.CAT)
- References (REF.CAT)
- Calibration information and data sufficient to enable a user to understand and reproduce the calibration of higher level products
- Data processing production methodology and algorithms
- References to instrument papers for journals

3.4 MINI-RADIO FREQUENCY (MINI-RF) TECHNOLOGY DEMONSTRATION

The Mini-Radio Frequency Instrument Team has indicated a desire to follow SOC roles and responsibilities. To the extent Mini-RF wishes, the SOC roles and responsibilities apply, but Mini-RF is under no formal obligation to do so.

3.5 PLANETARY DATA SYSTEM (PDS)

The Planetary Data System (PDS) is the designated archive and public distribution center for the LRO Mission. The PDS will work with the LDWG and individual MOC/SOCs to ensure that the LRO archives are compatible with PDS standards and formats. The PDS Geosciences Node will provide overall coordination of PDS activities for LRO. A Data Engineer from the PDS Engineering Node will work with the PDS Discipline Nodes involved with the LRO Mission throughout the archive planning, generation, and validation phases. The PDS provides data archiving specifications, integration and test support, data archive, and distribution. The PDS is funded independent of the LRO budget for generation, distribution, and maintenance of LRO archives for the NASA planetary science community once the LRO data have been delivered.

4.0 DATA FLOWS

4.1 MISSION OPERATIONS CENTER (MOC)

All LRO data will be transmitted from the LRO Orbiter to the MOC. The MOC and Flight Dynamics Facility (FDF) will generate LRO SPICE data files for distribution to the SOCs. These data include lunar ephemeris, leap seconds, planetary constants, etc. The GS&O External ICD includes these data flows. The MOC will receive raw instrument data files and distribute instrument files along with relevant spacecraft files to the appropriate SOC. The MOC will archive all orbiter data along with mission products for the life of the mission. The MOC is responsible for transferring LRO SPICE data files to the PDS within 6 months of creation. The MOC will also distribute to the SOCs and PDS all reprocessed orbital data in SPICE format.

4.2 SCIENCE OPERATIONS CENTERS (SOCs)

The SOCs receive measurement data (raw or NASA Level 0 data according to SOC choice) and support data as well as SPICE data from the MOC, generate higher level products, and deliver all NASA Level 0 and higher data products to the Planetary Data System (PDS) within 6 months of creation per PDS specifications. The SOCs are responsible for all internal data handling and specified product generation. Those SOCs serving as PDS Data Nodes also have PDS responsibilities as noted in 4.3.

4.3 PLANETARY DATA SYSTEM (PDS)

The Planetary Data System archives and distributes all measurement data and support products meeting PDS standards submitted from the MOC and SOCs.

5.0 LRO MEASUREMENT DATA OBJECTIVES

The list of measurement data objectives below is similar to a list in the LRO Level 1 requirements. The MOC and SOCs may decide to aggregate them differently and map their data products to them such that there is not a one-to-one mapping between objective and product for delivery to the PDS. The PDS delivery aggregation will be documented by the SOCs in their DM&AP, SOC-PDS Discipline Node ICD, and SISs.

5.1 LRO MISSION OPERATIONS CENTER (MOC)

Destination PDS Node: Navigation and Ancillary Information Facility (NAIF) Node, JPL
Data Products: SPICE data generated by the MOC.

5.2 COSMIC RAY TELESCOPE FOR EFFECTS OF RADIATION (CRATER)

Principal Investigator: Dr. Harlan Spence, Boston University, Boston, Massachusetts
Destination PDS Node: Planetary Plasma Interactions Node, UCLA
Data Products:

- Measure and characterize that aspect of the deep space radiation environment, Linear Energy Transfer (LET) spectra of galactic and solar cosmic rays (particularly above 10 MeV), most critically important to the engineering and modeling communities to assure safe, long-term, human presence in space.
- Investigate the effects of shielding by measuring LET spectra behind different amounts and types of areal density, including tissue-equivalent plastic.

5.3 DIVINER LUNAR RADIOMETER EXPERIMENT (DLRE)

Principal Investigator: Dr. David Paige, UCLA, Los Angeles, California
Destination PDS Node: Geosciences Node, Washington University
Data Products:

- Direct temperature mapping at ~300M spatial resolution with minimum detectable temperature of 24K over an entire diurnal cycle enables the detection and characterization of cold traps in polar shadowed regions.
- Determine rock abundances of up to 50 selected potential landing sites.
- Provide illumination map derived from Illumination and Scattering Model (Includes slopes, raytraced shadows, and full 3-D radiosity solution for scattered solar and infrared radiation), and 1-D lunar thermal model
- Fine-component thermal inertia and lambert albedo from surface temperature, solar reflectance and topography measurements

5.4 LYMAN-ALPHA MAPPING PROJECT (LAMP)

Principal Investigator (Acting): Dr. Randy Gladstone, Southwest Research Institute, San Antonio, Texas
Destination PDS Node: Imaging Node, JPL

Data Products:
- Albedo maps of all permanently shadowed regions with resolutions down to 100m.
- Develop exposed water-frost concentration maps of the lunar polar regions. Mapping resolutions as good as 3km for frost abundances down to 1.5%.

5.5 LUNAR EXPLORATION NEUTRON DETECTOR (LEND)

Principal Investigator: Dr. Igor Mitrofanov, Institute for Space Research, and Federal Space Agency, Moscow, Russia
Destination PDS Node: Geosciences Node, Washington University
Data Products:
- Radiation Data Product for global distribution of neutrons at Moon's orbit with spatial resolution of 50 km at different energy ranges from thermal energy up to >15 MeV separately for periods of quiet Sun and for periods of Solar Particle Events.
- Develop maps of water ice column density on polar regions of the Moon with spatial resolution from 5-20km.
- Determine hydrogen content of subsurface at polar regions with spatial resolution from Half-Width Half-Maximum (HWHM)=5km and with variation sensitivity from 100 parts per million (ppm)

5.6 LUNAR ORBITER LASER ALTIMETER (LOLA)

Principal Investigator: Dr. David E. Smith, NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland
Destination PDS Node: Geosciences Node, Washington University (LOLA SOC has requested to be a PDS Node for LOLA data during the life of the LRO mission)
Data Products:
- Provide global digital elevation model of the moon with 1 m vertical resolution and 100 m horizontal resolution with 1 km average cross track sampling at the equator.
- Provide global topography with 1 m vertical resolution and 100 m horizontal resolution with 1 km average cross track sampling at the equator.
- Provide digital elevation model of topography in permanently shadowed polar regions with 50m horizontal resolution, 1m vertical resolution.
- Provide reflectance data from the permanently shadowed regions (PSRs) to identify surface ice signatures at a limit of 4% ice surface coverage by area.
- Provide topography, surface slopes, and surface roughness at 25-m spacing over a 70-m wide field of view (FOV) swath at up to 50 selected potential landing sites.
- LOLA will map the polar regions poleward of latitudes 86° with a vertical resolution of 10 centimeters (cm) and a spatial resolution of 25 to 35m after one year, which will identify potential sites of optimal solar power generation

5.7 LUNAR RECONNAISSANCE ORBITER CAMERA (LROC)

Principal Investigator: Dr. Mark Robinson, Arizona State University, Tempe, Arizona
Destination PDS Node: Imaging Node, USGS, Flagstaff, Arizona (LROC SOC has requested to

be a PDS Node for LROC data during the life of the LRO mission).
Data Products:

- For areas of high interest (targets), provide 2m scale Digital Elevation Models (DEM) for areas 5km x 5km.
- Acquire 100m/pixel global stereo imaging reducible to 1km/pixel global topography in EDR format (no maps). Back up for LOLA data, if needed WAC.
- 100m/pixel global color mosaic @ nominal 50km orbit.
- Provide up to 50 Mosaics of selected potential landing sites with 1 m/pixel resolution.
- Provide uncontrolled illumination movies, 1 each of North and South Lunar Poles over the course of 1 lunar year at an average time resolution of 5 hours or better. (Wide Angle Camera [WAC])
- Provide 1 m/pixel resolution summer (uncontrolled) mosaics of the lunar poles (+/- 4 degrees). (Narrow Angle Camera [NAC]). There will be some gores in the data due to tolerance (20km) of the nominal 50km orbit altitude.
- Global imaging 400m/pixel in the ultraviolet (UV) bands and 100m/pixel in the visible bands, ten uncontrolled demonstration multi-spectral mosaics for high priority targets.

5.8 MINI-RADIO FREQUENCY (MINI-RF) TECHNOLOGY DEMONSTRATION

Principal Investigator: Dr. Stu Nozette, Naval Air Warfare Center (NAWC), China Lake, California
Destination PDS Node: Geosciences Node, Washington University, St. Louis, Missouri
Data Products:

- Products as agreed between LPO and Mini-RF PI

6.0 ARCHIVE GENERATION, VALIDATION, TRANSFER, AND DISTRIBUTION

The list of products and other tabular material supporting this section can be found in the Appendix.

6.1 GENERATION

LRO science operations will be geographically distributed, with a Project-controlled central database at the MOC containing telemetry data, SPICE files, and other information needed by the SOCs to generate their products. The MOC will transfer this data to the SOCs.

An Interface Control Document (ICD) will exist for each relationship between a facility that provides data and the PDS node that receives it. This document will describe the management interface between the two entities, roles and responsibilities of each side, and policies and procedures that govern the flow of data from provider to PDS. Each type of data product to be delivered to PDS will be described in a Data Product Software Interface Specification (SIS), which may be included as an Appendix to the ICD. The SIS will include an example of the PDS label for the data product. In addition, an Archive Volume SIS will describe the contents and organization of the complete archive to be delivered to PDS, including data products, indices, documentation, software, and other supporting materials. The Archive Volume SIS may also be appended to the ICD. The data product SIS and volume SIS serve as the definitive documents for defining the contents, structure, and organization of the data deliveries. The data product SIS and archive volume SIS may be combined into a single document, if this is acceptable to both the instrument team and the PDS Node leader.

The archives are intended to preserve observational data that support instrument calibration as well as measurement data. Measurement data acquired during the LRO mission cruise and commissioning phases may also be archived in PDS at the discretion of the instrument Principal Investigator. Calibration data acquired during cruise and in orbit will be archived in the same manner as measurement observations. Calibration data gathered by the instrument team before LRO launch will also be archived in PDS. These pre-flight calibration data, or a suitable roll-up of these data as applicable, will be archived in PDS in "safed mode." Safed mode archive data have no SIS documentation and do not undergo a peer review.

The archives associated with instrument data and measurement data investigations will be assembled at the SOCs, using archive volume SISs that define the elements of archives and the associations among the elements. Archive volume SISs will pertain both to online archives and to the physical volumes that must be made and transferred to the PDS. Archives produced by the MOC, namely telemetry files, SPICE files, engineering data sets, and any other relevant information, will follow the same procedures that are designated for the measurement archives.

6.2 VALIDATION AND PEER REVIEW

The LDWG will provide oversight and coordination of validation of archives. The validation process includes the following components:

1. A quality control activity built in to SOC product generation.
2. Analysis of the derived products.
3. SOCs, and the Project, as relevant, will check the products for conformance to SIS documents.
4. SOCs and the relevant PDS node will check the archive volumes for conformance to Archive Volume SIS documents.

PDS requires data sets to be peer reviewed before they can be accepted as PDS archives. A typical PDS peer review includes a committee of a few scientists who are knowledgeable about the type of data under review, along with representatives from the data provider and the PDS. The committee is asked to review the data set for completeness and scientific utility. The result of a peer review is a list of liens against the data set that must be resolved before PDS can accept it. PDS will arrange for these peer reviews.

For data products from ongoing missions that are delivered periodically, the peer review takes place as follows.

1. Before data production begins, the committee reviews a representative sample of data products along with associated documentation, software, and other ancillary files that will make up the archive to be submitted to PDS. This is done early to allow time for the data provider to make any necessary changes to the product design, and to ensure that sufficient ancillary materials are provided so that the typical user can access and interpret the data (e.g., software).
2. The committee also reviews the data "pipeline"; that is, the procedures that the provider will use to generate standard products during the mission. The idea is that with the reviewers' approval of a sample of the product and the method for generating it, the PDS can be reasonably sure that future products generated in the same way will be equally valid.
3. Reviewers have an opportunity to view revised products and supporting materials to ensure that the liens have been resolved. Data Product SIS documents are updated as necessary to describe the revised products.
4. With each delivery of data products, the appropriate PDS node performs a standard set of validation procedures to ensure that products conform to the Data Product and Archive Volume SISs. As long as the product design and processing steps do not change, no further peer review is necessary.

6.3 TRANSFER

Data will be transferred from the SOCs and MOC to the PDS via mechanisms detailed in the relevant SOC-PDS ICD or GS ICD.

6.4 DISTRIBUTION

Once released to the PDS, the LRO archives will be available to the general public.

Appendix 1. LRO Payload

Data Source	Data Source Type	Investigator	Key Parameters	PDS Archive Node	PDS ICD & Reference ID
CRaTER	Lineal energy transfer spectrometer	Dr. Harlan Spence, Boston University, Boston, Massachusetts	Continuous LET spectra (0.2–7000 KeV/µm in Si) of primary cosmic rays behind varying materials including tissue-equivalent plastic.	PPI	CRaTER-PDS PPI ICD
DLRE	9-channel high-precision radiometer sensing 0.3 to 200 micrometer wavelength radiation	Dr. David Paige, University of California, Los Angeles (UCLA), Los Angeles, California	At 500 m spatial resolution: Global Surface Temperature, Annual Min, Max and Average Surface Temperature, Lambert Albedo, Fine Component Thermal Inertia, Anisothermality, Rock Abundance	Geosciences	DLRE-PDS GEO ICD
LAMP	Far-ultraviolet spectrograph	Dr. Randy Gladstone, Southwest Research Institute, San Antonio, Texas (Acting)	Far-UV brightness, landform albedo, H_2O absorption feature depth maps; atmospheric and atmospheric brightness spectra	Imaging	LAMP-PDS IMG ICD
LEND	Collimated sensor and sensors to detect thermal, epithermal, and high-energy neutrons	Dr. Igor Mitrofanov, Institute for Space Research, and Federal Space Agency, Moscow, Russia	Maps of hydrogen in upper 1 m of Moon at 10 km scales; epithermal neutrons and high energy neutrons with high angular resolution	Geosciences	LEND-PDS GEO ICD
LOLA	5-spot, 28-Hz, 1064-nm laser altimeter	Dr. David E. Smith, NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland	~25 m scale polar topography at < 10 cm vertical, global topography, surface slopes and roughness	Geosciences	LOLA-PDS GEO ICD
LROC	Two Narrow Angle Camera (NAC) with 0.5 meter per pixel resolution, and a Wide Angle Camera (WAC) with 100 meter per pixel resolution	Dr. Mark Robinson, Arizona State University, Tempe, Arizona	1000's of 50cm/pixel images, and entire Moon at 100m in UV, Visible. Illumination conditions of the poles	Imaging	LROC-PDS IMG ICD
Mini-RF	Miniature Synthetic Aperture Radar system	Dr. Stu Nozette, Naval Air Warfare Center (NAWC), China Lake, California	Targeted X & S band SAR imaging strips with 6 or 4 km swath width at a spatial resolution of 75 m/pixel or 15 m/pixel. Targeted interferometry strips with 6km swath width and 75 m/pixel spatial resolution.	Geosciences	MRF-PDS GEO ICD

Appendix 2. Total Mission LRO Data Volume (in GB) Delivered to PDS by Data Type

Data Type	Data Volume	Percent of Total
EDR (CODMAC 1)	22	0%
EDR (CODMAC 2)	20,360	29%
CDR (CODMAC 3)	45,512	66%
RDR (CODMAC 4)	340	0%
RDR (CODMAC 5)	3,155	5%
Ancillary (CODMAC 6)	7	0%
Total	69,374	100%

Appendix 3. Total Mission LRO Data Volume (in GB) Delivered to PDS by Delivery

Data Source	IOC + 6 Mo	IOC + 9 Mo	IOC + 12 Mo	IOC + 15 Mo	IOC + 18 Mo EOM + 6 Mo	Total
MOC	2	1	1	1	1	7
CRaTER	113	113	113	113	0	452
DLRE	30	646	646	646	624	2,592
LAMP	525	525	525	598	0	2,173
LEND	8	10	10	10	1	38
LOLA	87	142	196	250	223	898
LROC	15,000	15,000	15,000	18,071	0	63,071
Mini-RF	0	83	0	83	0	166
Total	15,765	16,519	16,491	19,771	849	69,396

Note: Initial Operational Capability (IOC) date is the day after the end of the commissioning period.

Appendix 4. Nominal PDS Schedule for Public Release of LRO Data

Date	Event
October 15, 2008	Launch
December 15, 2008	Launch + 2 Months, End of commissioning phase, beginning of data capture (IOC)
June 15, 2009	Launch + 8 Months, IOC + 6 Months, First 3 months of data delivered
September 15, 2009	Launch + 11 Months, IOC + 9 Months, Second 3 months of data delivered
December 15, 2009	Launch + 14 Months, IOC + 12 Months, Third 3 months of data delivered
March 15, 2010	Launch + 17 Months, IOC + 15 Months, Fourth 3 months of data delivered
June 15, 2010	Launch + 20 Months, IOC + 18 Months, EOM + 6 Months, Final data delivery

Appendix 5. LRO Standard Products Archived in PDS

Instrument/Product Short Name	Product Long Name/Description	NASA Level	CODMAC Level	Mission Volume (GB)	Mission Volume Includes Reprocessing (Y/N)
MOC	Total MOC Mission Standard Data Volume			6.58	
FDF-29	Definitive SPICE SPK File		6	1.14	N
FDF-30	LRO Predictive SPICE SPK File		6	0.43	N
FDF-35	SPICE Definitive CK (Definitive S/C, Orientation)		6	1.14	N
FDF-36	Reprocessed SPICE SPK Data		6	1.14	Y
MOC-2	SPICE SCK – Clock Correlation File		6	0.01	N
MOC-33	SPICE Event kernel		6	0.00	N
MOC-39	SPICE FK – Frame Kernels		6	0.00	N
MOC-41	SPICE Predicted CK (Predicted S/C Orientation)		6	0.43	N
MOC-xx	SPICE Definitive HGA CK		6	1.14	N
MOC-xx	SPICE Definitive SA CK		6	1.14	N
CRaTER	Total CRaTER Mission Standard Data Volume			451.92	N
CR_L0_HK	Unprocessed Housekeeping data	0	2	0.13	N
CR_L0_PS	Unprocessed Primary Science data	0	2	17.50	N
CR_L0_SS	Unprocessed Secondary Science data	0	2	1.38	N
CR_L1_HK	Depacketed housekeeping data	1	3	0.33	N
CR_L1_PS	Depacketed primary science data	1	3	128.67	N
CR_L1_SS	Depacketed secondary science data	1	3	4.32	N
CR_L2_HK	Time-tagged housekeeping data	2	3	0.39	N
CR_L2_PS	Lineal energy transfer deposition in Si primary science data	2	4	293.28	N
CR_L2_SS	Time-tagged secondary science data	2	3	5.71	N
CR_L3_SCI	Lineal energy transfer spectra sorted by solar particle events and galactic cosmic rays	3	5	0.12	N
CR_L4_SCI	Lineal energy transfer spectra in tissue	4	5	0.12	N
DLRE	Total DLRE Mission Standard Data Volume			3,095.00	
Level 0	Depacketized Time-Sequenced Raw Science and Housekeeping Data	0	2	119.00	N
Level 1b	Calibrated Radiances and Housekeeping Data merged with project-supplied geometry and timing information	1b	3	2,464.00	N
Global Temperatures	Gridded (Lat, Lon, Local Time) Global Surface Temperature	2	5	1.00	N
Global Temperature Database	Gridded (Lat, Lon, Local Time) Global Surface Temperature and Annual Min, Max and Average Surface Temperature In Queryable Online Database	2	5	1.00	N
Global Fields	Gridded Derived Global Fields: Lambert Albedo, Fine Component Thermal Inertia, Anisothermality, Rock Abundance	3	5	1.00	N
Global Fields Database	Gridded Derived Global Fields: Lambert Albedo, Fine Component Thermal Inertia, Anisothermality, Rock Abundance In Queryable Online Database	3	5	1.00	N

Polar Resource Maps	Polar Resource Products: Maps of permanently shadowed regions, Localized maps of derived surface and subsurface temperatures, illumination levels, water ice near infrared reflectance maps for all regions potentially containing cold-trapped volatiles	3	5	4.00	N
LAMP	Total LAMP Mission Standard Data Volume			2,172.50	
Photon Event Stream	FITS file of the time-tagged photon event stream	0	2	100.00	N
Transformed Photon Event Stream	Level 0 located and transformed with needed ancillary and auxiliary data	1a	3	2,000.00	Y
Far-UV Brightness Maps	Far-UV Brightness Maps	3	5	36.00	Y
Far-UV Landform Albedo Maps	Far-UV Landform Albedo Maps	3	5	36.00	Y
H2O Absorption Feature Depth Map	H2O Absorption Feature Depth Map	3	5	0.50	Y
Atmospheric Spectrum	Atmospheric Spectrum	3	5	< 0.1	Y
Atmospheric Brightness Spectrum	Atmospheric Brightness Spectrum	3	5	< 0.1	Y
LEND	Total LEND Mission Standard Data Volume			38.00	
LEND_SCI_EDR	Raw Spectra	0	2	11.00	N
LEND_HK_EDR	Engineering / Housekeeping	0	2	3.00	N
LEND_IDR	Raw Spectra, Spatial and Temporal	1a	3	19.00	N
LEND_DER_RDR	Derived Spectral Data	1b	4	2.00	N
LEND_AVG_RDR	Averaged Derived Data	2	5	1.00	N
LEND_SCDP_RDR	Surface Composition Data	3	5	1.00	N
LEND_RDP_RDR	Radiation Data	3	5	1.00	N
LOLA	Total LOLA Mission Standard Data Volume			903.01	
LOLA_EDR	Raw experiment science and status data		2	107.00	N
LOLA_RDR	Geolocated science and status in SI units		3	746.00	Y
LOLA_GDR	Gridded experiment data records		4	45.00	Y
LOLA_SHADR	Selenodetic shape and potential		5	0.01	Y
LROC	Total LROC Mission Standard Data Volume			63,071.00	
NAC EDR	NAC EDR	0	2	12,000.00	N
NAC CDR	NAC CDR	1a	3	24,000.00	N
WAC EDR	WAC EDR	0	2	8,000.00	N
WAC CDR	WAC CDR	1a	3	16,000.00	N
Landing Site Assessment	Up to 50 mosaics of selected potential landing sites with one meter scale resolution	1c	5	500.00	N
Polar Illumination Characterization	Provide uncontrolled illumination movies, 1 for each pole over the course of 1 lunar year at an average time resolution of 5 hours	1c	5	179.00	N
Meter-scale Polar Illumination Conditions	Polar uncontrolled mosaics (86º to 90°), composed of summed 2x observations (1 m/p) arranged into 103 tiles (lambert and stereographic projections)	1c	5	293.00	N
Selected High Resolution Topography	For areas of high interest collect multi-look NAC data reducible to 2 m scale DEM for 25 km sq areas (photometric and stereo), generate a few test DEM models	1c	5	25.00	N

Global Multi-spectral Observations	7 band global color observations: three campaigns to obtain 10° to 40° incidence equator crossings; 100 m/pixel VIS; 400 m/pixel UV; and ten uncontrolled demonstration multispectral mosaics for high priority targets	1c	5	639.00	N
Global BW Basemap	Best effort, uncontroled global monochrome WAC mosaic at 100m/p resolution	1c	5	27.00	N
Regolith Characterization	Target key areas to investigate variations in regolith thickness and structure	1c	5	128.00	N
Impact Rate	Determine current small impact hazard by rephotographing areas imaged by Apollo Pan camera (1 m/p) and Lunar Orbiter (1 m/p)	1c	5	1,280.00	N

Appendix 6. LRO Special Products Archived in PDS

Instrument/Product Short Name	Product Long Name/Description	NASA Level	CODMAC Level	Mission Volume (GB)	Mission Volume Includes Reprocessing (Y/N)
CRaTER	Total CRaTER Mission Special Data Volume			0.24	
CR_L3_SCI	Lineal energy transfer spectra sorted by solar particle events and galactic cosmic rays	3	5	0.12	N
CR_L4_SCI	Lineal energy transfer spectra in tissue	4	5	0.12	N
Mini-RF	Total Mini-RF Mission Special Data Volume			165.50	
SAR Raw Data	SAR Raw Data	Packet	1	9.30	N
SAR range-azimuth Strips (V, H, & cross products)	SAR range-azimuth Strips (V, H, & cross products)	1A	3	10.00	N
SAR range-azimuth Strips (stokes parameters)	SAR range-azimuth Strips (stokes parameters)	1A	3	10.00	N
SAR range-azimuth Strips (LCP, RCP, albedo and CPR)	SAR range-azimuth Strips (LCP, RCP, albedo and CPR)	1A	3	10.00	N
SAR projected strips (V, H & Cross products)	SAR projected strips (V, H & Cross products)	1C	3	30.00	N
SAR projected strips (stokes parameters)	SAR projected strips (stokes parameters)	1C	3	30.00	N
SAR projected strips (LCP, RCP, albedo and CPR)	SAR projected strips (LCP, RCP, albedo and CPR)	1C	3	30.00	N
Interferometry raw data	Interferometry raw data	Packet	1	12.20	N
Interferometry range-azimuth strips	Interferometry range-azimuth strips	1A	3	24.00	N

Note: This data is included in Appendices 2 and 3 summaries.

Appendix 7. LRO Special Products Archived in CDDIS, FDF, and Laser Ranging

Instrument/Product Short Name	Product Long Name/Description	NASA Level	CODMAC Level	Mission Volume (GB)	Mission Volume Includes Reprocessing (Y/N)
LOLA	Total LOLA Mission Special Data Volume			5.001.14	
LOLA_LRFDF-29	ILRS Range Data and Normal PointsDefinitive SPICE SPK File		3,4	5.001.14	NN

Note: This data is not included in Appendices 2 and 3 summaries.

Appendix 8. Definitions of Processing Levels for Measurement Data Sets

NASA	CODMAC	Description
Packet data	Raw Level 1	Telemetry data stream as received at the ground station, with science and engineering data embedded.
Level 0	Edited Level 2	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
Level 1-A	Calibrated Level 3	Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
Level 1-B	Resampled Level 4	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength).
Level 1-C	Derived Level 5	Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction).
Level 2	Derived Level 5	Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling.
Level 3	Derived Level 5	Geophysical parameters mapped onto uniform space-time grids.
	Ancillary data Level 6	Nonscience data needed to generate calibrated or resampled data sets. Consists of instrument gains, offsets; pointing information for scan platforms, etc.

Appendix 9. Suppliers of LRO Archive Components

Component	Contents	Supplier
SPICE Archives	SPICE Kernels	MOC
Measurement Data Archives	High-level mission, spacecraft, instrument, and data set descriptions for the PDS Catalog Software Interface Specification (SIS) Documents Archive Volume Software Interface Specification Documents Processing Descriptions, Algorithms, and Software (to use in understanding reduced data product generation) Instrument Calibration Reports and associated data needed to understand level 1 product generation Experiment Data Records and Reduced Data Records, containing standard products, with PDS Labels	SOCs
Engineering Data Archives	Software Interface Specification Documents Uplink sequences and notebook entries Telemetry data	MOC

Appendix 10. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
CCB	Configuration Control Board
CDDIS	Crustal Dynamics Data and Information System
CDR	Calibrated Data Record
CM	Configuration Management
CMO	Configuration Management Office
CODMAC	Committee on Data Management, Archiving, and Computing
CRaTER	Cosmic Ray Telescope for Effects of Radiation
DLRE	Diviner Lunar Radiometer Experiment
DM&AP	Data Management & Archive Plan
EDR	Experiment Data Record (also called Engineering Data Record)
EOM	End of Mission
FDF	Flight Dynamics Facility
GS	Ground System
ICD	Interface Control Document
IOC	Initial Operational Capability
LAMP	Lyman-Alpha Mapping Project
LDWG	LRO Data Working Group
LEND	Lunar Exploration Neutron Detector
LOLA	Lunar Orbiter Laser Altimeter
LPO	LRO Project Office
LPRP	Lunar Precursor and Robotic Program
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
Mini-RF	Mini-Radio Frequency Technology Demonstration
MOA	Memorandum of Agreement
MOC	Mission Operations Center
NAIF	Navigation and Ancillary Information Facility
PDS	Planetary Data System
PI	Principal Investigator
RDR	Reduced Data Record
SIS	Software Interface Specification
SOC	Science Operations Center
SPICE	Spacecraft, Planet, Instrument, C-matrix (pointing), and Events
TBD	To Be Determined
TBR	To Be Resolved