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Lunar Reconnaissance Orbiter (LRO)

Data Management and Archive Plan

LRO GSFC CMO

May 6, 2013

RELEASED

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

CM FOREWORD

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LUNAR RECONNAISSANCE ORBITER PROJECT

CHANGE HISTORY LOG

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Rev –	Released per 431-CCR-000319	C. Tooley	6/26/2007
Rev A	Modified to include SMD Mission concepts per CCR 451-CCR-1466	R. Burns R. Vondrak	01/13/2012
Rev-B	This revision extends the DM&AP through the LRO Extended Science Mission and provides information about MRF bi-static operations and data, per CCR 451-CCR-001481	R. Burns J Keller	05/06/2013

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) Missions 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 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 Exploration Systems Mission Directorate (ESMD) mission, and by 6 months after the end of the Science Mission Directorate (SMD) mission. The final delivery may be deferred to the end of the Extended Science Mission (ESM) rather than the end of the SMD mission, where the products continue to be produced during the ESM mission. Any instrument data from the commissioning phase could be archived in PDS at the instrument Principal Investigator's discretion at launch + 8 months.

Initially during the LRO ESMD mission, the Mini-RF technology demonstration data were delivered to the PDS Geosciences Node every 6 months, where the data were 6-9 months old. This schedule coincided with every other data delivery for the LRO instruments, starting with their second deliveries at launch plus 11 months. During the ESMD mission, the Mini-RF team decided to deliver data on the same schedule as the other teams due to the large Mini-RF data volume. This schedule was continued during the SMD mission with the Mini-RF considered as an instrument rather than a technology demonstration. The Mini-RF transmitter failed in December 2010. The MRF data products described in this document were no longer produced after the failure.

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 sent 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, were performed as part of Mission Readiness Testing (MRT) #5 and #6, where these tests occurred during the period November 2007 through June 2008.

The schedule for SOC data deliveries to PDS and for PDS Releases of LRO data to the public, for the ESMD, SMD, and ESM missions, is in Appendix 4.

2.0 MISSION OVERVIEW

2.1 LRO CONTEXT AND GOALS

LRO is the first mission of the Lunar Precursor and Robotic Program (LPRP). LRO was launched in June 2009. 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 ESMD instrument complement includes six core instruments and one demonstration instrument (Mini-RF). For the SMD mission, Mini-RF was given full science instrument status:

- Cosmic Ray Telescope for Effects of Radiation (CRaTER): CRaTER investigates 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 maps 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 observes virtually the entire lunar surface in the far ultraviolet. LAMP searches for surface ices and frosts in the polar regions and provides 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 maps the flux of neutrons from the lunar surface to search for evidence of water ice and provides measurements of the space radiation environment. This can be useful for future human exploration.
- Lunar Orbiter Laser Altimeter (LOLA): LOLA determines the global topography of the lunar surface at high resolution, measuring landing site slopes and searching for polar ice in shadow regions.
- Lunar Reconnaissance Orbiter Camera (LROC): LROC acquires targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards. LROC also produces wide-angle images at multiple wavelengths of the lunar poles to document the changing illumination conditions and potential resources.
- Mini-Radio Frequency (Mini-RF): Mini-RF was a technical demonstration of a unique miniaturized multi-mode dual frequency (X&S band), dual polarization radar observatory during the ESMD mission. The primary image data products are multi-mode Stokes parameters (or their primitives), a major pioneering capability in space-based radar astronomy. Additional communications and navigation demonstrations are made to validate new instrument technologies. Mini-RF was given full science instrument status for the SMD mission, but ceased acquiring monostatic radar data in December 2010 due to transmitter failure. Bi-static radar measurements began in 2011.

3.0 ROLES AND RESPONSIBILITIES

3.1 LRO PROJECT OFFICE (LPO)/SPACE SCIENCE MISSION OPERATIONS (SSMO) PROJECT

The LRO Project Office (LPO) had overall responsibility for the acquisition, integration, launch, and operation of the LRO Observatory, and ensured compliance by all parties with contractual requirements. LRO management transitioned from LPO to the Space Science Mission Operations (SSMO) Project in January 2010.With regard to mission measurement and support data, LPO/SSMO 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 missions the LDWG provides the coordination needed to ensure that archives are assembled, validated, and delivered to the PDS according to schedule.

Documentation provided by LPO:
- This LRO Data Management and Archive Plan

Documentation provided by 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 missions. Within six months of the completion of the LRO ESMD and SMD Missions, or extended mission if applicable, the LOLA and LROC archives will be transferred respectively to the PDS Geosciences and Imaging Nodes.

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

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

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

- 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

For the ESMD mission, the Mini-Radio Frequency Instrument Team had indicated a desire to follow SOC roles and responsibilities. To the extent the Mini-RF team wished, the SOC roles

and responsibilities applied, but Mini-RF was under no formal obligation to do so. During the SMD and ESM missions, SOC roles and responsibilities were applicable to the Mini-RF SOC.

3.5 PLANETARY DATA SYSTEM (PDS)

The Planetary Data System (PDS) is the designated archive and public distribution center for the LRO Missions. The PDS team works with the LDWG and individual MOC/SOC teams to ensure that the LRO archives are compatible with PDS standards and formats. The PDS Geosciences Node provides overall coordination of PDS activities for LRO. A Data Engineer from the PDS Engineering Node works 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 are transmitted from the LRO Orbiter to the MOC. The MOC and Flight Dynamics Facility (FDF) 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 describes these data flows. The MOC receives raw instrument data files and distributes instrument files along with relevant spacecraft files to the appropriate SOC. The MOC archives 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 also distributes 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, for all instruments except Mini-RF. 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 Software Interface Specifications (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, University of New Hampshire, Durham, New Hampshire
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: Dr. Kurt Retherford, 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)

Principal Investigator: Dr. Ben Bussey, Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland
Destination PDS Node: Geosciences Node, Washington University, St. Louis, Missouri

Mini-RF measurements include:

- Imaging from 50km altitude surface areas that have been imaged by Forerunner with the same dual polarization, resolution, and S-band frequency as was used by Forerunner. The Forerunner instrument is on the ISRO Chandrayaan-1 mission to the Moon.
- Imaging polar areas with both S- and X-band, and at both baseline and zoom resolutions
- Acquiring data in a continuous transmit mode that is applicable for topography generation using post processing techniques
- Conduct a set of experiments to test the usability of Mini-RF hardware as a communications asset.
- During the science mission, a primary goal was to acquire significant global-scale s-band zoom data. After Mini-RF ceased acquiring mono-static radar data in December 2010, it began acquiring bi-static radar measurements in 2011.

The Mini-RF concept of operations has six primary components:

- The communications experiment consists of two 10-minute data takes, approximately 24

hours apart, which occurred during the instrument commissioning phase, before the ESMD mission.

- SAR Data Acquisition during ESMD mission: Mini-RF acquired one 4-minute SAR data strip every month. Within this strip it is possible to alternate between different SAR modes, e.g. S or X band, baseline or zoom resolution. In addition, twice a year, Mini-RF acquired four 2-minute strips from four consecutive orbits.
- Continuous Mode Data Acquisition during ESMD mission: Mini-RF acquired one 4-minute SAR data strip every month. Additionally, twice a year, Mini-RF acquired four 2-minute strips on four consecutive orbits.
- Mini-RF Exploration Utilization Plan (MEUP): additional polar campaign data acquisitions were allowed during late ESMD mission and early SMD mission during periods where the Beta angle is greater than 60 degrees (to mitigate impact on spacecraft solar array).
- During the SMD mission, a primary goal is to acquire significant global-scale s-band zoom data.
- Starting in 2011, Mini-RF was used to collect the first ever planetary bi-static radar images at non Beta=0 angles, to determine if the Moon's polar craters contain ice. These measurements can be used for studies of the composition and structure of pyroclastic deposits, impact ejecta and melts, and the lunar regolith.

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 are 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 transfers these data to the SOCs.

An Interface Control Document (ICD) exists for each relationship between a facility that provides data and the PDS node that receives it. This document describes 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 archive 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 may be archived in the same manner as measurement observations. Calibration data gathered by the instrument team before LRO launch may also be archived in PDS. These pre-flight calibration data, or a suitable roll-up of these data as applicable, may 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 are 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 are made and transferred to the PDS. Archives produced by the MOC, namely telemetry files, SPICE files, engineering data sets, and any other relevant information, follow similar procedures to those designated for the measurement archives.

6.2 VALIDATION AND PEER REVIEW

The LDWG provides 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. SOC teams, and the Project, as relevant, check the products for conformance to SIS documents.
4. SOC teams and the relevant PDS node team 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 manages 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 are 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 are made 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, University of New Hampshire, Durham, New Hampshire	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. Kurt Retherford, Southwest Research Institute, San Antonio, Texas	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. Ben Bussey, Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland	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 ESMD 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	69,396	100%
Note: data volume total in original document is corrected in this version		
S. Scott 2011-07-20		

Appendix 3. Total ESMD 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	6
CRaTER	113	113	113	113	0	452
DLRE	30	646	646	646	624	2592
LAMP	525	525	525	598	0	2173
LEND	8	10	10	10	1	39
LOLA	87	142	196	250	223	898
LROC	15,000	15,000	15,000	18,071	0	63071
Mini-RF	0	83	0	83	0	166
Total	15,765	16,520	16,491	19,772	849	69,397
Notes: 1. Initial Operational Capability (IOC) date is September 15, 2009 2. EOM is End of Mission 3. Some of the totals are different in the original document due to rounding						
S. Scott 2011-09-28						

Appendix 4. PDS Schedule for Public Release of LRO Data

LRO ESMD & SMD Data Release Schedule

PDS Release Date	Release Description	Mission	SOCs' PDS Delivery Date	Data Start Date	Data End Date
2010-03-15	Data Release #1	ESMD	2010-02-22	2009-09-15	2009-12-14
2010-06-15	Data Release #2	ESMD	2010-06-01	2009-12-15	2010-03-14
2010-09-15	Data Release #3	ESMD	2010-09-01	2010-03-15	2010-06-14
2010-12-15	Data Release #4	ESMD	2010-12-01	2010-06-15	2010-09-14
2011-03-15	ESMD Final Data Release	ESMD	2011-02-22	2009-06-19	2010-09-14
2011-03-15	Data Release #5	SMD	2011-03-01	2010-09-15	2010-12-14
2011-06-15	Data Release #6	SMD	2011-06-01	2010-12-15	2011-03-14
2011-09-15	Data Release #7	SMD	2011-09-01	2011-03-15	2011-06-14
2011-12-15	Data Release #8	SMD	2011-12-01	2011-06-15	2011-09-14
2012-03-15	Data Release #9	SMD	2012-03-01	2011-09-15	2011-12-14
2012-06-15	Data Release #10	SMD	2012-06-01	2011-12-15	2012-03-14
2012-09-15	Data Release #11	SMD	2012-09-01	2012-03-15	2012-06-14
2012-12-15	Data Release #12	SMD	2012-12-01	2012-06-15	2012-09-14
2013-03-15	SMD Final Data Release *	SMD	2013-02-22	2010-09-15	2012-09-14

* only applicable for products no longer produced in the LRO ESM mission

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LRO ESM Data Release Schedule

PDS Release Date	Release Description	Mission	SOCs' PDS Delivery Date	Data Start Date	Data End Date
2013-03-15	Data Release #13	ESM	2013-03-01	2012-09-15	2012-12-14
2013-06-15	Data Release #14	ESM	2013-06-01	2012-12-15	2013-03-14
2013-09-15	Data Release #15	ESM	2013-09-01	2013-03-15	2013-06-14
2013-12-15	Data Release #16	ESM	2013-12-01	2013-06-15	2013-09-14
2014-03-15	Data Release #17	ESM	2014-03-01	2013-09-15	2013-12-14
2014-06-15	Data Release #18	ESM	2014-06-01	2013-12-15	2014-03-14
2014-09-15	Data Release #19	ESM	2014-09-01	2014-03-15	2014-06-14
2014-12-15	Data Release #20	ESM	2014-12-01	2014-06-15	2014-09-14
2015-03-15	ESM Final Data Release	ESM	2015-02-22	2009-06-19	2014-09-14

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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
MOC-42	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-43	SPICE Definitive HGA CK		6	1.14	N
MOC-44	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, uncontrolled 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

Note: data volume estimates are for the ESMD mission. Since the SMD mission is twice as long as the ESMD mission, data volumes for the SMD mission are approximately double those for the ESMD mission. Data volumes for the ESM mission are approximately the same as for the SMD mission. The MRF team delivered approximately 10.51 TB of standard data products for the SMD mission, but did not deliver new standard data products during the ESM mission.

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
DLRE Level 2 GDR	Level 2 Gridded Data Record (ESMD Mission)	2	5	3000	N
DLRE Level 3 GDR	Level 3 Gridded Data Record (ESMD Mission)	3	5	1.1	N
DLRE Level 4 PRP	Level 4 Polar Resource Product (ESMD Mission)	4	5	0.12	N
LAMP GDR	Gridded Data Record (ESMD Mission)	3	5	26	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
MRF Targeted Bi-Static Observations	MRF bi-static radar measurements from a high-power signal transmitted from the Arecibo Observatory Planetary Radar and reflected off the lunar surface	1	3	600 (ESM mission)	N

Note: These data are included in Appendices 2 and 3 summaries, with the exception of DLRE, LAMP, and Mini-RF bi-static data.

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 Points Definitive SPICE SPK File		3,4	5.001.14	NN

Note: These data are 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)
ESM	Extended Science Mission
ESMD	Exploration Systems Mission Directorate (NASA Headquarters)
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
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
SMD	Science Mission Directorate (NASA Headquarters)
SOC	Science Operations Center
SPICE	Spacecraft, Planet, Instrument, C-matrix (pointing), and Events
SSMO	Space Science Mission Operations

Note: NASA Headquarters combined ESMD with the Space Operations Mission Directorate during the SMD mission, to create the Human Exploration and Operations Mission Directorate.